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Deforestation and environmental valuation of mangaba tree (*Hancornia speciosa* Gomes) in Sergipe State, Brazil

Desmatamento e valoração ambiental da mangabeira (Hancornia speciosa Gomes) no estado de Sergipe, Brasil

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ABSTRACT

The aim of the current study is to evaluate deforestation in mangaba tree (*Hancornia speciosa* Gomes) growing areas and environmental valuation in fairs held in Sergipe State, in order to suggest environmental service payment mechanisms to help conserving natural mangaba tree-growing areas in the state. Land use and cover, as well as deforestation, were measured based on MapBiomas data. Information about annual mangaba production was extracted from data provided by IBGE on Vegetable Extraction and Silviculture Production. The environmental valuation by mangaba consumers at fairs was measured through questionnaire application. Natural mangaba tree-growing areas in Sergipe State have shown low rates of forest cover and natural non-forest sites in the last 34 years. However, these areas are mainly used for agricultural purposes, a fact that compromises mangaba production. Sergipe State has shown considerable reduction in mangaba production rates from 1995 to 2016; however, such a production presented remarkable recovery in the last three years. Contingent valuation has shown that potential stakeholders are willing to financially contribute to the conservation of both mangaba trees and the Atlantic Forest.

KEYWORDS: environmental services; non-timber forest product; deforestation; payment for environmental services; Atlantic Forest.

RESUMO

Este trabalho teve como objetivo avaliar o desmatamento nas áreas de ocorrência de mangaba (*Hancornia speciosa* Gomes) e a valoração ambiental nas feiras do estado de Sergipe, para que se possa propor mecanismos de pagamentos por serviços ambientais para conservação das áreas de ocorrência natural da mangaba no estado de Sergipe. O uso e cobertura da terra e o desmatamento foram quantificados com uso de dados do MapBiomas. A produção anual de mangaba foi extraída de dados da Produção da Extração Vegetal e da Silvicultura do IBGE. A valoração ambiental dos consumidores de mangaba nas feiras foi obtida por meio de entrevistas. As áreas de ocorrência natural de mangaba no estado de Sergipe em 34 anos apresentaram baixos percentuais de cobertura florestal e áreas naturais não florestais. Nessas áreas predomina o uso agropecuário, o que compromete a produção de mangaba. De 1995 a 2016 houve uma grande redução da produção de mangaba no estado de Sergipe, no entanto houve recuperação nos últimos três anos. A valoração contingente demonstrou que os potenciais stakeholders (tomadores de decisão) estão dispostos a contribuir financeiramente para a conservação das mangabeiras e da Mata Atlântica.

PALAVRAS-CHAVE: serviços ambientais; produto florestal não madeireiro; desmatamento; pagamento por serviços ambientais; Mata Atlântica.

INTRODUCTION

The Brazilian Atlantic Forest is fragmented; despite the significant changes it has experienced over the years, it is still essential to provide environmental resources and services to approximately two thirds of the Brazilian population living in its incidence area (GUEDES & SEEHUSEN 2011). The Atlantic Forest originally

covered 1.3 million km²; however, only 8% to 16% of its original area remains nowadays (INPE 2020, RIBEIRO et al. 2009).

The Atlantic Forest in the Northeastern region extends along a continuous coastal strip from Rio Grande do Norte State to Bahia State, as well as in discontinuous areas over plateaus, mountains, dunes and valleys in Ceará and Piauí states - it originally covered 255,245 km² and occupied 28.84% of the Northeastern region territory as a whole (TABARELLI et al. 2006). Sergipe State houses only 13% of its original forest cover (SEDURBS 2014); only 8% of forest remnants of the Atlantic Forest Biome remains in it (SANTOS & VILAR 2012).

These remnants are under constant anthropogenic pressure, and it has been causing fast landscape, territorial and socio-geographic changes in them (SANTOS & VILAR 2012). Thus, species such as *Hancornia speciosa* Gomes, which is a mangaba tree of significant economic and sociocultural importance for Sergipe State, have been constantly threatened by activities such as real estate expansion, tourism, shrimp farming and agribusiness, which are carried out in their natural incidence areas (SILVA JÚNIOR et al. 2011).

