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Conservation of the genetic resources of *mangaba*, genipap, and guavaberry, native fruit species, of the Northeastern region of Brazil

Abstract – The conservation of the genetic resources of native fruit trees, carried out at Embrapa Tabuleiros Costeiros, encompasses three forms of conservation: genebanks, the maintenance of Atlantic Forest remnants, and the protection of the way of life of traditional communities, Indigenous Peoples, and family farmers. The objective of this work was to document and analyze the actions of Embrapa for the ex-situ, in-situ, and on-farm conservation of the genetic resources of three important species of native fruit trees of the Northeastern region of Brazil - *mangaba*, genipap, and guavaberry. These actions aimed the use of these fruits and the mitigation of biodiversity loss in the Atlantic Forest, aggravated in the context of climate emergencies. These actions have contributed to the conservation of genebanks and to the maintenance of areas and their forest cover, with an impact on the reduction of problems arising from climate change. Other contributions include the development of sustainable production systems and the subsidy of public policies that aim to guarantee the conservation of territories, natural resources, and their use by communities.

Index terms: *Genipa americana*, *Hancornia speciosa*, *Myrciaria floribunda*, biodiversity, traditional communities.

Conservação dos recursos genéticos de mangaba, jenipapo e cambuí, espécies de fruteiras nativas, da região Nordeste do Brasil

Resumo – A conservação dos recursos genéticos de fruteiras nativas, realizada pela Embrapa Tabuleiros Costeiros, engloba três formas de conservação: bancos de germoplasma, manutenção dos remanescentes florestais da Mata Atlântica e proteção dos modos de vida das comunidades tradicionais, povos indígenas e agricultores familiares. O objetivo deste trabalho foi documentar e avaliar as ações da Embrapa quanto à conservação ex-situ, in-situ e em campo dos recursos genéticos de três importantes espécies de fruteiras nativas da região Nordeste do Brasil – mangabeira, jenipapeiro e cambuizeiro. Estas ações visaram o uso das frutas e a mitigação da perda de biodiversidade da Mata Atlântica, agravada no contexto das emergências climáticas. Ademais, as ações têm contribuído para a conservação dos bancos genéticos e para a manutenção das áreas e sua cobertura florestal, com impacto na redução dos problemas advindos das mudanças climáticas. Outras contribuições incluem o desenvolvimento de sistemas de produção sustentáveis e o subsídio

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de políticas públicas que visam a garantir a conservação dos territórios, dos recursos naturais e do seu uso pelas comunidades.

Termos para indexação: *Genipa americana*, *Hancornia speciosa*, *Myrciaria floribunda*, biodiversidade, comunidades tradicionais.

Introduction

Plant genetic resources are components of biodiversity with real and potential socioeconomic, scientific, cultural, and environmental value for use by humanity, whether for the production of food, fibers, oils, wood, medicines, resins, and dyes. Genetic resources are the basis of food security and global agriculture, and they must have the genetic variability necessary to prevent hunger and economic losses. Genetic resources constitute a strategic asset of inestimable value for the country, given their role in the environment and their multiplicity of possible applications and uses (Pádua et al., 2021).

Considering the genetic erosion, to which many species of interest have been subjected, several governments have made efforts to protect and conserve their native, exotic, or naturalized genetic resources. Strategies have been developed by government and private research and education institutions, as well as by traditional communities, family farmers, and Indigenous Peoples, and by civil society organizations to conserve and ensure the sustainable use of genetic resources and ecosystems.

Fruit trees are one of the main groups of plants used, with species of extreme importance for food and agriculture. As stated by Giacometti (1993), Brazil is made up of ten centers of diversity of fruit species that are home to more than 500 native species, many of which are in an advanced process of genetic erosion.

The genetic erosion of these species in all Brazilian biomes could cause immediate and incalculable damage to society in general and, in particular, to the ecosystems and communities that survive on their products as food, or as source of income.

The collection of germplasm from native fruit trees in the country is still limited, and their ex-situ conservation is insufficient given the continental size of Brazil, the diversity of species, and the existing intraspecific variability. In most cases, conservation is done in genebanks in field conditions, since seeds

of most species of native fruit trees have a recalcitrant nature, that is, they do not withstand a reduction of the humidity level to be stored at low temperatures (Pádua et al., 2021).

Unlike the exotic fruit trees traditionally cultivated in the country (citrus, banana, grape, etc.), whose research and use are at a more advanced stage, most native fruit trees still lack both efforts to reach a wider markets and work aimed at the collection, conservation, and characterization of their genetic resources (Ferreira, 1999). The demand for foods and products anchored in sociobiodiversity, produced sustainably, healthy, rich in nutrients and antioxidants, and with a distinctive flavor and aroma has led to a great appreciation of Brazilian fruits by the population, the market, and the agribusiness (Silva Júnior et al., 2021).

The Atlantic Forest Diversity Center is home to many species of native fruit trees of interest (Giacometti, 1993). Out of these, the following genera are worthy of note: *Eugenia* (uvaia, cambucá, cagaita, pitanga), *Psidium* (araçá), *Campomanesia* (guabiroba), *Myrciaria* (jabuticaba), *Passiflora* (passion fruit), and families including Anacardiaceae, Arecaceae, and Annonaceae, with numerous species.

Out of the fruit trees of the Atlantic Forest, the mangaba (*Hancornia speciosa* Gomes, Apocynaceae) and the genipap (*Genipa americana* L., Rubiaceae) are two of the most important raw materials for the agroindustry and the production of juices, frozen pulps, ice creams, liqueurs, sweets, and jellies. Mangaba juice and ice cream are part of the agro-food and cultural landscape of the Northeast coast. Genipap liqueur is the most popular fruit liqueur in the Northeast Region of Brazil, in which Bahia and Sergipe's industrial and artisanal productions stand out. Additionally, a dark blue natural dye is extracted from the immature pulp genipap fruit, widely used by Indigenous Peoples, but also by the food, textile, and cosmetics industries. Although the use of guavaberry (cambu) – [*Myrciaria floribunda* (H. West ex Willd.) O. Berg., Myrtaceae] – is more restrict from a geographical point of view; it represents a significant source of income for communities on the coast and inland of the Northeastern Brazil. These communities use its fruit to make drinks and jams.

Despite the widespread use of these fruits by the population, including as medicinal drugs, their existence in the ecosystems where they occur is threatened by

factors related to human action on natural areas, such as forest fragmentation, urban expansion, and monocultures.

The objective of this review was to document and analyze the research, development, and innovation actions of Brazilian Agricultural Research Corporation (Embrapa), for the ex-situ, in-situ, and on-farm conservation of genetic resources of three species of native fruit trees: *mangaba*, genipap and guavaberry. These efforts aim to mitigate the loss of biodiversity in the Atlantic Forest in Northeastern Brazil, aggravated in the context of climate emergencies.

These actions are linked to Embrapa's Genetic Resources Platform, which includes species with a high-degree of socioeconomic development, as well as species grouped as "Plants for the Future", listed by the Ministry of the Environment (Ministério do Meio Ambiente/MMA) as high priorities for conservation and research, such as *mangaba*, genipap and guavaberry (Coradin et al., 2018). These are species of regional importance with great potential to reach domestic and foreign markets.

