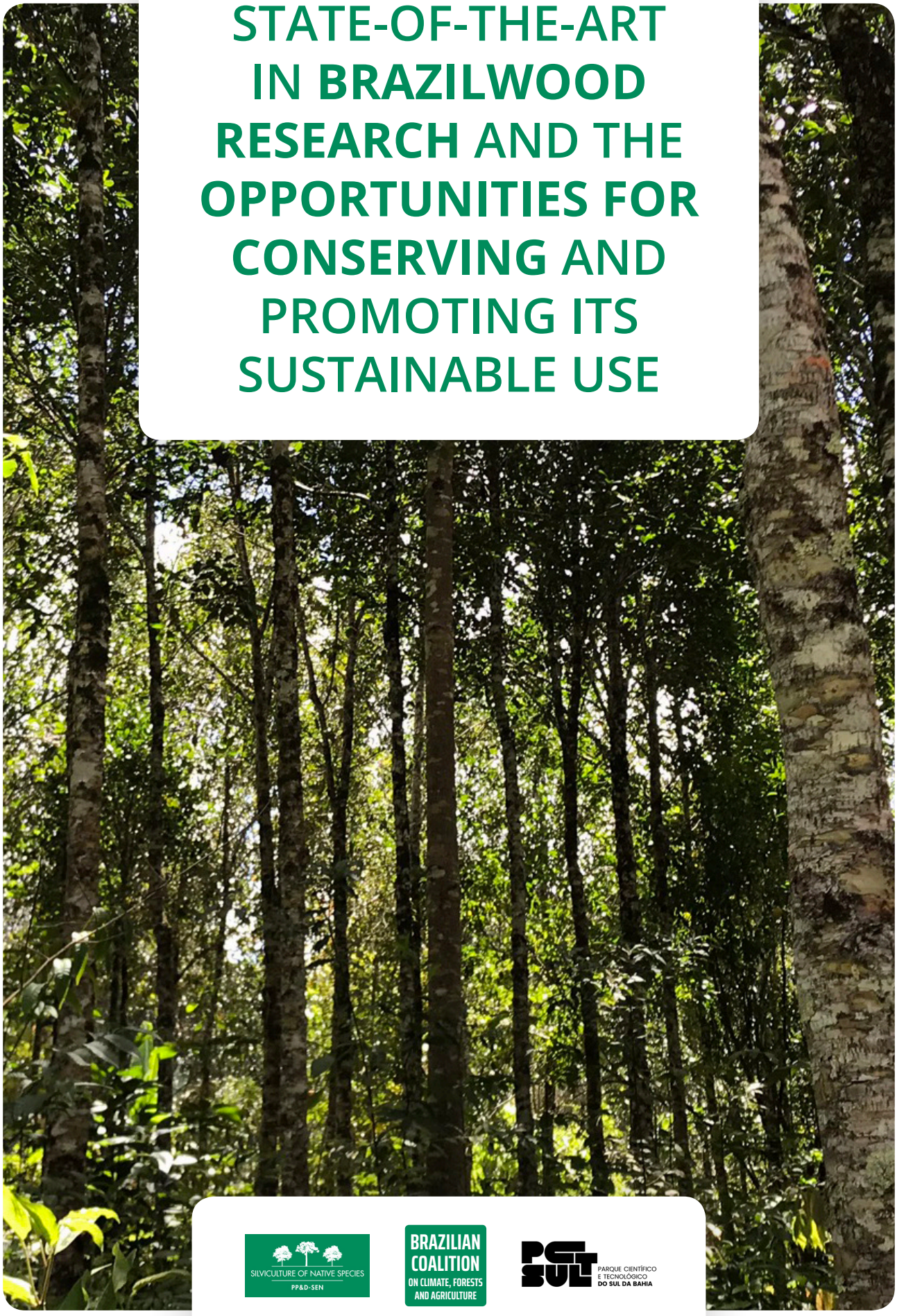
STATE-OF-THE-ART IN **BRAZILWOOD RESEARCH** AND THE **OPPORTUNITIES FOR CONSERVING** AND PROMOTING ITS SUSTAINABLE USE