The Atlantic Forest in Sergipe State, and its associated ecosystems where natural mangaba tree populations grow in, cover approximately 101,241.48 hectares that are divided into forest, mangrove, *restinga* and natural non-forested areas (JESUS et al. 2014). Mangaba fruit extraction is the main income source for many families living in Sergipe State; these fruits are mainly, and directly, sold to consumers in fairs, as well as to large pulp and ice cream industries in the state.

Brazil has approved law n. 14,119, which provides on the National Policy on Payment for Environmental Services (BRASIL 2021) and aims at reducing deforestation. This law also highlights the important role played by traditional populations and landowners, such as female mangaba fruit collectors and owners of natural mangaba tree-growing areas, as well as the payment for environmental services to these groups in order to offset the opportunity cost.

The economic theory provides tools to analyze environmental issues, such as environmental valuation, which, in association with the use of geographic information systems, enables the adoption of important methodologies to support decision-making processes about the use of natural resources. Understanding environmental services' value allows their effective management process, including economic incentives aimed at protecting these services. However, valuing environmental services does not mean "commodifying them" to be traded in private markets (ANSOLIN et al. 2018).

Thus, environmental valuation plays important role at the time to define the price to be paid to female mangaba fruit collectors and to owners of natural mangaba tree-growing areas, in order to guarantee the sustainable exploitation of mangaba fruits for the current and future generations. It is worth emphasizing the relevance of studies conducted with groups of female mangaba fruit collectors who were acknowledged as culturally differentiated population in 2010 (SERGIPE 2010), along with the 64 communities and 1,628 families involved in this activity, in that very same year (VIEIRA & RODRIGUES 2009, 2010).

Therefore, the aim of the current study was to assess deforestation in mangaba tree (*Hancornia speciosa* Gomes) incidence areas and environmental valuation in fairs held in Sergipe State, in order to encourage the reflection about the likelihood of proposing payment mechanisms for environmental services to help conserving natural mangaba tree-growing areas in the state.

MATERIAL AND METHODS

The study site was defined based on RODRIGUES et al. (2017), who mapped the entire natural mangaba tree-growing area in Sergipe State, a "shapefile" was generated for the study site (Figures 1 and 2).

The climate in the investigated region is classified as tropical humid (Aw) with dry summer, based on Köppen's climate classification system. Mean temperature reaches 23 °C in the coldest months and 31 °C, in the warmest ones (SILVA 2001, SOARES 2001).

The georeferenced vector database about natural mangaba tree-growing areas in Sergipe State, which was used in the current study, was made available by Embrapa Tabuleiros Costeiros (Embrapa Coastal Tablelands) (RODRIGUES et al. 2017).

Land use and cover data were extracted from MapBiomas (http://mapbiomas.org/), which is a highly reliable source of classified and geo-referenced land-use data based on the Landsat satellite. It is available for the entire country at 30 m spatial resolution.

The MapBiomas classification process takes into consideration annual land use and cover maps, based on a Random Forest classification routine applied to satellite images. Classification accuracy higher

than 80% (Table 1) was observed for different years analyzed and obtained at the MapBiomas website.

Figure 1. Mangaba fruit extraction process (A) and collected fruits (B). Source: MOURA (2018).