Materials and Methods

The work was developed based on a detailed historical survey and selection of studies and research conducted for *mangaba* since the 1990s, and for genipap and guavaberry, since the first half of the 2000s, by Embrapa Coastal Tablelands (research center located in Aracaju, SE). For this purpose, the researchers involved, the Ideare project platform of the Embrapa's management system (Sistema Embrapa de Gestão/SEG), and the electronic platforms of the National Council for Scientific and Technological Development (Conselho Nacional de Desenvolvimento Científico e Tecnológico/CNPq) were consulted. For the bibliographic survey, the agricultural research database of Embrapa (Base de Dados da Pesquisa Agropecuária/BDPA), the catalog of theses and dissertations of the Coordenação de Apoio ao Pessoal de Nível Superior/CAPES, Web of Science, and Scopus were consulted.

For the survey of geospatial data, the digital platform Embrapa spatial data infrastructure (GeoInfo) was consulted. The platform Alelo Genetic Resources (Alelo Recursos Genéticos, 2025) provides information on the documentation and management of conservation activities of genetic resources; and the

website of resources network of Northeast plant genetic (Recursos Genéticos Vegetais do Nordeste – RGVNE, 2025) gathers information on all plant genebanks in the region. The national institute of industrial properties (Instituto Nacional da Propriedade Industrial/INPI), by an e-patent system, was used to review the patent documents.

The three different forms of native fruit tree genetic resource conservation conducted at Embrapa Coastal Tablelands served as the basis for organizing and arranging the data, namely: i) ex-situ conservation performed outside the areas where the species naturally occur, (genebanks, in vitro collections, etc.); ii) in-situ conservation is carried out in natural environments and ecosystems (conservation units, legal reserves, remnants not legally protected, etc.); and iii) on-farm conservation is carried out by Indigenous Peoples, traditional communities, or family farmers in their areas (landrace genebanks, or areas with small-scale cultivation of useful species in family farm) (Brasil, 2015, 2025). In addition, characterization, evaluation and documentation activities were included, which are directly related to conservation.

The research was registered in the national system for the management of genetic heritage and associated traditional knowledge (Sistema Nacional de Gestão do Patrimônio Genético e do Conhecimento Tradicional Associado/SISGEN), with a view to studying native species linked to genetic heritage, as well as accessing traditional knowledge, when necessary, for which prior consent required by current legislation was obtained.

Conservation of Atlantic Forest native fruit trees at Embrapa Coastal Tablelands

In Northeastern Brazil, research and teaching institutions have been concerned about the conservation of native fruit species, since the beginning of the second half of the 20th century, with emphasis on the pioneering work of the former agricultural research and experimentation institutes of the Ministry of Agriculture in the establishment of genebanks (Silva Junior et al., 2021). At Embrapa, the main research on these species is currently concentrated in its Genetic Resources Network, in the specific long-term project Active Germplasm Banks of Native Fruit Trees, coordinated by Embrapa Coastal Tablelands, and in the project In-situ/On-farm Conservation of Plant Genetic Resources and Interaction with Ex-situ Conservation,

under the leadership of Embrapa Genetic Resources & Biotechnology (Brasília, DF).

Mangaba research at Embrapa Coastal Tablelands began in the first half of the 1990s, based on work of the late researcher Raul Dantas Vieira Neto. In 2003, Embrapa Coastal Tablelands, with the support by the Brazilian Society of Fruit Growing, also organized the 1st Brazilian Symposium on *Mangaba* Culture in Aracaju. This event brought together Brazilian experts from various knowledge areas, and the discussions ranged from botany and genetic resources to industrialization and financing. The symposium generated the book *A Cultura da Mangaba* (Silva Júnior & Léo, 2006), which dealt with the state of

the art of the species and was the most complete work published to date on the stages of its production system (Rodrigues et al., 2021). Subsequently, investments were made in different lines of research, covering different segments of the *mangaba* production chain.

Regarding genipap, research began in 2009, following the implementation of the genebank, and about guavaberry, research was established in the same year, in prospective studies of natural populations on the coast of Sergipe.

From the beginning, Embrapa Coastal Tablelands has invested heavily in the conservation of the genetic resources of these species (Figure 1, Table 1,), given

