



PROJECT CITES S 608: IDENTIFICATION OF ORIGIN AND BRAZILIAN MAHOGANY WOOD BY NIRS TECHNOLOGY.

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FINAL REPORT

CONSULTING OBJECTIVES: TECHNICALLY ENABLE THE CONDUCT OF A CASE STUDY ON THE TRACKING OF *SWIETENIA MACROPHYLLA* KING (MAHOGANY) WOOD OR SIMILAR WOOD, FROM ITS ORIGIN TO AN EXPORT PORT USING NEAR-INFRARED SPECTROSCOPY OR NIRS TECHNOLOGY ASSOCIATED WITH MULTIVARIATE STATISTICAL ANALYSIS FOR WOOD IDENTIFICATION AND ITS GEOGRAPHICAL ORIGIN.

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1. INTRODUCTION

One of the control measures to combat the illegal extraction and trade of tropical woods in Brazil is related to a fast and reliable identification of the species and its legal origin. Regulations in the country for forest areas under sustainable forest management and for traders of tropical woods increase the pressure for the correct identification and origin of the traded woods. This is because the accurate identification of wood is an essential task for its preservation, exploitation, and monitoring of the forest product trade.

This project is part of a long-term research aimed at developing a friendly, fast and reliable tool for the identification of woods and their geographical origin, to be used by environmental and regulatory agents from state and federal agencies, in field operations and at checkpoints and monitoring stations.

NIRS technology (near infrared spectroscopy, 800-2500 nm) and multivariate data analysis based on chemometric models (PLS-DA and SIMCA) has shown to be a promising tool on the identification and geographical origin of wood species (Pastore et al. 2011; Braga et al. 2014; Santos et al. 2013; Bergo et al. 2016 and Soares et al. 2017). This technology is recommended on “**Best Practice Guide for Forensic Timber Identification**”, published by United Nations Office on Drugs and Crime - UNODC / UNO (2016) and on “**Overview of current practices in data analysis for wood identification: a guide for the different timber tracking methods**”, published by Global Timber Tracking Network - GTTN (2020), mentioned by Diego et al. (2018).

In this context, the main objective of this work was to carry out a case study on monitoring commercial shipments of the species *Swietenia macrophylla* (mahogany) and *Cedrela odorata* L. (cedar), which have similar anatomical characteristics, from their origin (sustainable forest management projects, in the states of Acre - AC and Rondônia - RO, approved by IBAMA, which is the CITES authority in the country), to their final destination at a port for export (foreign trade) or commercial deposit (domestic market). Therefore, the main task was to test the use of NIR technology in the field. The results obtained demonstrate the efficiency of the method and the practicality of the portable NIR equipment for monitoring and tracking commercial wood shipments in the field environment, validating the identification of the species and their origin, from end to end.

Thus, the project aims to contribute to making the international trade of tree species listed under CITES consistent with the conservation and sustainable management of tropical

species, through the identification and origin of traded species.

2. TECHNICAL APPROACH AND APPLIED METHODS

A study published in the Journal of Sustainable Forestry, titled Global Tree Search, conducted by a group of experts and coordinated by the Botanical Gardens Conservation International (BGCI), compiled data from its network of 500 botanical gardens around the world and determined numbers, species names, and the distribution of trees in their respective countries (Beech et al. 2017). 60,065 trees were identified worldwide, and Brazil appears as the country with the largest number of species in the world (14% of the total), followed by Colombia (9.61%) and Indonesia (8.56%). According to the study, there are 8,715 native trees in Brazil, and of these, 4,333 are endemic, meaning they are only found in our country. Endemic species are the most vulnerable to possible threats such as deforestation, climate change, and other human activities.

In 2014, the Brazilian Government published the "Official National List of Endangered Flora Species" (MMA Ordinance No. 443, of 12/17/2014), which indicates the existence of 7,880 cataloged tree species in the country, and of these, 2,113 are on the list of endangered species. Species listed in categories such as extinct in the wild (EW), critically endangered (CR), endangered (EN), and vulnerable (VU) are fully protected, including the prohibition of collection, cutting, transportation, storage, management, processing, and commercialization. In some cases, these restrictions do not apply. For species classified in the vulnerable (VU) category, cutting and use through sustainable management may be allowed.