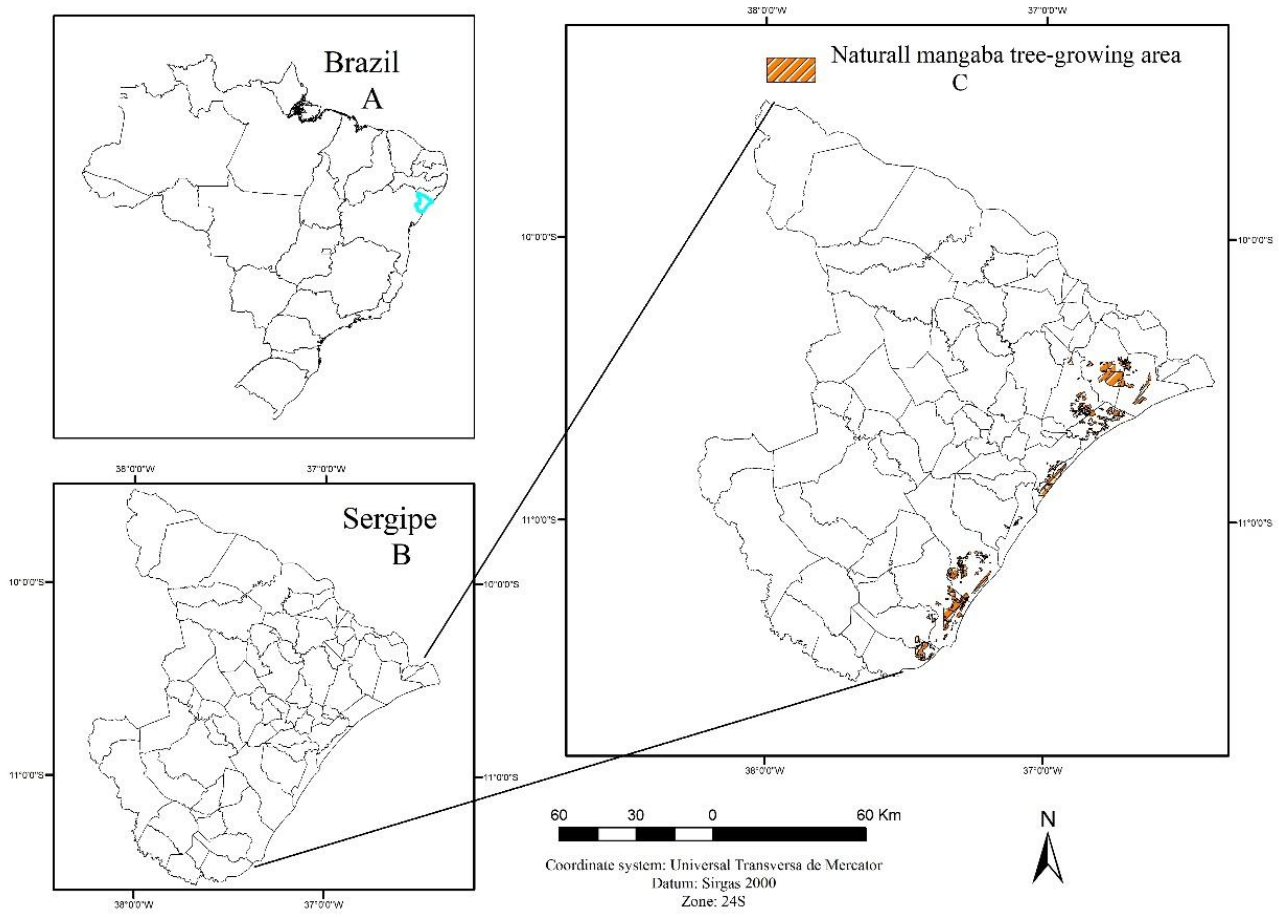

Figure 2. Natural mangaba tree-growing areas in the Atlantic Forest area in Sergipe State. Map of Brazil (A). Map of Sergipe State (B). Map of natural mangaba tree-growing areas in Sergipe State (C).

Table 1. Global accuracy observed for mangaba tree-growing areas in Sergipe State, Brazil, in different

years.

	Global Accuracy (Year)	
Atlantic Forest Biome	1985	2019
	0.89	0.90

The accuracy of land use and cover maps plotted for the study site was assessed based on confusion matrix (CONGALTON & GREEN 2008), which enabled calculating Kappa accuracy and agreement index (LANDIS & KOCH 1977). In total, 1000 samples were randomly selected by taking into consideration 2019 Landsat image data classified by MapBiomas, based on land use and cover type distribution features of the study site. These homogeneous areas in the sample were easily identified through visual observation; the same image classified by MapBiomas was used as reference. The distribution of sample pixels was regular and well-represented throughout the study site. Randomly selected sample pixels were used to quantitatively assess the accuracy of the land use and cover classification, based on indicators such as producer and user accuracy, omission and commission error, overall accuracy and Kappa agreement index (CONGALTON & GREEN 2008, MATHER & TSO 2016).

Therefore, accuracy assessment has estimated 80.25% and 86.21% of Kappa agreement index. This outcome has evidenced substantial classifier performance and good reliability level of classification results (ARAYA & CABRAL 2010, KEENAN et al. 2015).

Files from the MapBiomas project version 5.0 were acquired. The QGSIS 2.18 software was used to select polygons of land use and cover in natural mangaba tree-growing areas in 1985 and 2019. Land use and cover classes of MapBiomas project version 5.0 were used as described in Table 2.

Table 2. Land Use and Cover Classes of MAPBIOMAS project version 5.0.