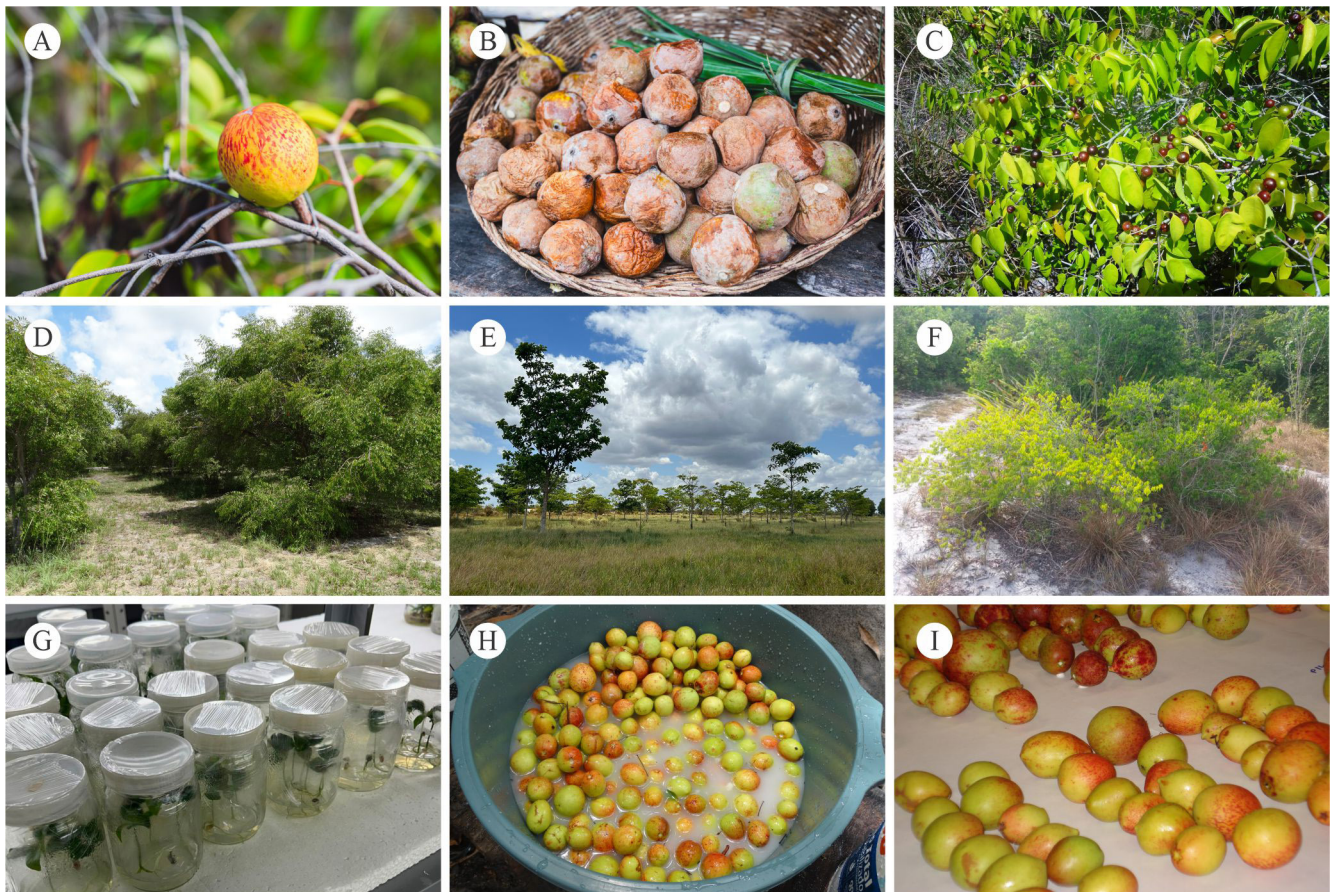


Figure 1. Aspects of the conservation of native fruit trees of the Atlantic Forest, at Embrapa Coastal Tablelands, Brazil. A) *Mangaba* (*Hancornia speciosa* Gomes) (photo by Saulo Coelho Nunes). B) Genipap (*Genipa americana* L.) (photo by Saulo Coelho Nunes). C) Guavaberry [*Myrciaria floribunda* (H. West ex Willd.) O. Berg.] (photo by Ana Veruska Cruz da Silva). D) *Mangaba* Genebank (photo by Josué Francisco da Silva Júnior); E) Genipap Genebank (photo by Ana Veruska Cruz da Silva). F) Natural population of guavaberry in “restinga” vegetation (photo by Ana Veruska Cruz da Silva). G) In vitro collection of genipap germplasm (photo by Ana da Silva Léo). H) *Mangaba* collected by gatherers in Sergipe, Brazil (photo by Josué Francisco da Silva Júnior). I) Characterization of *mangaba* germplasm (photo by Ana Veruska Cruz da Silva).

their socioeconomic importance and the serious threats to natural populations identified during the surveys.

The research network resulted from 19 RD&I projects involving Embrapa's research centers, partner institutions, with the participation of traditional communities, Indigenous Peoples, family farmers, and undergraduate and graduate scholarship holders, which enabled the development of technological products, social technology, patents, subsidies for public policies, technical and scientific publications, theses and dissertations, audiovisual production, and training, seminars, meetings, field days, among other products.

1. Ex-situ conservation

1.1. *Mangaba*

In 2006, the *Mangaba* Genebank of Embrapa Coastal Tablelands was implemented at the Itaporanga experimental field (Campo Experimental de Itaporanga/CEI), located in the municipality of Itaporanga d'Ajuda, SE, Brazil. Since then, continuous efforts have been made to enrich the genebank with new introductions from collection expeditions. Although the conservation of accessions is prioritized in the Northeast Coastal Tablelands and Coastal Lowlands areas, the genebank has examples of ecosystems related to the "cerrado" (of the state of Minas Gerais); the "campos" of Marajó Island, of the state of Pará,

and the "campos gerais" of Chapada Diamantina, of the state of Bahia, which are types of savannah.

The region is situated within a "restinga" (coastal sandbank) geological formation, at 11°06'40"S and 37°11'15"W. The soil in this area is classified as Podzol (according to the FAO World Reference Base), and the climate is categorized as As, which denotes a tropical rainy climate with a dry summer (according to the Köppen-Geiger's classification). The *Mangaba* Genebank has 32 accessions (292 individuals) named according to the location where samples of the population were collected (Table 2). In addition, linked to the genebank, an area of 4.7 ha of the private natural heritage reserve of Caju (Reserva Particular do Patrimônio Natural/RPPN), located in the CEI, is intended for the in-situ conservation of a *mangaba* subpopulation, as well as for the naturally occurring specimens present in the surroundings of the bank.

Mangaba Genebank is the Faithful Depository of Subsamples of Components of the Species' Genetic Heritage in Brazil. Since its conservation is carried out under field conditions, maintenance and management activities are constantly performed on the plants. The genebank is dynamic and has been enriched every year through collections, which has led the curatorship to expand its facilities, incorporating a new area adjacent to the oldest one.

Mangaba Genebank of Embrapa Coastal Tablelands, along with the genebanks of Embrapa Amapá

Table 1. Forms of conservation of three native fruit trees of the Atlantic Forest, at Embrapa Coastal Tablelands, in the state of Sergipe, Brazil, 2025.

Species	Form of conservation
<i>Mangaba</i> (<i>Hancornia speciosa</i> Gomes)	Ex situ (in vivo and in vitro), in situ and on farm
Genipap (<i>Genipa americana</i> L.)	Ex situ (in vivo and in vitro)
Guavaberry [<i>Myrciaria floribunda</i> (H. West ex Willd.) O. Berg.]	In situ

Table 2. Number of accessions, number of individuals, and states of origin of genetic resources maintained in the *Mangaba* and Genipap Genebanks of Embrapa Coastal Tablelands, in the state of Sergipe, Brazil, 2025.

Species	Location of the genebank	Number of accessions	Number of individuals	State of origin
<i>Mangaba</i> (<i>Hancornia speciosa</i> Gomes)	Itaporanga d'Ajuda, SE	32	292	AL, BA, CE, MG, PA, PB, PE, SE
Genipap (<i>Genipa americana</i> L.)	Nossa Senhora das Dores, SE	29	247	BA, CE, DF, MA, MG, SE

States of origin: AL, Alagoas; BA, Bahia; CE, Ceará; DF, Distrito Federal; MA, Maranhão; MG, Minas Gerais; PA, Pará; PB, Paraíba; PE, Pernambuco; SE, Sergipe.

(Macapá, AP), Embrapa Cerrados (Planaltina, DF), and Embrapa Mid-North (Teresina, PI), constitute the ex-situ repositories of the species and its botanical varieties within Embrapa and are linked to its Genetic Resources Platform. Due to the wide distribution of the species across the national territory (from the state of Amapá to the north of the state of Paraná), these regional banks have focused the conservation work on the geographic areas of operation of each of those four Embrapa's research units.

1.2. Genipap

The Genipap Genebank of Embrapa Coastal Tablelands, implemented in 2009, is the only one in Brazil. It served as the *Faithful Depository of subsamples of components of the species' genetic heritage* in the country, similarly to the *Mangaba* Genebank. Located in the Jorge do Prado Sobral experimental field, in the municipality of Nossa Senhora das Dores, in the Agreste region of Sergipe, the genebank is situated at 10°29'30"S, 37°11'36"W, at 204 m altitude. The soil type in the experimental field is a Lixisol (according to the FAO World Reference Base), with a clayey texture and undulating relief. The region's climate is tropical with a dry season in the summer, with 1,050 mm average annual rainfall of and 24.2°C average temperature.

Currently, it has 29 accessions of genipap represented by 247 individuals. There are 28 accessions of the species *G. americana* and one of *G. infundibuliformis* Zappi & Semir, from different Brazilian biomes and ecosystems. The main topics addressed in research at the Genipap Genebank have been, to date, tissue culture/micropropagation (37.5%), genetic diversity/molecular biology (12.5%), genetic resources (16.66%), bioactives (12.5%), propagation (8.3%), and post-harvest (Santos et al., 2024). Studies on the genetic diversity have highlighted the need to establish strategies that allow of the recovery and increase of genetic variability both in situ and ex situ.

1.3. In-vitro conservation of *mangaba*, genipap and guavaberry

Biotechnology is a tool used in the management of genetic resources, with various techniques applied for conservation, propagation, and characterization. Plant tissue culture enables the rescue of zygotic embryos

of species with difficulties in sexual propagation, asexual multiplication by organogenesis, and somatic embryogenesis, processes that are essential for the regeneration of plants subjected to in vitro conservation by slow growth and cryopreservation. Both techniques have been developed as complementary strategies for the in-situ and ex-situ conservation of plant genetic resources.