Based on information from the Brazilian Forest Service (SFB), Table 01 below was assembled, with 15 Brazilian tree species on the list of endangered species but of great interest to loggers. The trees are divided into categories: critically endangered (CR), endangered (EN), and vulnerable (VU).

Table 01. Threatened tree species and those of great interest to loggers.

Identification	Other common names	BIOME	Classification
Garapeira <i>Apuleia molaris</i>	<i>Amarelinho, barajuba, grapia, gema-de-ovo jataí, muirajuba, cumararana, sapucajuba</i>	Amazon, Caatinga and Cerrado	Vulnerable
Mahogany <i>Swietenia macrophylla</i> King	<i>Acaju, caoba, aguano, cedro-aguano, cedro- mogno, araputanga, cedrorana, Mara</i>	Amazon	Vulnerable
Cedar <i>Cedrela odorata</i> L.	<i>Capiúva, cedrinho, cedro-amargoso, cedro- aromático, cedro, cedro-bordado, cedro- cheiroso, cedro-fêmea, cedro-manso, cedro- pardo, cedro-verdadeiro</i>	Amazon, Caatinga, Cerrado and Atlantic Forest	Vulnerable
Chesnut tree <i>Bertholletia excelsa</i>	<i>Amendoeira-da-américa, castanha-do-brasil, cós-do-Brasil, tucari</i>	Amazon	Vulnerable
Bicuíba <i>Myrística Bicuhyba</i>	<i>Bocuva, bocuba, becuíba, bicuíba vermelha, vicuíba, bocuva-assú</i>	Atlantic Forest	Endangered
Rosewood from Bahia <i>Dalbergia nigra</i> Benth	<i>Caviúna, graúna, jacarandá-cabiúna, cabiúna do mato, pau-preto</i>	Atlantic Forest	Vulnerable
Jatoba <i>Hymenaea courbaril</i>	<i>Abati, corbaril, castanheiro-de-bugre, catá, comer-de-arara, copal, embiúva, farinha, jataizinho, jataí, jataíba, jaçaí, olho-de-boi, quebra-corrente, quebra-machado, trabuca</i>	Amazon	Vulnerable
Angelim-pedra-amarelo	<i>Mirarema, sucupira-amarela, angelim-da- mata faveira, angelim-macho</i>	Amazon	Vulnerable
Braúna preta <i>Melanoxylon braúna</i>	<i>Árvore-da-chuva, braúna-preta, canela, canela-amarela, coração-de-negro, maria- preta, muiraúna, paravaúna, rabo-de-macaco</i>	Atlantic Forest	Vulnerable
Ucuíba <i>Virola michellii</i> Heckel	<i>Bicuíba, andiroba, árvore-do-sebo, noz- moscada, leite-de-mucuíba, mucuíra</i>	Amazon, Caatinga	Vulnerable
Pau-roxo <i>Peltogyne lecointei</i>	<i>Amarante, coataquiçaua, roxinho, violeta, jataí-monte.</i>	Amazon	Vulnerable
Cherry tree <i>Amburana acreana</i>	<i>Amburana, cumaru-de-cheiro, cumaré, Imburana, louro-ingá</i>	Amazon	Vulnerable
Pau-amarelo <i>Euxylophora paraensis</i>	<i>Amarelão, amarelinho, amarelo-cetim, cetim, muiratana, pau-cetim, piquiá-cetim</i>	Amazon	Critically endangered
Araucária <i>Araucária angustifolia</i>	<i>Pinheiro-do-paraná, pinheiro-brasileiro, curi</i>	Atlantic Forest	Endangered
Jequitibá-branco <i>Couratari domestica</i>	<i>Estopa, cachimbeiro, pau-de-cachimbo, pau- estopa, mussambê, coatinga</i>	Amazon, Cerrado and Atlantic Forest	Endangered

2.1. Species chosen for this work

The species selected for this work, namely Mahogany (*Swietenia macrophylla* King) and Cedar (*Cedrela odorata*), in addition to their anatomical similarities and being listed in the appendices of CITES, are also part of the Official National List of Endangered Flora Species, where they are classified in the "Vulnerable" category, as shown in Table 01.

However, according to Brazilian legislation (MMA Ordinance No. 443 of 12/17/2014), these species can be harvested and exploited through sustainable forest management, duly approved and authorized by the competent agency.