SILVICULTURE OF NATIVE SPECIES
PP&D-SEN

BRAZILIAN COALITION ON CLIMATE, FORESTS AND AGRICULTURE

PCT SUL
PARQUE CIENTÍFICO E TECNOLÓGICO DO SUL DA BAHIA

INTRODUCTION

A species native to Brazil and a national symbol, brazilwood *(Paubrasilia echinata)* or pau-brasil, also known as pernambuco, is globally renowned for being ideal for crafting quality bows for stringed instruments like violins and cellos. The species is endangered due to a lack of effective forest management alongside widespread environmental degradation of the Atlantic Forest biome, resulting principally from urban and agricultural development, as well as illegal timber exploitation. This underscores the urgent need for conservation and restoration of natural populations and for sustainable production efforts.

On December 5-6, 2024, the Federal University of Southern Bahia, Brazilian Coalition on Climate, Forests and Agriculture (Coalizão) and Southern Bahia Scientific and Technological Park (PCTsul) convened the “National Symposium on the Conservation and Sustainable Production of Brazilwood” in the city of Ilhéus. During the event, researchers and experts presented state-of-the-art findings on the species and discussed the scientific, technological, and knowledge-related challenges and opportunities to identify and implement solutions that will protect and restore the natural populations of brazilwood while promoting its cultivation for sustainable wood production.

This publication presents a summary of the key findings presented during the Symposium, a concise overview of brazilwood, and a more detailed discussion of the key findings, which are divided into four sections: Ecology, Conservation, Wood, and Silviculture. Enjoy your reading!

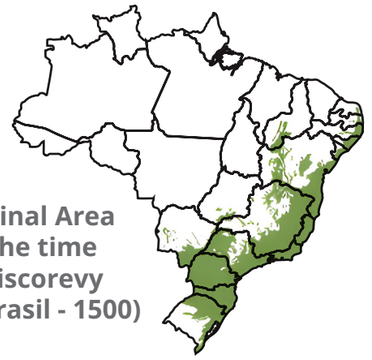
OVERVIEW OF BRAZILWOOD

A CONCISE OVERVIEW
OF BRAZILWOOD

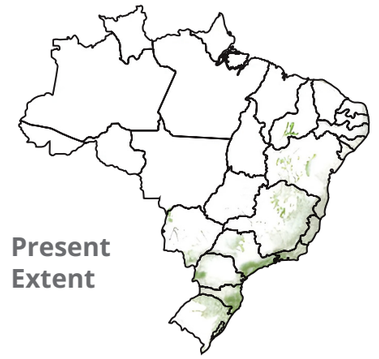
Brazilwood is a native species commonly found in the Lowland Semideciduous Seasonal Forest and Dense Ombrophilous Forest of the Atlantic Forest biome, spanning a strip from Rio Grande do Norte to Rio de Janeiro.

As a result of excessive exploitation, deforestation, and the degradation of the Atlantic Forest, brazilwood now survives naturally only in small fragments. The species is classified into three morphotypes and five lineages, each clearly defined by its geographic location.

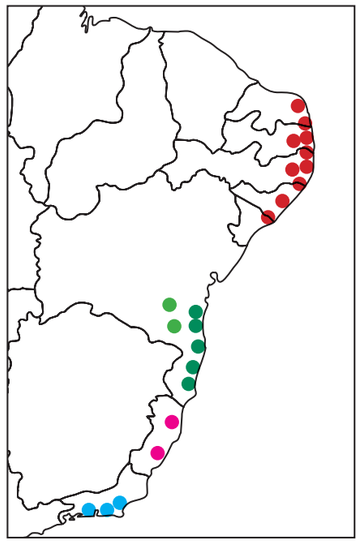
ATLANTIC FOREST



Original Area (at the time of Discorevy of Brasil - 1500)



Present Extent



Brazilwood exhibits 3 morphotypes and 5 lineages

3 morphotypes:

- Café
- Arruda
- Laranja

5 lineages:

- Arruda-RJ
- Arruda-BA
- Arruda-NE
- Café
- Laranja

SUMMARY OF KEY FINDINGS

ECOLOGY

- **Wood anatomy varies across lineages**, characterized by differences in the presence of cellular tissue, or parenchyma, within the wood composition.
- **The arruda-RJ lineage has been identified in 43 fragments** along the coast of the state of Rio de Janeiro. Many of these fragments have some level of protection, and several are highly significant for conservation efforts due to their size or genetic diversity. The primary threat to this lineage is urbanization.
- A study on **the impact of climate change on the café and arruda morphotypes** indicates that both would survive even under the worst-case scenario projected by the International Panel on Climate Change (IPCC). However, changes are expected in certain characteristics, such as foliage in the arruda morphotype and wood quality in the café morphotype.