Protocols for the multiplication of *mangaba* plants through organogenesis, embryo rescue, and conservation by slow growth have been successfully established (Sá et al., 2016; Oliveira et al., 2017; Nascimento et al., 2024). Cryopreservation is still a challenge due to the recalcitrance of the species, with initial results for pollen grains (Rocha et al., 2023). The few published protocols with apical meristems do not show reproducibility.

As an orthodox species, genipap presents a very vigorous in vitro behavior; and its seed and embryonic axes and pollen grain cryopreservation protocols have been validated for different accessions (Sá et al., 2015; Nascimento et al., 2020; Freire et al., 2024, 2025). In vitro multiplication by organogenesis is well established, with multiplication and rooting stages already defined.

Since 2024, Embrapa Coastal Tablelands has maintained two biological collections in its tissue culture laboratory, under slow in vitro growth with duplicate accessions of the Genipap and *Mangaba* Genebanks. The initial research of guavaberry was focused on the successful establishment of in vitro germination (Lédo et al., 2014), as well as on breaking dormancy and establishing substrates for seedling production.

2. In-situ conservation

2.1. *Mangaba*

Research on in-situ conservation of *mangaba* trees was a pioneering activity at Embrapa, and began more than two decades ago (Mota & Silva Júnior, 2003), even before ex-situ conservation actions, through expeditions to the natural areas where the species occurs, and to traditional communities related to *mangaba* collection activities. Based on the researchers' previous experience, the initial objective was to map the remaining areas and threats, as well as to understand the role of extractivists in resource conservation. Thus, 14 expeditions were conducted in 12 states located in Brazil's North, Northeast, Central-West, and Southeast regions, from

The first of these trips occurred in 2003, on the coast of the state of Sergipe. Due to the proximity of the headquarters of Embrapa Coastal Tablelands in this state, the expeditions continued until 2018, initially with only two researchers involved. The expeditions later extended to the north coast of Bahia, in 2004 and 2005, to the coast of Alagoas in 2004, and to the coast of Pernambuco, between 2004 and 2014. With the arrival of other researchers and scholarship holders, the expeditions were undertaken to the following places: Marajó Island and the Salgado Region (PA), in 2006; the coast of Paraíba and Rio Grande do Norte, in 2007 and 2022; Chapada Diamantina (BA), in 2008; Jalapão (TO), in 2009; Serra do Espinhaço and north of the state of

Detailed mapping of the remaining *mangaba* areas in the state of Sergipe started in 2009, and was updated in 2017 (Figure 2) using satellite images, georeferencing, transects, and interviews with key stakeholders (Vieira & Rodrigues, 2009; Rodrigues et al., 2017). The entire state of Pernambuco (Figures 3

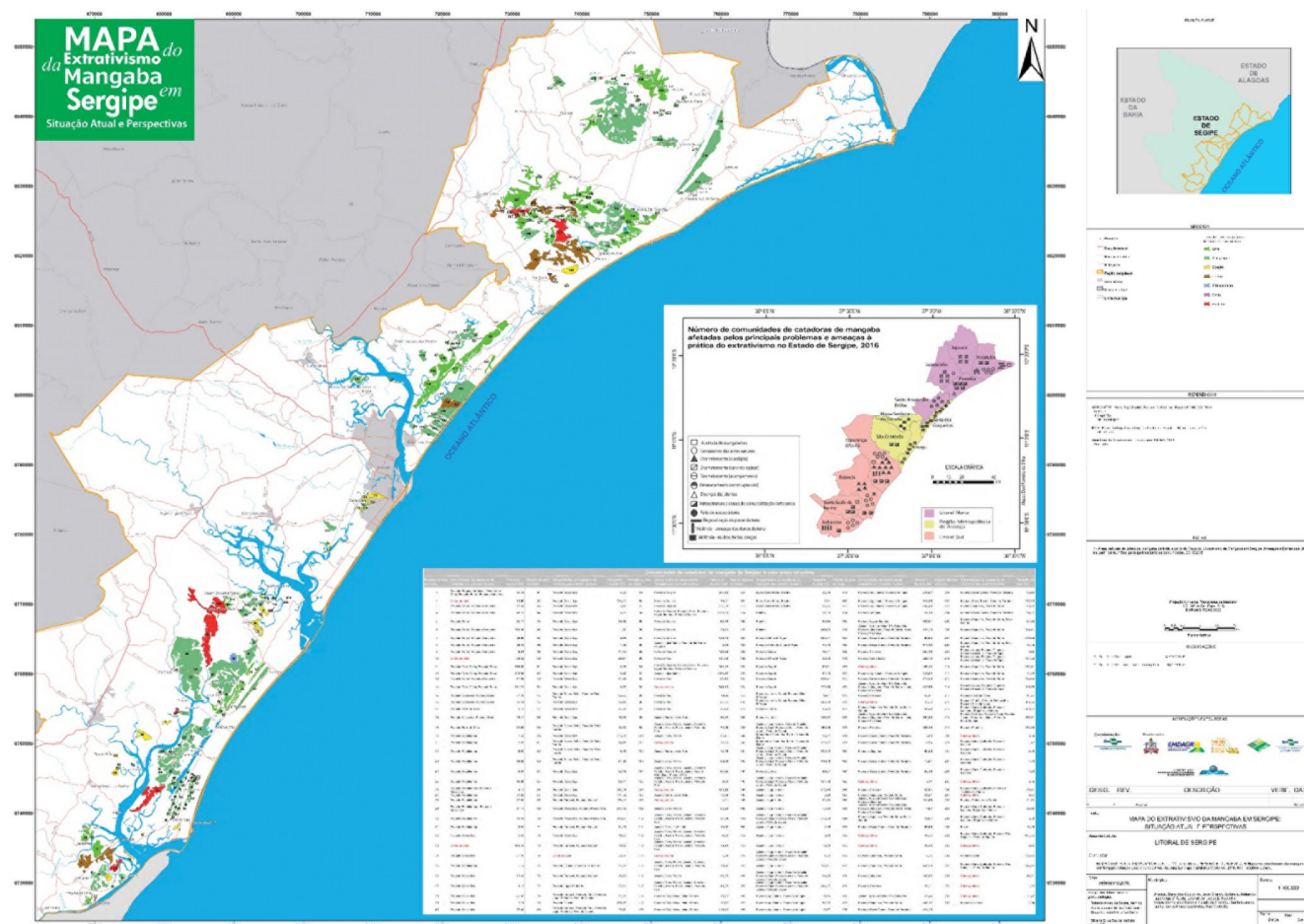


Figure 2. Map of extractivism and remaining areas of *mangaba* (*Hancornia speciosa* Gomes), in the state of Sergipe, Brazil. Source: Rodrigues et al. (2017).

and 4) was then surveyed in 2018 (Silva Júnior et al., 2018b) and, in 2023, the mapping of the state of Paraíba began, with an emphasis on the Potiguara Indigenous Territory, in partnership with the national foundation for Indigenous Peoples (Fundação Nacional dos Povos Indígenas/FUNAI).

A detailed and in-depth historical survey of the *mangaba* species, covering the pre-Columbian era, was also carried out by Mota et al. (2011); it has guided many expeditions, and remains an ongoing activity for researchers. In addition to the maps generated in all works, social and natural sciences were valued in the methods, generating a wealth of information on the history, profile, and typology of *mangaba* gatherers, threats to habitats, and areas of natural occurrence (conservation status), conflicts, management of areas, access and forms of management, knowledge and

traditions, organization of communities, and habits of consumption and sale of *mangaba* (Mota et al., 2011).