2.1.1. Mahogany (*Swietenia macrophylla* King)

In the Brazilian Amazon, the natural occurrence area of mahogany (*Swietenia macrophylla* King) was estimated to be about 1.5 million km², covering seven Federal Units (Fig.01). Mahogany occurs in an arc south of the eastern Amazon, from the Araguaia River to the borders with Bolivia and Peru, to the south and east of the region (Terezo, 2002). This arc extends from central-eastern Pará, passing through the southern part of the state, northwest of Tocantins, northwest of Mato Grosso, southeast of Amazonas, to most of Rondônia and Acre (Lamb 1966; Barros et al. 1992).



Fig. 01. Natural occurrence area of Mahogany (Lamb.1996 and Barros et.al.1992).

According to Carvalho (2007), in its etymology, the generic name *Swietenia* is in honor of the Dutch physician Gerard van Swieten; the specific epithet *macrophylla* means large leaf. It is a perennial or deciduous tree. Larger individuals can reach dimensions close to 70 m in height and 3.50 m in DBH (diameter at breast height) in adulthood. There are reports that a single felled tree in southern Pará provided 25 m³ of wood.

The trunk is erect, slightly grooved, and with tabular roots at the base. The stem is straight and cylindrical, generally without branching or bifurcations up to 25 m in length. It presents well-formed lateral expansions at the base of the trunk, 2 to 3 m in length, tabular roots or

buttresses. The crown is narrow, with dense foliage and a strongly green color (Carvalho, 2007).

The main characteristics of mahogany wood are (Pereira & Mainieri, 1957; Loureiro & Silva, 1968b; Chimelo et al., 1976; Mainieri & Chimelo, 1989):

- **Apparent specific mass (density):** mahogany wood is moderately dense (0.48 g/cm³ to 0.85 g/cm³), with a moisture content between 12% to 15%.
- **Color:** when freshly cut, the heartwood is light brown, slightly yellowish, darkening from a uniform brown to a darker brown. The sapwood is narrow and well-contrasted, white-yellowish or almost colorless.
- **General characteristics:** the grain is usually straight or slightly irregular (diagonal). The texture is medium and uniform. The smell is indistinct, and the taste is slightly bitter. The surface is lustrous, with golden reflections, and usually smooth to the touch with imperceptible odor.
- **Natural durability:** Mahogany wood is considered moderately resistant to decay and highly resistant to dry wood termite attack. In contact with soil and moisture, it has low durability.
- **Preservation:** in pressure treatment, mahogany wood is not very permeable to the penetration of preservative solutions.
- **Workability:** mahogany wood is easy to work with and can receive a refined finish.
- **Other characteristics:** mahogany presents variations according to the nature of the tree's habitat. In somewhat dry terrain, the wood is harder and more compact; in permanently humid areas, it is softer and less ornate; in secondary forests, it is redder and harder. It is an excellent producer of wood, considered one of the most expensive in the world for fine furniture. The most prized wood in the trade has a fine texture, strong color, and pronounced grain patterns.
- **Sawn wood:** as it is a wood that combines a set of qualities, such as color ranging from very light to dark chocolate, often with patterns, great resistance to decay, even when submerged in water, resistance to splitting and warping, moderately heavy wood with remarkable workability, also used in paneling, plywood, construction, interior decoration, decorative veneered sheets, special plywood, high-precision scientific instruments, internal finishes in civil construction such as trimmings, blinds, baseboards, moldings, floors, aviation industry, as well as to make musical instruments, especially pianos, mahogany has always been one of the most demanded woods by the world market.

The extraordinary commercial value that mahogany has reached in national and international markets has stimulated its intense extraction in the Brazilian Amazon in recent decades, since the early 1970s. From 1970 to 2001, mahogany was one of the world's most valuable timber species, with 1.0 m³ of superior quality sawn mahogany selling for around US\$1,200 (FOB price). During this period, Brazil had an estimated production of 5.7 million m³ of sawn mahogany, of which approximately 4.0 million m³ were exported. The majority (75%) was exported to the United States and England, with about 1.7 million m³ consumed in the domestic market. Considering a historical average price of US\$700/m³ for sawn mahogany, the estimated gross value of this production was around US\$3.9 billion (Grogan et al., 2002). The high commercial importance of mahogany and its ecological vulnerability have always been the subject of intense controversy regarding how to ensure the conservation and sustainable use of this species.