CONSERVATION

- **The laranja lineage in southern Bahia is in a critical state** due to the absence of protection and threats like deforestation and cattle ranching. The establishment of Conservation Units, along with genetic studies and silviculture initiatives, is essential for its preservation.
- The brazilwood collection at the State University of Santa Cruz (UESC) exhibits **significant genetic diversity**, though there are indications of inbreeding. This collection serves as an important repository and should be expanded.
- **Environmental compensation plans** for large construction projects should include endangered species in the list of plants used for habitat restoration, to support and maintain biodiversity.

WOOD

- **The sapwood and heartwood of brazilwood share similar physical and mechanical properties**, but the chemical composition indicates that the heartwood is more suitable for crafting bows.

- **Isotopes can serve as natural geographic markers to trace the origin of brazilwood**, particularly strontium.
- **Mass spectrometry chemotyping** can differentiate between native and planted wood, and lineages and geographical origin, by analyzing the chemical profiles of metabolites.
- The near-infrared spectroscopy (NIRS) method associated with chemometrics enables the **identification and separation of brazilwood lineages based on spectral information**.
- An analysis of structural polymers in brazilwood planted in the state of Espírito Santo revealed that **morphotypes with medium and large leaves have a higher lignin content**, contributing to superior wood quality.
- **A test with a bow crafted from planted brazilwood demonstrated that it adequately met musical requirements**, suggesting potential avenues for sustainable production of the species.

SILVICULTURE

- In Linhares (state of Espírito Santo), **planted brazilwood has an average diameter growth rate of 0.76 cm per year**, requiring approximately 30 years to reach 25 cm and be harvested. Improved site conditions and genetic selection could potentially shorten this cycle to at least 25 years.
- An analysis of over 1,000 samples of planted brazilwood revealed that **environmental factors, such as abundant rainfall, significantly influence tree height and diameter**, while wood density appears to be more closely linked to genetics.
- The **use of artificial intelligence to model the relationship between climatic variables and brazilwood growth** has identified average air temperature as a significant factor for the species' development. However, further research is necessary to deepen these insights.
- The **stacking factor enables the calculation of the volume of bow sticks** in a pile, which can assist in combating illegal trade and helping companies to manage their inventories more effectively.

DISCUSSION OF KEY FINDINGS PRESENTED

ECOLOGY

The fragmented distribution of natural brazilwood populations, along with the existence of three morphotypes divided into five lineages, underscores the need for a deeper understanding of each group, particularly for conservation efforts. Beyond historical threats, the impact of climate change must also be taken into account. Below are the findings from the research presented.

ANATOMICAL VARIETY WITHIN THE **SPECIES PRESENTS A CHALLENGE** FOR GAINING A DEEPER UNDERSTANDING

BRAZILWOOD'S significant anatomical variation complicates its identification. Claudia Franca Barros, from the Rio de Janeiro Botanical Garden (JBRJ), presented research that distinguishes morphotypes and lineages through the anatomical characteristics of the wood and microscopic analyses of tissue walls. The laranja and arruda samples, from both the NE and RJ lineages, exhibit differences in the amount of parenchyma. By analyzing this characteristic in European bows over 100 years old, for example, it was determined that they were crafted from brazilwood of the arruda morphotype from the Northeast region. However, there is still insufficient data to conduct a similar analysis for the café morphotype.
Comparative wood anatomy studies on native and planted populations are recommended.