Based on the construction of knowledge and on the exchange of information between scientists and communities, the Women *Mangaba* Gatherers Movement (Movimento das Catadoras de Mangaba/MCM) was created in 2007. It aimed at promoting the national visibility of female extractivists, holding state events, participating in local and national committees and forums, and in government public policies (Mota et al., 2007, 2008; Rodrigues et al., 2015). In addition, it was possible to generate the social technology *Strategies for the Empowerment of Female Mangaba Gatherers in Sergipe* (Estratégias para o Empoderamento de Mulheres Catadoras de Mangaba em Sergipe), certified by the Bank of Brazil Foundation in 2011. This initiative encompassed all

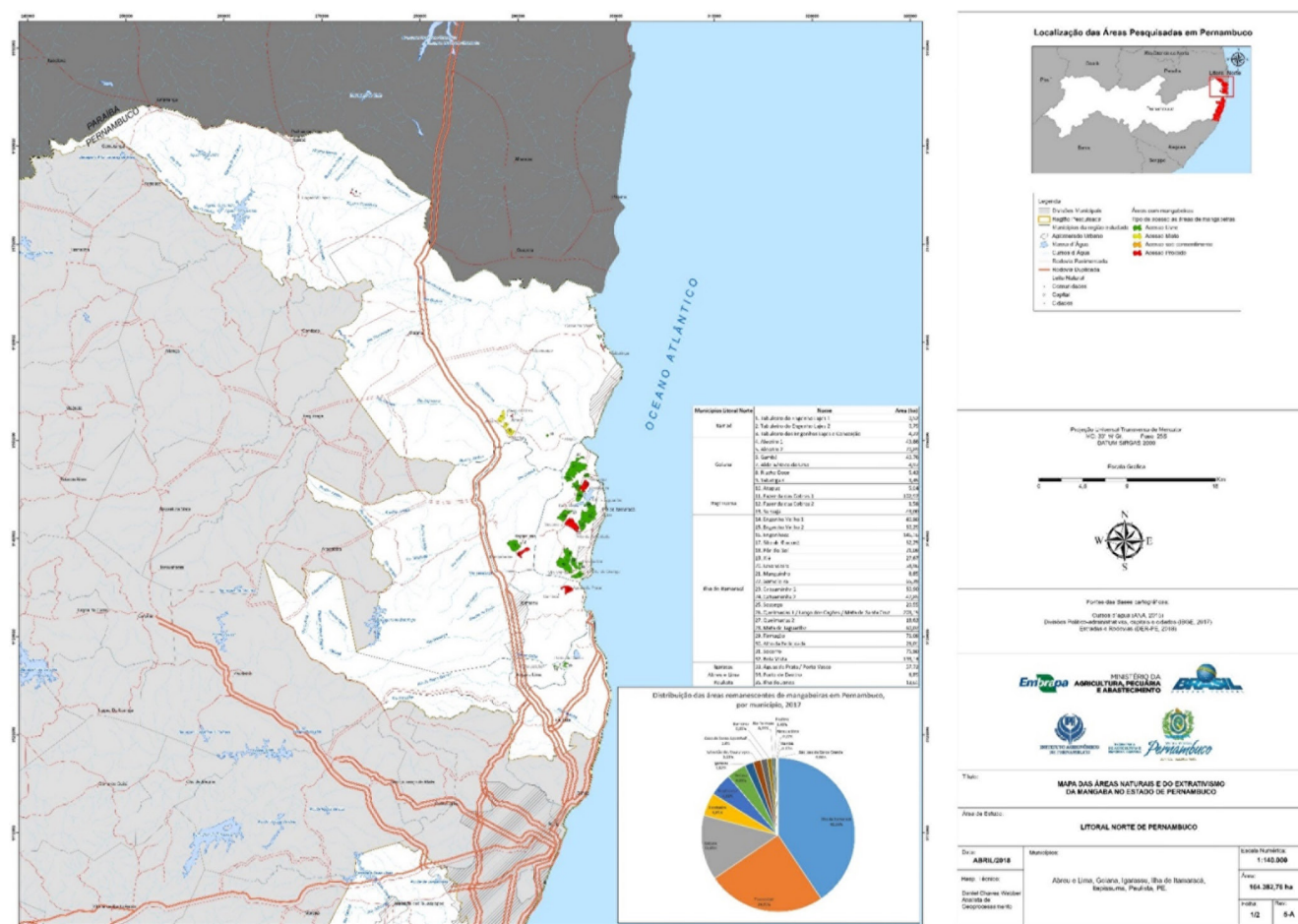
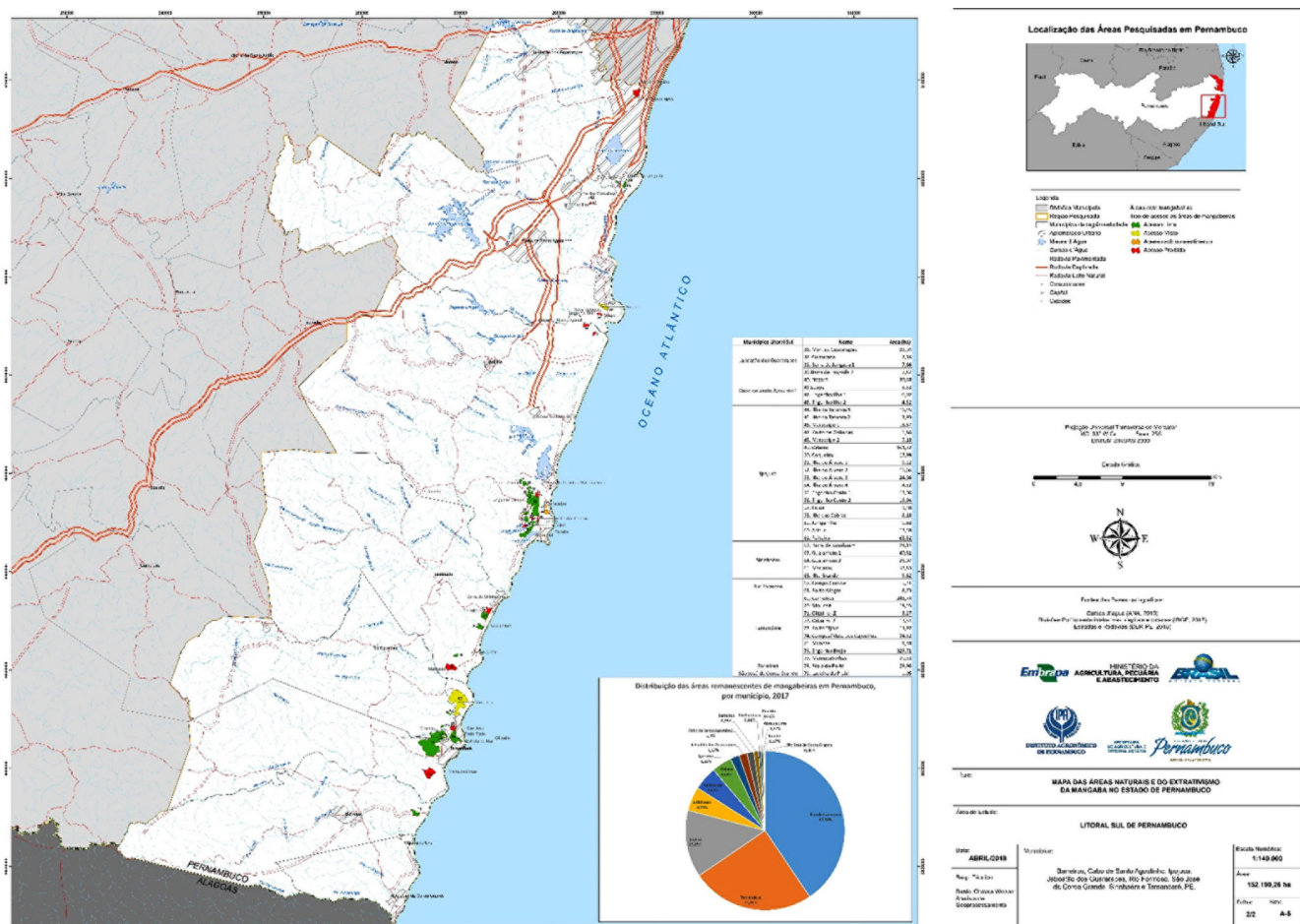