As the logging industry approached the last natural stocks of mahogany in southern Pará, southeastern Amazonas and Acre, Brazilian environmental agencies tried to respond to national concerns about the commercial future of this species: i) reducing export quotas since 1990; ii) prohibiting the authorization of new forest management plans for mahogany since 1996; and iii) banning the transport, processing and commercialization of this species after detecting illegal exploitation practices in southern Pará in 2001. On the other hand, to ensure the future of the species as a natural heritage and renewable resource, it was necessary to convert the available technical information into guidelines and policies for sustainable forest management, according to public interests, viable for the industry and auditable by environmental agencies (Grogan et al., 2002).

As a result of this extensive selective logging, mahogany is considered a threatened species and has been included in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) to ensure its survival.

In Brazil, currently, although mainly restricted to Public Forests - Indigenous Reserves, Biological Reserves and National Forests - mahogany is still a species of great interest to entrepreneurs. At the moment, only one sustainable forest management project, with the species mahogany, located on private property in the state of Acre, has approval and licenses from Brazil's CITES authority - IBAMA, to exploit and commercialize this species. Thus, PROJECT CITES S 608 identified this unique opportunity to test whether the NIRS tool in use will be able to provide robust and reliable results to monitor commercial loads of the mahogany species from its origin to a port for export.

2.1.2. Cedar (*Cedrela odorata* Linnaeus)

The genus *Cedrela* was established by P. Browne in 1756 for the tree *Cedrela odorata* found in Jamaica. This genus has seven wood-producing species, distributed from the Antilles and Mexico to Argentina (Pennington, 1981). In South America, *Cedrela odorata* is not found naturally only in Chile and Uruguay. This species is distinguished from *Cedrela fissilis* mainly by its noticeably smaller fruits (Carvalho, 2010).

In our country, *Cedrela odorata* occurs in 20 states, as shown in Fig. 02. In these locations, it is known by the following common names: in Acre, *cedro*, *cedro-rosa*, and *cedro-vermelho*; in Amapá, *cedro* and *cedro-vermelho*; in Amazonas, *cedrinho*, *cedro*, and *cedro-rosa*; in Bahia, *cedro*, *cedro-aromático*, *cedro-cheiroso*, *cedro-fêmea*, *cedro-rosa*, *cedro-verdadeiro*, and *cedro-vermelho*; in Espírito Santo, *cedro-rosa*; in Maranhão, *cedro*; in Mato Grosso, *cedro-de-mato-grosso* and *cedro-rosa*; in Minas Gerais, *acaju*, *cedro*, and *cedro-do-brejo*; in Pará, *cedro*, *cedro-cheiroso*, and *cedro-vermelho*; in Pernambuco, *cedro*, *cedro-branco*, and *cedro-vermelho*; in the state of Rio de Janeiro, *cedro* and *cedro-rosa*; in Rio Grande do Sul, *cedrilho* and *cedrinho*; in Roraima, *cedro-amargo*; and in the state of São Paulo, *cedro*, *cedro-cheiroso*, *cedro-do-brejo*, and *cedro-rosa*. The commercial name in the international market is cedar (Carvalho, 2010).