**Text based on the presentation by Claudia Franca Barros, JBRJ*

RESEARCH EVALUATES THE CONSERVATION **POTENTIAL OF THE RIO DE JANEIRO** ARRUDA LINEAGE

THE ARRUDA-RJ lineage is unique to the state of Rio de Janeiro, located in southeastern Brazil. Currently, it is found naturally only in small fragments along the coastal region. Research presented by Patrícia da Rosa, from the State University of Rio de Janeiro (UERJ), mapped and analyzed these fragments based on their level of protection, types of threats, area size, and the presence of individuals at seedling, juvenile, and adult stages.
Of the 43 fragments mapped, most are small and located within protected areas.

Using a scoring system, the fragments were categorized as very important, important, or concerning. Specific conservation and genetic study actions were recommended for each category.
It is worth noting that the northern region of the state hosts the largest number of fragments and the greatest genetic diversity, making it a key area for conserving the lineage.

** Text based on the presentation by Patrícia da Rosa, UERJ*

A WARMING PLANET AFFECTS SPECIES DEVELOPMENT

TO ASSESS THE IMPACT of climate change on brazilwood's growth and wood quality, researchers from the Federal University of Espírito Santo (UFES) studied one-year-old specimens from the café and arruda morphotypes exposed to three distinct climate scenarios over a 90-day period.
One scenario simulated the current conditions of the Atlantic Forest in the Southeast region. The other two scenarios replicated the planet's average temperature increases projected by the IPCC: 2°C (RCP 4.5) and 3.5°C (RCP 8.5). Additionally, two humidity levels were established: 40% (representing water deficit) and 80% (as the control condition).
No scenario affected plant survival; however, notable changes were observed. Under the worst-case scenario, the arruda morphotype (sun-tolerant) could experience reduced leaf area production and photosynthesis, while the café morphotype (less sun-tolerant) could see its wood quality compromised.

** Text based on the presentation by Geraldo Rogério Faustini Cuzzuol, UFES*

CONSERVATION

Conservation efforts, including the preservation of genetic diversity and the maintenance and restoration of habitats for natural brazilwood populations, are crucial to removing the species from the endangered list. Each lineage is at a different stage of conservation. Below are the highlights of the research presented in this section.

THE CRITICAL CONDITION OF **BRAZILWOOD** IN SOUTHERN BAHIA

CONSERVATION EFFORTS are needed to safeguard the few remaining fragments of brazilwood belonging to the laranja lineage in southern Bahia. Recent findings on its conservation status reveal that none of the nine fragments where this lineage exists are located within Conservation Units. One of the fragments contained only a single specimen, which has already been lost. All remnants are situated on private land, either in Legal Reserves or without any form of protection, and are under constant threat from deforestation, cattle ranching, and urbanization. None of the fragments were deemed highly significant for conservation, underscoring the critical condition of this lineage. Numerous initiatives will be required to protect natural forests and support "ex-situ" efforts for the laranja lineage, including the establishment of Conservation Units, genetic studies, and silviculture programs.

** Text based on the presentation by Patrícia da Rosa, UERJ*

BRAZILWOOD COLLECTION IS A **GENETIC REPOSITORY**

UNDERSTANDING THE GENETIC diversity of brazilwood is essential for effective conservation and silviculture efforts. Research presented by Eullaysa Nascimento Saboia, from the Federal University of Piauí (UFPI), highlights the significant genetic diversity within the brazilwood collection at UESC in Ilhéus, state of Bahia. This collection comprises 96 individuals representing the three known morphotypes.
An evaluation of the entire collection, as well as specific analyses for each morphotype, confirmed this genetic diversity, likely due to the origin of the matrices from southern Bahia, a region known for its rich biodiversity. However, there are indications of a loss of this diversity caused by inbreeding.
The collection serves as an important genetic reservoir with significant potential for use in restoration projects. It is also recommended that UESC continues to expand its collection of brazilwood specimens.