Forest	Forest formation
	Savanah formation
	Mangrove
Non-forest natural formation	Apicum
	Other non-forest formations
Farming	Pasture
	Sugarcane
	Agriculture and pasture mosaic
	Other temporary crops
	Planted forest
Non-vegetated area	Urban infrastructure
	Other non-vegetated areas
	Beach and dune
Waterbodies	River, lake and ocean
	Aquaculture

Data about mangaba production in Sergipe State were compiled from IBGE's Vegetal Extraction and Forestry Production survey; they can be accessed on the website: https://sidra.ibge.gov.br/pesquisa/pevs/tabelas. Data referring to Sergipe State's production (in tons) from 1986 to 2019 were collected and tabulated.

The study site used for environmental valuation purposes was defined by crossing two information sources, namely: the incidence of mangaba fruit extraction in several municipalities in Sergipe State (VIEIRA & RODRIGUES 2009, 2010) and the indication of municipal fairs where mangaba fruits are traded in, based on information obtained during workshops conducted with female mangaba fruit collectors linked to Female Mangaba Collector Associations in Sergipe State (OLIVEIRA et al. 2017).

Thus, the main fairs in municipalities mentioned in both information sources were included in the data collection process; such a process totaled 15 municipalities and 16 fairs: Aracaju (Augusto Franco Market and CEASA), Capela, Carmópolis, Estância, Indiaroba, Itabaiana, Japaratuba, Laranjeiras, Santa Luzia do Itanhy, Maruim, Pirambu, Riachuelo, Salgado, São Cristóvão and Umbaúba.

The contingent valuation or willingness-to-pay (WTP) method was herein used due to lack of market costs or prices associated with environmental services provided by natural mangaba-producing areas, and because it is the only technique capable of capturing the existence value (MOTTA 1997). Thus, it was possible assessing the voluntary contribution to the preservation of areas where mangaba trees and the Atlantic Forest grow in Sergipe State.

Data were collected through a semi-structured form applied during one-on-one interviews conducted with users at open fairs in Sergipe State. Interviews were carried out by a team of five individuals, throughout the day, in each visited fair, in the first half of 2016. After participants received clarifications about the research and about the purpose of environmental valuation, they were asked two questions: 1) how much would you be willing to pay if you had to voluntarily contribute to a fund for the conservation of mangaba trees? 2) how much would you be willing to pay if you had to voluntarily contribute to a fund for the conservation of the Atlantic Forest? Then, respondents were introduced to a card with six alternatives ranging from R$ 0.00 to R$ 5.00.

Respondents' socioeconomic data such as age, income and schooling were also collected. Chi-square test was used to investigate whether socioeconomic features had influence on individuals' willingness to pay (ZAR 1999, SILVA et al. 2019).

There are no official data about the number of consumers going to open markets in Sergipe State, a fact that makes it impossible calculating a probabilistic sample. Thus, the target audience was selected through intentional non-probabilistic sampling, since it enables selecting a population subgroup that is considered representative of the investigated reality based on the information available and on researcher's judgment - whenever it is necessary including a small number of units in the sample (MARCONI & LAKATOS 2008, MAROTTI et al. 2008). Consumers were approached from 7:00 a.m. to 11:00 a.m.; inclusion criteria to participate in the interview were to be over 18 years old and willingness to participate in the research. In total, 340 interviews were carried out.

It is worth emphasizing that the research was previously registered at the Research Ethics Committee of Federal University of Sergipe. All participants were informed about the research aims and were asked to give their consent by signing the Informed Consent Form.

RESULTS AND DISCUSSION

Land use and cover classes classified as forest typologies (forest formation, savannah formation and mangrove) presented total natural mangaba tree-growing area in Sergipe State equal to 17.19%, in 1985; and to 10.94%, in 2019 (Table 3). There was forest cover loss by 6.25% within 34 years, and it resulted in low forest remnant rate. However, estimates observed in the current study were lower than those reported by RODRIGUES et al. (2017), who, in 2016, observed forest cover decrease by 29.6% in natural mangaba tree-growing areas, over a six year period.

Table 3. Land use and cover quantification, and their respective rates, between 1985 and 2019, in natural mangaba tree-growing areas in Sergipe State.