Figure 3. Map of extractivism and remaining areas of *mangaba* (*Hancornia speciosa* Gomes) in the North Coast of the state of Pernambuco, Brazil. Source: Silva Júnior et al. (2018b).

gatherers as a distinct cultural group and establishes self-recognition as a criterion of the law, among other provisions (Sergipe, 2010); the Sustainable Use Authorization Term (TAUS) of the South Coast of the state of Sergipe, of 2017, on the allocation of areas of the Union for communities of *mangaba* gatherers and artisanal fishermen, in an estuarine region of the South Coast of the state of Sergipe (Brasil, 2017); the Municipal Law nº 859/2017, of April 18, 2017, of the Municipal Government of Barra dos Coqueiros, SE, which provides for the donation of land from the Municipal Heritage to the Association of Mangaba Gatherers of the Municipality of Barra dos Coqueiros (Barra dos Coqueiros, 2017); TAUS nº 001/2023 of Santa Maria, Aracaju, SE, of 2023, on the transfer of the *mangaba* areas of the Union, in the Santa Maria neighborhood, to the Association of *Mangaba*

Based on the work with traditional communities and on data generated by Embrapa and partners, it was possible to support public policies, as follows: the review of the minimum price of *mangaba* by the National Supply Company (Companhia Nacional de Abastecimento/CONAB) in 2010; the effective participation, including a guaranteed seat, in the National Council of Traditional Peoples and Communities (Conselho Nacional dos Povos e Comunidades Tradicionais/CNPCT), a collegiate body of the Ministry of Environment (MMA); the State Law of *Mangaba* Gatherers of Sergipe (Law n° 7082 of December 17, 2010), which recognizes *mangaba*



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Gatherers Padre Luiz Lemper (Brasil, 2023); Decree n° 6775, of 04/20/2022, of the Municipal Government of Aracaju, SE, which creates the Irmã Dulce dos Pobres Mangabeiras Extractive Reserve, in Aracaju, SE (Aracaju, 2022; Rodrigues et al., 2023).

In 2016, the partnership between Embrapa and The Bioversity International (Rome, Italy) allowed of the development of a set of good practices aimed at the traditional management of natural ecosystems of *mangaba* (Silva Júnior et al., 2016).

2.2. Guavaberry

In 2011, the RPPN of Cajú was established on the premises of Embrapa Coastal Tablelands, in an area belonging to the CEI, in Itaporanga d'Ajuda, a protected area with 763.37 hectares, inserted in the Atlantic Forest Biome (Nogueira Junior et al., 2015). This conservation unit was created to protect the “restinga”, mangrove, and “apicum” ecosystems located in the estuarine complex of the Vaza-Barris River. Research on guavaberry plant populations in the RPPN has been conducted since 2009, and it was later expanded to the entire area of the CEI and to remnants of the municipalities of Barra dos Coqueiros and Neópolis, SE. Guavaberry is a source of food and income for traditional communities on the northeastern coast, especially in the states of Sergipe and Alagoas. These communities are primarily responsible for its extraction and commercialization, as well as for the conservation of the plants.

3. On-farm conservation

3.1. *Mangaba*

Although Brazilian *mangaba* production is predominantly extractive, several initiatives for cultivation, as well as conservation of *mangaba* populations in family-based farming areas, have been identified in the country, especially on the northeastern coast. From 2019 to 2022, Embrapa Coastal Tablelands carried out a survey on planted areas in the states of Sergipe, Paraíba, and Rio Grande do Norte, using geomorphological, pedological, and climatic analysis, as well as mapping the cultivated areas and rural establishments. In this research, it was possible to identify 249.9 hectares planted with *mangaba* trees, in 144 establishments, in the three states: 201.2 ha in

Sergipe, 46.0 ha in Paraíba, and 2.7 ha in Rio Grande do Norte (Silva Júnior et al., 2023b).

The characterization of the different *mangaba* production systems used in Sergipe, Paraíba, and Rio Grande do Norte allowed of the identification of sustainable practices, as well as natural areas or native plants preserved in the establishments, while the agroecosystem was enriched with cultivated genotypes (Silva Júnior et al., 2023a).

Cultivated areas have only recently expanded, but research on cultivation techniques has been conducted for decades by institutions and communities. At Embrapa, the experimental results, observations, and experience accumulated by technicians gave rise to some *mangaba* production systems in Northeastern Brazil, such as those for the Coastal Tablelands and Coastal Lowlands (Vieira Neto et al., 2002), and a more comprehensive system for all producing areas in the Northeastern Region (Silva Júnior & Léo, 2016). In the latter, management practices related to extractive production were also addressed, given the predominance of this system in *mangaba* production.

As mentioned by Rodrigues et al. (2023), even with the available guidelines, *mangaba* cultivation is evidenced by different practices in local spheres, resulting from adaptations based on the socioeconomic and cultural specificities of agro-extractivists and farmers in production systems.

4. Characterization and evaluation

4.1. *Mangaba*

Germplasm characterization and evaluation are performed using morphological, phenological, agronomic, ecophysiological, physicochemical descriptors, molecular, environmental, and socioeconomic markers, which are gathered in the manual *Descriptors for Mangaba (Hancornia speciosa* Gomes), published by Bioversity International and Embrapa (Silva Júnior et al., 2018a).

The work of Embrapa Coastal Tablelands for the characterization in natural populations aiming at in-situ conservation began in 2003, in Sergipe (Ledo et al., 2003; Silva Júnior et al., 2003), and then in 2005, in Pernambuco (Silva Júnior et al., 2007), both using morphological descriptors. From 2014 onward, genetic structure determinations were carried out in samples from populations from different regions of Northeast

Brazil (Amorim et al., 2015; Soares et al., 2016; Silva et al., 2017).

The partnership with the Universidade Federal Rural de Pernambuco (UFRPE) allowed of molecular studies of genetic diversity to be performed in natural remnants of Pernambuco (Jimenez et al., 2015) and, in a broader work, later developed between UFRPE, Embrapa Coastal Tablelands, the Universidade Federal de Goiás (UFG), and Universidade Federal de Alagoas (UFAL), in the Caatinga, Atlantic Forest, and Cerrado biomes of Brazil, it was possible to determine the genetic structure of the remnants, and the results indicated the participation of two botanical varieties (*H. speciosa* var. *speciosa*, and *H. speciosa* var. *pubescens*) in the formation of natural *mangaba* populations (Terto et al., 2024).