** Text based on the presentation by Eullaysa Nascimento Saboia, UFPI*

ENVIRONMENTAL COMPENSATION NEEDS TO CONSIDER THE RICHNESS OF BIODIVERSITY

ENVIRONMENTAL COMPENSATION is a mechanism designed to mitigate the impacts of vegetation loss caused by large-scale projects. However, an evaluation of the environmental compensation plans for the Porto Sul Intermodal Complex, presented by Sand Rocha from the Federal University of Southern Bahia (UFSB), reveals that, even when developed in compliance with environmental legislation, these plans exhibit gaps that warrant further attention.
The Porto Sul Intermodal Complex, a port and railroad project planned for Ilhéus, will require the removal of 686.01 hectares of vegetation. As a compensatory measure, 313.07 hectares must be restored through the planting of native vegetation. However, the list of species designated for planting does not include brazilwood.
Environmental compensation plans should incorporate endangered species to support the conservation of local biodiversity, particularly in a biome like the Atlantic Forest, recognized as a global biodiversity hotspot.

** Text based on the presentation by Sand Rocha, UFSB*

WOOD

The uniqueness of brazilwood, because of its properties such as rigidity and flexibility, creates an incentive for illegal logging and trade. Combating illegal trade requires the ability to trace the wood's origin. Additionally, questions persist among artisans about whether planted brazilwood matches the quality of native wood. New technologies have been applied to address these challenges, and this section highlights some of the findings.

WOOD: KEY FINDINGS

ASSESSING BRAZILWOOD FOR COMMERCIAL USE

THERE ARE VARIOUS METHODS to assess wood quality to determine its optimal use. A study conducted at the Federal Rural University of Rio de Janeiro (UFRRJ) compared the chemical and physical properties, as well as the workability of the sapwood and heartwood, of a brazilwood sample.
In machining tests — including planing, sanding, drilling, and nail insertion — the results for heartwood and sapwood were very similar. Both showed poor performance during nail insertion, with cracks forming. Additionally, no significant differences were observed in physical properties such as density and anisotropy (differential growth patterns).
The difference emerged in the chemical composition, with the heartwood containing a higher number of extractives, which affects the quality of bows for musical instruments.
The heartwood and sapwood were rated as good to fair for commercial use.
Chemical composition studies of other species could help determine whether there is potential, from a botanical perspective, to discover an alternative to brazilwood suitable for bow production.

** Text based on the presentation by Alexandre Monteiro de Carvalho, UFRRJ*

FORENSIC ISOTOPES HELP TRACE WOOD ORIGIN

ISOTOPES INCORPORATED into plants act as natural geographical markers, reflecting the environmental conditions in which they grew, such as temperature, rainfall, and soil composition. This makes them a valuable tool for identifying the origin of brazilwood.
A study of oxygen, carbon, and strontium conducted by researchers from the Center for Nuclear Energy in Agriculture at the University of São Paulo (Cena/USP) identified strontium as the most promising. Strontium remains unchanged within the plant and reflects the age of its geological substrate.
By understanding Brazil's geological characteristics, the origins of wood can be traced.
A case study with Amazonian wood yielded positive results. The project now aims to develop "isoscapes" (isotopic models of spatial distribution) to determine the geographical origin of wood used to craft brazilwood bows.

** Text based on the presentation by Isabela Maria Souza Silva and Maria Gabriella da Silva Araújo, Cena/USP*

MOLECULAR FINGERPRINTS DIFFER BETWEEN PLANTED AND NATIVE BRAZILWOOD

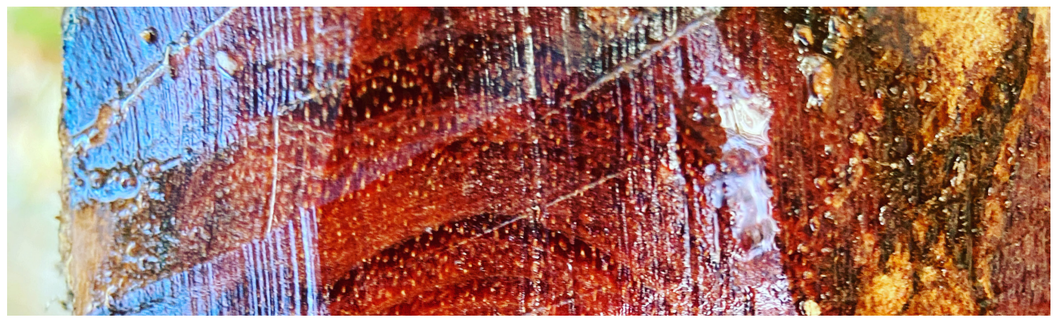
IN ADDITION TO PULP and lignin, wood contains secondary metabolites that create molecular fingerprints, or phytochemical markers. The INMETRO (National Institute of Metrology, Quality and Technology) project employs mass spectrometry chemotyping to analyze the chemical profile of metabolites in samples of planted and native brazilwood from various regions of Brazil. This technique is already utilized by the U.S. Forest Service.
A total of 198 samples were collected from herbaria containing wood specimens (xylotheques), authorized plantations, and wood confiscated by the Federal Police.
Preliminary results revealed distinct spectral profiles for native and planted brazilwood, as well as variations among the different lineages. This indicates that the technique can be effectively used to investigate the illegal trade of the species and to distinguish between brazilwood from native forests and plantations.