Land use and cover classes	1985	2019	1985	2019
	Km^2		%	
Forest formation	54.89	30.54	15.38	8.56
Savanah formation	1.30	2.85	0.36	0.80
Mangrove	5.18	5.65	1.45	1.58
Apicum	0.42	0.54	0.12	0.15
Other non-forest formations	11.63	6.73	3.26	1.89
Pasture	115.92	134.13	32.47	37.58
Sugarcane	0.00	18.26	0.00	5.12
Agriculture and pasture mosaic	150.08	125.29	42.04	35.10
Other temporary crops	5.81	20.78	1.63	5.82
Planted forest	0.00	0.001	0.00	0.01
Urban infrastructure	0.04	3.36	0.01	0.94
Other non-vegetated areas	2.69	1.80	0.75	0.51
Beach and dune	6.88	4.47	1.93	1.25
River, lake and ocean	2.13	2.03	0.60	0.56
Aquiculture	0.00	0.48	0.00	0.13

Natural non-forest formations (apicum and other non-forest formations) corresponded to 3.38% of the natural mangaba tree-growing area in Sergipe State in 1985, but this rate decreased to 2.04% in 2019 (Table 3). Mangaba species are capable of growing in both forest and non-forest formations (other non-forest formations), and it may explain the low rate recorded for this land use and cover class between 1985 and 2019.

Mangaba can be considered the most important non-timber forest product in Sergipe State. According

to VIEIRA & RODRIGUES (2009), 1,628 families living in Sergipe State collected mangaba fruits in 2009. On the other hand, RODRIGUES et al. (2017) have updated the estimate by VIEIRA & RODRIGUES (2009) and found that 1,776 families were involved in the mangaba extraction activity in 2016.

Farming (pasture, sugarcane crops, agriculture and pasture mosaic, other temporary crops and planted forest) accounts for the largest land use and cover in natural mangaba tree-growing areas. These activities, altogether, accounted for 76.15% of land use and cover in 1985, as well as for 83.63% of it in 2019 (Table 3). Thus, natural mangaba tree-growing areas in Sergipe State are under intense agricultural use, and it has direct impact on mangaba fruit production and on the very survival of this species. Pasture stood out as the main land use and cover (37.58%) adopted in natural mangaba tree-growing areas in Sergipe State in 2019 (Table 3).

Non-vegetated areas (urban infrastructure, other non-vegetated areas, beaches and dunes) accounted for 2.69% of land use and cover in 1985; they recorded small increase to 2.70% in 2019 (Table 1). Waterbodies (rivers, lakes, the ocean and aquaculture), in their turn, recorded low incidence rates in natural mangaba tree-growing areas in Sergipe State in 1985 (0.60%) and 2019 (0.69%) (Table 3).

The lowest mangaba production rate in Sergipe State was recorded in 1986; values remained low until 1995. Between 1996 and 2006, the state recorded the highest annual mangaba production rates. Then, the production declined from 2007 to 2016, but it presented annual mangaba production resumption between 2017 and 2019 in the state (Figure 3).