The characterization research on the *Mangaba* Genebank of Embrapa Coastal Tablelands began with the collaboration of the Universidade Federal de Sergipe (UFS) in 2006, using ecophysiological descriptors for young plants. The first morphological evaluation was conducted by Silva et al. (2008). Subsequently, the first studies on genetic divergence within the genebank were carried out using molecular markers of the random amplified polymorphic DNA (RAPD) type (Costa et al., 2011; Silva et al., 2011). In 2013, the first fruiting of the *Mangaba* Genebank occurred (Silva et al., 2015), and its fruit showed significant variation for both physical and physicochemical characteristics. Santos et al. (2017) used fruit of *mangaba* tree accessions from Bahia and Sergipe, and the accessions BI, CA, PR, and PT stood out for their high vitamin C content. When using 30 descriptors in 54 plants, from 10 accessions (CA, AB, PT, PR, TC, PA, LG, BI, IP, and AD), Muniz et al. (2019) also recorded the average vitamin C content in all accessions, with 394.45 mg 100 g⁻¹ average. In fruit of accessions BI, CA, LG, PR, PT, and TC, it was possible to identify, by high-performance liquid chromatography (HPLC), chlorogenic acid (93.71–131.66 mg 100 g⁻¹), ferulic acid (0.85–2.27 mg 100 g⁻¹), and rutin (238.59–442.94 mg 100 g⁻¹) (Santos et al., 2021b). Correlation analyses of these fruit characteristics reinforced the importance of the values found for both vitamin C and fresh matter mass (Santana et al., 2021).

In a major research advance, conducted between 2006 and 2021, a relevant record was released by Silva et al. (2021) in which 21 descriptors (morphological

and physicochemical) were used, and success in the enrichment, maintenance, and diversity of germplasm was observed. As a result of these observations, progenies of selected accessions were developed in from 2016 to 2018. These progenies were evaluated during development (Cardoso et al., 2019a, 2019b), and their diversity was estimated by microsatellites (Soares et al., 2018; Silva et al., 2019, 2024). The first phenological characterization with estimates of flowering and fruiting intensity, in 19 accessions, showed variation among accessions (Machado et al., 2020). The distribution of flowering and fruiting was observed at different times of the year, with two main production peaks – one from November to February, and another from May to June. The description of the phenological behavior of these accessions and its relationship with the rainfall distribution serve as a basis for developing strategies to manage this species, as well as assisting in the monitoring of the *Mangaba* Genebank.

All results concluded that the *Mangaba* Genebank shows genetic variability, and no clones were detected among its accessions. In a research coordinated by Embrapa Genetic Resources & Biotechnology, in three *mangaba* genebanks – Embrapa Coastal Tablelands, Embrapa Cerrados, and UFG – using advanced genomic resources, it was possible to verify that most variability is found within each genebank, and all showed a significant reduction of heterozygosity.

4.2. Genipap

The genetic diversity in the Genipap Genebank was first assessed by Silva et al. (2014), in 160 individuals. To understand the diversity in natural populations and enrichment of the genebank, Cardoso et al. (2019b) assessed 15 populations, using inter simple sequence repeats (ISSR) markers, and observed intermediate genetic diversity, leading to the collection of nine new accessions.

Every year, all individuals are characterized for growth, botanical, and physiological aspects. These observations resulted in the development of the *Descriptors for Genipap (Descritores para Jenipapeiro)* manual, published by Embrapa (Silva et al., 2020a). In 2019, the occurrence of the first fruiting was confirmed, and this phenological period was monitored in detail. In 2020, the chemodiversity and bioactivity of essential oil of accessions were observed,

and the potential to control the coconut necrosis mite [*Aceria guerreronis* Keifer (Acari: Eryophyidae)] was found, (Jesus et al., 2020). A preliminary work with a participatory approach began in 2021, mainly with fruit traders in public markets, to understand the origin and criteria adopted by consumers (Lima & Silva, 2021). In a study by Santos et al. (2024), a 13-year history of the Genipap Genebank was compiled, which included collection expeditions, bank enrichment, survival, fruiting, and evaluation of 20 descriptors.

4.3. Guavaberry

Characterization studies of guavaberry trees at Embrapa Coastal Tablelands began in 2010. Genetic diversity was initially estimated using RAPD markers, highlighting the fruit quality for its vitamin C content, especially purple fruit (Pinheiro et al., 2011). Over

time, the identification of individuals in the native area was expanded, and diversity continued to be evaluated. In addition, fruit quality attributes, fruit and seed biometrics, and phenology were evaluated. In the observed area, there is a high genetic diversity (Nascimento et al., 2019) and heterogeneity in the ripening of purple and orange fruit. The highest ripening peak occurs at 63 days after anthesis (83.2% of orange fruit and 68.3% of purple fruit) (Silva et al., 2020c). Guavaberry fruit are rich in vitamin C (129.43 mg ascorbic acid 100 g⁻¹ pulp) (Table 3), and the purple fruit exhibit superior physical attributes, while the orange ones stand out for their greater acidity and higher flavonoid content (Nascimento et al., 2020; Santos et al., 2022).

Recent studies have indicated guavaberry as a natural source of potential molecules against COVID-19 (Santos et al., 2022). In addition to the

Table 3. Bioactive compounds and functional attributes identified in three native fruit trees of the Atlantic Forest, in research developed at Embrapa Coastal Tablelands and partner institutions, 2025.

Species	Functional attribute/ bioactive compound	Application	Institution	Reference
<i>Mangaba</i> (<i>Hancornia speciosa</i> Gomes)	Vitamin C, polyphenols	Antioxidant	Embrapa Coastal Tablelands/ Universidade Federal de Sergipe	Silva et al. (2015)
	Vitamin C	Antioxidant	Embrapa Coastal Tablelands/ Universidade Federal de Sergipe	Santos et al. (2017); Silva et al. (2017, 2021); Muniz et al. (2019); Santana et al. (2021)
	Rutin	Antioxidant and anti-inflammatory	Embrapa Coastal Tablelands/ Universidade Federal de Sergipe	Machado et al. (2018)
	Polyphenols	Antibacterial for inhibiting disease-causing bacteria, especially Gram-negative bacteria.	Institute of Technology and Research – Universidade Tiradentes/Embrapa Coastal Tablelands	Barbosa et al. (2019, 2024)
	Phenolic compounds	Antioxidant and anti-inflammatory	Embrapa Coastal Tablelands/ Universidade Federal de Sergipe	Silva et al. (2020b)
	Chlorogenic acid, ferulic acid, phenols, and rutin	Antioxidant and anti-inflammatory	Embrapa Coastal Tablelands/ Universidade Federal de Sergipe	Santos et al. (2021b)
Genipap (<i>Genipa americana</i> L.)	Iridoids, terpenes, and linoleic acid	Control of coconut mite <i>Aceria guerreronis</i> Keifer (Acari: Eriophyidae)	Embrapa Coastal Tablelands	Jesus et al. (2019, 2020)
Guavaberry [<i>Myrciaria floribunda</i> (H. West ex Willd.) O. Berg.]	Vitamin C	Antioxidant	Embrapa Coastal Tablelands	Pinheiro et al. (2011); Silva et al. (2020c)
	Flavonoids	Antimicrobial properties especially aimed at the inhibition of the growth of the Gram-positive bacterium <i>Enterococcus faecium</i> .	Institute of Technology and Research – Universidade Tiradentes/Embrapa Coastal Tablelands	Santos et al. (2021a); Fontes et al. (2024)
	Phenolic compounds	Potential for use as a nutritional supplement to inhibit COVID-19 infections.	Institute of Technology and Research – Universidade Tiradentes/Embrapa Coastal Tablelands	Santos et al. (2022)

characteristics of the fruit, the species has an unexplored ornamental potential. In 2021, the inventive patent BR 1020210196904 (Santos et al., 2021a) was filed, relating to the field of medicinal preparations, more specifically the production of tea containing a mixture of antibacterial agents, preferably flavonoids and other phenolic compounds from guavaberry, with action against the growth of the Gram-positive bacterium *Enterococcus faecium* (Orla-Jensen 1919) Schleifer & Kilpper-Bälz 1984, which is a multiresistant nosocomial pathogen (Fontes et al., 2024). In summary, the characterization work involving functional attributes and bioactive compounds developed with native fruit trees, at Embrapa Coastal Tablelands is very promising, with possibilities for immediate or potential use (Table 3).