** Text based on the presentation by Maíra Frasciotti, INMETRO*

WOOD IDENTIFICATION **USING NEAR-INFRARED SPECTROSCOPY** (NIRS)

THE BRAZILIAN FORESTRY SERVICE (SFB) has utilized the near-infrared spectroscopy (NIRS) method, combined with chemometrics, to evaluate the feasibility of identifying and differentiating brazilwood lineages based on spectral information.
The exploratory analysis was effective for arruda-BA, arruda-NE, and laranja lineages, demonstrating that the wood contains sufficient chemical information to distinguish among the five lineages.
One of the advantages of this device is its portability, which allows it to be used in the field for wood identification during timber trade inspections.

**Text based on the presentation by Tereza Cristina Monteiro Pastore, SFB/MMA*



ANALYSIS OF STRUCTURAL POLYMERS IN PLANTED BRAZILWOOD REVEALS A HIGH LIGNIN CONTENT

THE UFES PROJECT assessed brazilwood trees planted 20 years ago as part of a reforestation program in Espírito Santo, which distributed 200,000 seedlings across various municipalities. The samples were collected from locations with differing altitudes, humidity levels, and other environmental factors.
Structural chemical analysis, anatomy, and cell wall polymer content were examined. Morphotypes with small and large leaves exhibited higher pulp content, while those with medium and large leaves demonstrated higher lignin content, indicating greater potential for producing high-quality wood and crafting bows.
Further studies are needed on brazilwood's anatomy, as well as its mechanical and musical properties, to compare the wood from planted trees with that of native trees and bows, and to support the certification of planted trees.

** Text based on the presentation by Geraldo Rogério Faustini Cuzzuol, UFES*

BRAZILWOOD PLANTATIONS: **SUSTAINING MUSIC**

ACCORDING TO THE INTERNATIONAL Pernambuco Conservation Initiative (IPCI), there are approximately 400 artisanal bow makers worldwide, each producing between 10 and 25 bows annually. Combined with larger companies — excluding production in China — this amounts to roughly 15,000 bows per year, requiring approximately 15 cubic meters of wood.
This wood must meet the specific requirements for bows, including flexibility, robustness, and sound quality. The closer the performance of a new bow is to that of traditional bows, the better it is considered musically.

In addition to their expertise, craftsmen utilize instruments and measurement techniques to achieve efficiency and enhance bow quality. Young's modulus and wood density are key factors in predicting a bow's performance before it is crafted, optimizing wood usage, reducing waste, and improving sound quality.
A test using a bow crafted from planted brazilwood demonstrated that it adequately met musical requirements, suggesting a potential path toward the species' sustainable production.