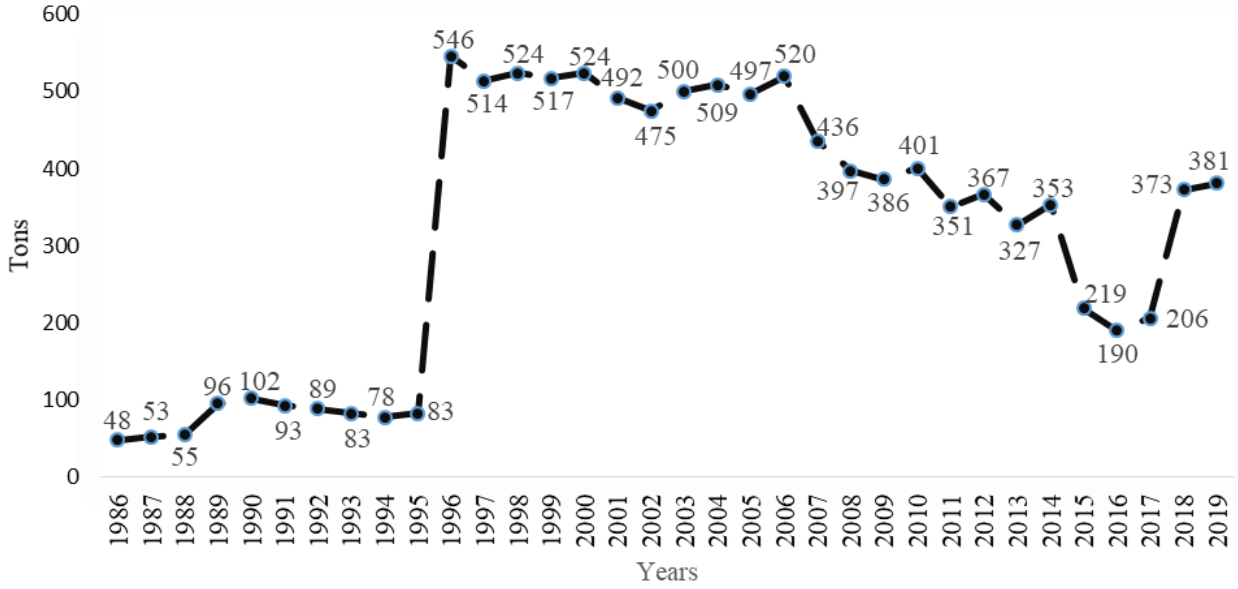

Figure 3. Mangaba production (in tons) in Sergipe State, from 1986 to 2019. Source: Elaborated by the author, based on PEVS data (IBGE 1985-2019).

Despite mangaba production decline in Sergipe State from 1996 to 2017, according to PEVS data provided by IBGE (2019), the state was the largest mangaba producer in Brazil between 2007 and 2016. According to estimates, mangaba fruit extraction in 2009 accounted for 25% of the entire fruit pulp production in Sergipe (EMDAGRO 2009).

Despite the social and economic importance of mangaba extraction and production processes, there are no environmental and social policies focused on protecting natural mangaba tree-growing areas and extractivist populations in Sergipe State. Thus, the pressure resulting from agricultural land use higher than 80% (Table 1) can lead to irreparable environmental and socioeconomic losses. According to MOURA (2018), mangaba fruit exploitation management, on a sustainable basis, in Sergipe State, is hampered due to lack of official data and/or of state knowledge about the number of families engaged in mangaba extraction activities or about the number of owners of natural mangaba tree-growing areas and/or plantations.

Buyers at open markets are among the main fresh mangaba fruit consumers in Sergipe State; thus, consumers in open fairs are seen as “stakeholders” (decision-makers) of mangaba market in the state. In addition, they play essential role in the formulation of environmental public policies aimed at protecting natural mangaba tree-growing and mangaba fruit-extraction areas, such as those focused on implementing Payment for Environmental Services (PES).

The contingent valuation process conducted with open-market consumers in Sergipe State and

consumers' willingness to pay (WTP) for the conservation of mangaba trees led to the following results: 94 (23.3%) interviewed consumers have said they would not pay a penny for it, 47 (11.7%) consumers would pay R$ 1.00/month^{-1}, 63 (15.6%) would pay R$ 2.00/month^{-1}, 22 (5.5%) would pay R$ 3.00/month^{-1}, 23 (5.7%) would pay R$ 4.00/month^{-1} and 154 (38.2%) would pay R$ 5/month^{-1}. Thus, the contingent valuation has estimated willingness to pay R$3.56, on a monthly basis, on average.

There was low rate of consumers who were not willing to pay for the conservation of mangaba trees, whereas 76.7% of "stakeholders" (decision-makers) would be willing to pay for it. This outcome has evidenced good acceptance towards the implementation of the PES program to protect the few conserved natural mangaba tree-growing areas (Table 1) that produce mangaba fruits in Sergipe State.

Subsequently, respondents were asked about their willingness to pay for the conservation of the Atlantic Forest: 149 (37%) of them have said they would not pay a penny for it, 43 (10.7%) would pay R$ 1.00/month^{-1}, 44 (10.9%) would pay R$ 2.00/month^{-1}, 33 (8.2%) would pay R$ 3.00/month^{-1}, 28 (6.9%) would pay R$ 4.00/month^{-1}, 105 (26.1%) would pay R$ 5.00/month^{-1} and 1 (0.25%) respondent did not answer the question. Thus, participants' willingness to pay for the conservation of the Atlantic Forest in Sergipe State corresponded to R$ 3.42, on a monthly basis, on average.