5. Documentation

Another activity of great importance for the development of genetic resources of native fruit species is their documentation. At Embrapa, records are made in the computerized system Alelo (Alelo Recursos Genéticos, 2025), and this database contains the *Mangaba* and Genipap Genebanks, as well as their accessions and data related to passport, characterization, and evaluation, partially shared with the public. At the local level, records are also made in computerized spreadsheets and notes are shared among team members.

The documentary work generated the timelines of the activities carried out with the three species illustrated in Figure 5.

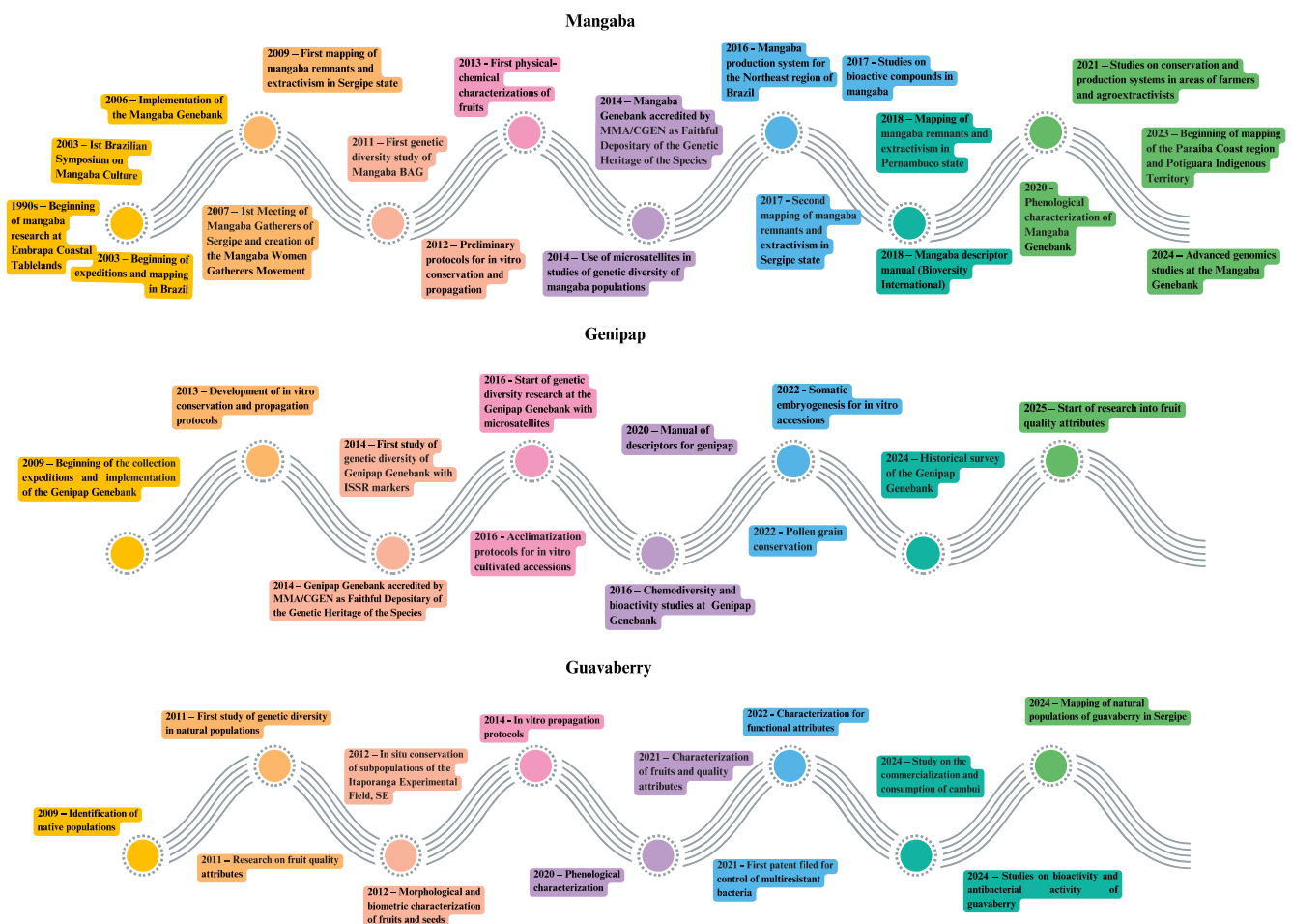


Figure 5. Timeline with highlights of the research on *mangaba*, genipap, and guavaberry, native fruit trees from the Atlantic Forest, at Embrapa Coastal Tablelands, Brazil, 2025.

Concluding Remarks

The integration of all forms of conservation increase the efficiency of the protection of biodiversity and its variability. The actions are complementary, the in-situ conservation of populations is extremely important and should be a priority, as it allows species to evolve in their environments. However, the natural areas of occurrence have been greatly reduced, resulting in the disappearance of populations without science even knowing about them. The wide distribution of the three species, restricted collection, and anthropogenic threats have been obstacles to the conservation of genetic resources, which can be further aggravated by climate emergencies.

The *Mangaba* and Genipap Genebanks exhibit high genetic variability, with early, productive accessions, rich in bioactive compounds and functional attributes. However, given the devastation of natural areas, there is a clear and urgent need for conservation efforts, especially for threatened populations throughout the Northeast Region of Brazil. The conservation actions for guavaberry should be complemented with the implementation of a genebank, due to the intense genetic erosion to which the species has been subjected.

It should be noted that there are few conservation units in the environments of the Coastal Lowlands and Coastal Tablelands, and the original vegetation of these two ecoregions is one of the most threatened in the Atlantic Forest Biome, especially the “restinga”, which is considered a permanent preservation area.

Other conservation alternatives have been the subject of research for the three species, with advances recorded in both in vitro conservation and cryopreservation. However, bottlenecks in some phases still need to be resolved, to help reduce access losses in the field.

Conservation actions developed in partnership with scientists, traditional communities, farmers, and agro-extractivists have contributed to the maintenance of some areas and their forest cover, with a possible impact on reducing problems arising from climate change. Therefore, it is necessary to increase the number and size of areas that require conservation, not only for biodiversity, but also to enable culturally differentiated ways of life. Traditional management should be valued, as it is full of knowledge that is always deeply associated with the balance between nature and human beings.

The actions listed in this work have contributed to the development of sustainable production systems and supported public policies aiming to guarantee the conservation of territories, natural resources, and their use by communities.

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Data available: research data are available in the Platform Embrapa Alelo Genetic Resources repository.

Declaration of use of AI technologies

No generative artificial intelligence (AI) was used in this study.

Conflict of interest statement

The authors declare no conflicts of interest.

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