** Text based on the presentation by Sidney Sabbag and Thomas Gerbeth, IPCI*

SILVICULTURE: KEY FINDINGS ●

SILVICULTURE

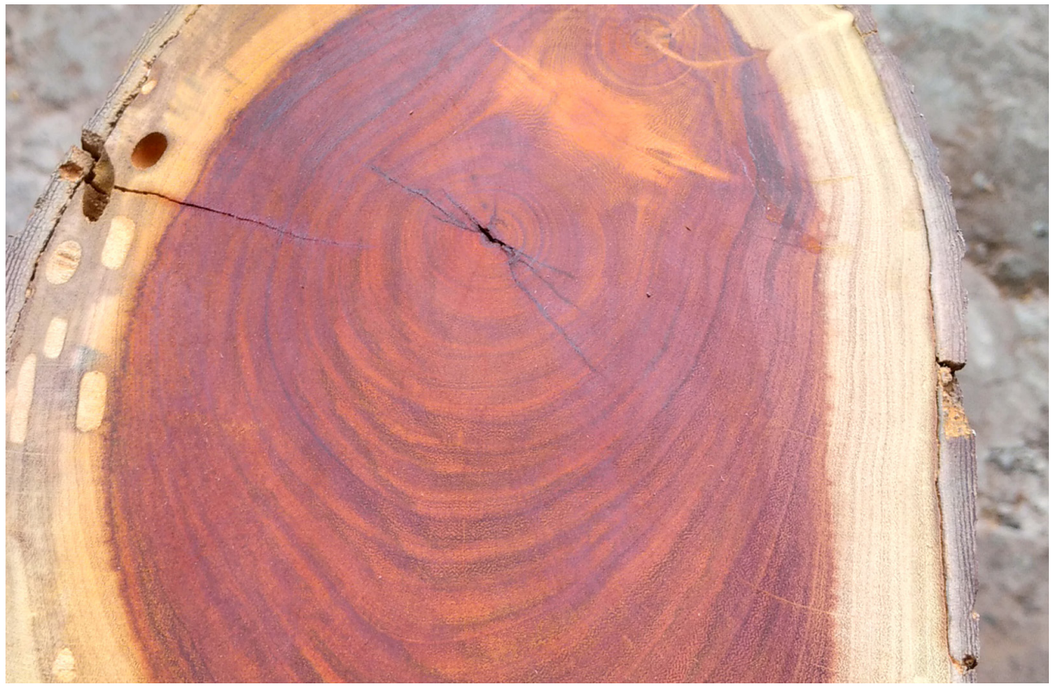
The cutting of native brazilwood is prohibited by law, making sustainable silviculture the only viable option for recovering and restoring the species' populations, and meeting the demand for bows. Effective cultivation requires addressing knowledge gaps regarding diameter growth rates, genetic diversity, and optimal production systems. This section highlights key findings from research aimed at addressing these challenges.

ANALYSIS OF DIAMETER GROWTH RATE IN PLANTED BRAZILWOOD

IN 1989, 196 BRAZILWOOD trees were planted in a pure stand at the Vale Natural Reserve in Linhares, Espírito Santo, with 2 x 2 meter spacing. Initially, there was a high mortality rate, but over 24 years, the surviving trees exhibited varying diameter growth.
Based on the collected data, a mathematical model revealed that, in this region, brazilwood's diameter increases by an average of 0.76 cm per year. This growth rate indicates that it takes approximately 30 years for planted brazilwood to reach a diameter of 25 cm, suitable for harvesting.

With improved site conditions and the selection of high-quality genetic material, this harvesting cycle could potentially be reduced to 25 years.
To enhance growth models and advance brazilwood silviculture, continuous inventory data is required from both pure and mixed plantations across various locations, combined with proper management practices such as pruning and thinning.

** Text based on the presentation by Samir Rolim, Research and Development Program in Silviculture of Native Species (PP&D-SEN)*



GROWTH AND WOOD DENSITY OF BRAZILWOOD PLANTATIONS **ALONG THE BRAZILIAN COAST**

LIMITED KNOWLEDGE EXISTS regarding the impact of environmental factors, genetics, and production systems on the growth and wood density of planted brazilwood.
To address this gap, a UFSB project collected over 1,000 samples of planted brazilwood from 14 locations spanning Espírito Santo to Rio Grande do Norte.
The study aimed to compare growth and wood density while accounting for the three morphotypes and the production systems.
In general, plantation trees tend to produce short-stemmed individuals (low or forked trees) with diameters ranging from 30 cm to 40 cm at harvest. This suggests that, unlike the large brazilwood trees illegally harvested from native forests, the standard for planted brazilwood intended for timber production will be smaller trees.
Trees from regions with abundant and evenly distributed rainfall exhibited faster growth and lighter wood.
Among the morphotypes, the laranja morphotype demonstrated the highest growth rate. However, wood density appeared unaffected by environmental or external factors, indicating a stronger connection to the genetics of the individual trees.
It is recommended to source seeds from trees exhibiting the desired traits, such as growth and wood quality, or to clone these individuals for use in commercial brazilwood plantations.