In total, 403 consumers were interviewed at all 15 visited fairs, 129 men and 274 women, 32% and 68% of respondents, respectively. Interviews were only carried out with individuals in the age group over 18 years old. The sample was divided into age groups, based on IBGE's classification: 18 young individuals (18-19 years old, 4.5%), 341 adult individuals (20-59 years old, 84.6%) and 40 elderly individuals (60 years old or older, 9.9%); 4 participants did not inform their age.

Respondents' schooling was divided into 9 categories: illiterate (n = 11; 2.7%), incomplete elementary school (n = 140; 34.7%), complete elementary school (n = 29; 7.2%), incomplete high school (n = 35; 8.7%), complete high school (n = 105; 26.1%), incomplete higher education (n = 13; 3.2%), complete higher education (n = 39; 9.7%), postgraduate education (n = 4; 1%) and 27 (6.7%) did not report their schooling level.

With respect to employability, 148 respondents did not have a job, 231 had a job and 24 did not inform. Among the ones who had a job, 23 (9.9%) were informal salaried workers, 54 (23.4%) were formal salaried workers, 40 (17.3%) were civil servants, 109 (47.2%) were self-employed and 6 (2.6%) fell into other categories (employer, military, among others).

As for their mean family income (sum of all residents' income[1]), 13 (3.2%) respondents did not want to inform it, 41 (10.2%) were unable to inform it, 3 (0.7%) reported to not have any income, 110 (27.3%) earned up to 1 minimum wage, 92 (22.8%) earned from R$ 881.00 to 2 minimum wages, 54 (13.4%) earned from R$ 1,760.00 to 3 minimum wages, 38 (9.4%) earned from R$ 2,640.00 to 4 minimum wages, 14 (3.5%) earned from R$ 3,520.00 to 5 minimum wages, and 38 (9.4%) earned more than R$ 4,400.00. Based on the chi-square test, there was not association between WTP and variables such as schooling, family income and age.

Approximately 62.8% of "stakeholders" (decision-makers) have shown willingness to pay for/financially contribute to the conservation of the Atlantic Forest. This outcome has shown that not only mangaba trees, but also the biome sheltering them, and other associated species/ecosystem services, are considered important by interviewees.

Sergipe State does not have economic instruments to enable the conservation of the Atlantic Forest and natural mangaba tree-growing areas. Therefore, a fund based on financial contributions for such a conservation could be feasible, as observed in the contingent valuation conducted with free-fair consumers who live in the state.

State Law n. 7,082 was enacted on December 16, 2010, due to the socio-economic importance of mangaba plants. This law acknowledges female mangaba fruit collectors as culturally differentiated group; therefore, they must be "protected based on their own social organization forms, as well as on their territories and natural resources, which are essential to ensure their physical, cultural, social, religious and economic reproduction" (SERGIPE 2010, OLIVEIRA et al. 2017). However, command and control measures, such as the enactment of this law, were not enough to curb deforestation in natural mangaba tree-growing areas. Thus, it is necessary conducting further in-depth studies about other natural conservation mechanisms, such as payment for environmental services.

[1] US DOLLAR Ptax[4]/ Closing Prices, from 01/01st/2016 to 06/30th/2016: simple average recorded for the period 3.70 (buy and sell), quoted in Real (Brazilian currency). Available at: https://www.bcb.gov.br.

CONCLUSION

Natural mangaba tree-growing areas in Sergipe State have shown low rates of forest cover and non-forest natural areas in 34 years. Agricultural land use prevails in these areas (83.62%), a fact that has compromised mangaba production between 1995 and 2016, when there was large decrease in mangaba production in Sergipe State.

Contingent valuation has shown that potential “stakeholders” (decision-makers) were willing to financially contribute to the conservation of both mangaba trees and the Atlantic Forest: R$ 3.56 and R$ 3.42, on average, respectively. The value of environmental services can be used to create a fund for the conservation of mangaba trees in Sergipe State aimed at paying owners of natural mangaba tree-growing areas, as well as female mangaba fruit collectors, for their environmental services.

Sergipe State should implement a strong policy focused on protecting natural mangaba tree-growing areas. This policy should include mechanisms to allow the payment for environmental services, since the mere acknowledgement by State Law n. 7.082/2010 of the need to protect these areas was not enough to reduce deforestation and to stop the conversion of natural areas into pasture areas and/or into other land uses that can lead to irreparable mangabeira trees and biodiversity losses in Sergipe State.

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