** Text based on the presentation by Daniel Piotto, UFSB*

ARTIFICIAL INTELLIGENCE TO UNDERSTAND THE RELATIONSHIP BETWEEN CLIMATE VARIABLES AND BRAZILWOOD GROWTH

THIS STUDY INVESTIGATED the potential of artificial intelligence to model the relationship between climatic variables and brazilwood growth, an analysis that is increasingly crucial in the context of climate change.
The data utilized in this study was collected from a 24-year-old brazilwood plantation in Linhares, Espírito Santo, located at an altitude of 30 to 60 meters, with an average minimum temperature of 18°C and 750 mm of annual rainfall.
The growth variables were selected using two attribute selection algorithms—Correlation and Relief F—and modeled with an Artificial Neural Network (ANN).
The algorithms identified average air temperature as the most important climatic variable; however, the variables did not provide significant improvements in estimating diameter growth. As a preliminary study, future research could incorporate additional variables or explore other algorithms.

** Text based on the presentation by Ana Paula Marques Martins, UFSB*

USING THE STACKING FACTOR TO **ESTIMATE BOW STICK VOLUME**

The objective of this study was to assess the effectiveness of the stacking factor in determining the volume of the brazilwood stock at a company in Aracruz, Espírito Santo. A total of 55,244 units were organized into nine piles.
The average unit volume, calculated from 188 samples, was 0.00016 m^3 per stick, indicating a total of 8.89 m^3 of brazilwood, with 27% of the volume consisting of empty space.
The average stacking factor was 0.73, resulting in a total volume of 8.99 m^3, which closely aligns with the calculation based on the average unit volume.
This method can be utilized in enforcement actions and for companies to manage their stocks. Additionally, it can serve as a reference for bow production.

** Text based on the presentation by Salim Calil Salim Neto, IEMA/ES*

CONSERVATION AND GENETIC IMPROVEMENT OF BRAZILWOOD

GENETIC VARIATION between brazilwood populations is greater than it is within individual populations, indicating genetic impoverishment. Additionally, there are signs that the species exhibits tolerance to inbreeding.
Therefore, brazilwood conservation efforts must prioritize maintaining genetic diversity by focusing on populations with the highest possible variability and the greatest number of unrelated matrices.
Several formulas already exist to calculate and support the establishment of germplasm banks and estimate the size of future populations. The ConservaGen tool enables the calculation of efficiency rates for such projects.
A partnership has been established between IPCI and UFSB to develop a brazilwood germplasm bank, while PP&D-SEN will implement a progeny test to estimate the genetic value of individual trees. These initiatives will contribute to both conservation and silviculture efforts.

** Text based on the presentation by Andrei Caíque, UFSB*

ORGANIZATION

SILVICULTURE OF NATIVE SPECIES
PP&D-SEN

UFSB
UNIVERSIDADE FEDERAL DO SUL DA BAHIA

BRAZILIAN COALITION ON CLIMATE, FORESTS AND AGRICULTURE

PCT SUL
PARQUE CIENTÍFICO E TECNOLÓGICO DO SUL DA BAHIA

SUPPORT

BEZOS EARTH FUND

INSTITUTO FLORESTA VIVA

IPCI FRANCE EUROPE
IPCI Deutschland e.V.
IPCI USA
IPCI CANADA
International Pernambuco Conservation Initiative
25 2000 2025

ALLIANCE

CREDITS

SCIENTIFIC COMMITTEE
Daniel Piotto
Haroldo C. Lima
Tereza C. M. Pastore
Alexandre M. de Carvalho
Dan E. V. P. Lobão
Samir G. Rolim

WRITING
Chiaki Karen Tada
Renata Costa

GRAPHIC DESIGN
Gerson Mora

TRANSLATION
Gabriel Furtado

PHOTOS
UFSB

SUPPORTING STAFF
Lyvia Julyenne Souza Rego
Carlos Eduardo Silveira
Tatiana Amaral

PUBLISHED: MAY 2025