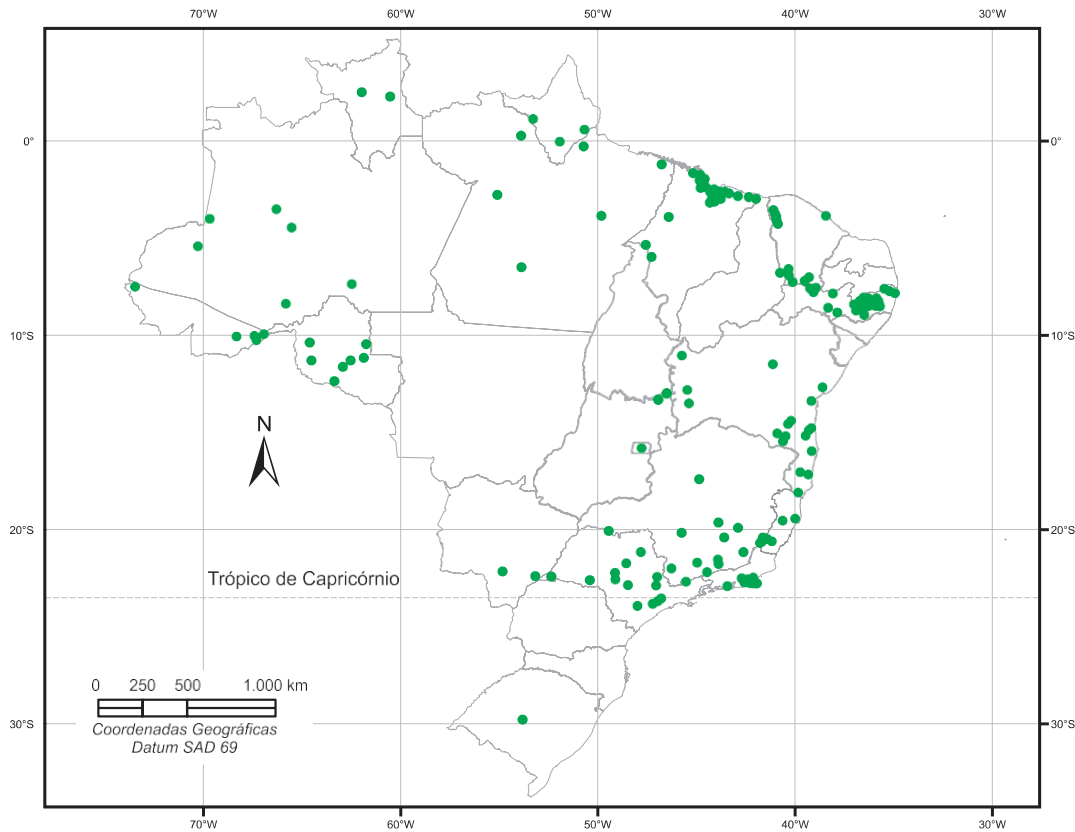


Fig. 02. Identified locations of natural occurrence of *Cedrela odorata* in Brazil (Carvalho, 2010).

The main characteristics of *Cedrela odorata* wood are (Loureiro; Silva, 1968b; Lamprecht, 1990; Rodríguez Rojas; Sibille Martina, 1996; Timyan, 1996; Melo et al., 2002):

- **Apparent specific mass (density):** light to moderately dense wood 0.33 g/cm^3 to 0.70 g/cm^3 .
- **Color:** heartwood varies from light brown to dark pinkish beige and reddish brown, somewhat demarcated from the sapwood, which is pale pink.
- **General characteristics:** straight or slightly wavy grain; coarse texture; aromatic smell and slightly bitter taste. Very durable wood, with medium to high luster, with golden reflections. It is easy to work with machinery and hand tools, receiving a good finish.
- **Sawn timber:** Cedar wood is one of the best in the country. It is widely used in joinery, carpentry, in the manufacture of plywood, laminates, interior decorations,

luxury furniture or for export, packaging, office supplies, picture frames, musical instruments, in civil construction and aeronautics, frames, internal works, carpentry, cigar boxes, boat building, chessboards, and flooring. It is a preferred wood for making religious sculptures (BUSTAMANTE, 1948). It is a highly valued wood in the southern and southeastern regions of the country, for the construction industry and furniture manufacturing.

2.2. Applied method

Wood is a chemically complex material, since its basic composition varies depending on the environmental conditions of the location where the tree developed. Trees that grow in forests around the world are influenced by local climate, soil, slope, forest density, silvicultural practices, fungi, wildlife, facilities, and other factors in addition to the genetic variation of the individuals themselves. These parameters have some influence on the chemical composition of the wood, especially on the content of extractives, cellulose, lignin, and hemicellulose (Sandak et al. 2011, 2015). The science that deals with the identification of woods based on their chemical composition is called chemotaxonomy and can be performed using chemical analysis (Sandermann 1962), or by specifying other indirect methods (Rana et al. 2008; Wang et al. 2017).

The data from near-infrared spectroscopy (NIRS, 800-2500 nm) are also related to the chemical composition of wood. The observable differences are small, and the spectral evaluation is made using chemometric models (Pastore et al. 2011). The NIRS approach is an indirect method approach and relies on careful calibration under specific conditions, taking into account wood moisture, surface roughness, and other parameters (Tsuchikawa 2007, Sandak et al. 2011; Tsuchikawa and Kobori 2015).

Tools for the rapid identification and origin of woods traded in the timber market are fundamental and necessary. Although several new tools have been established to aid in the control of timber harvesting and illegal trade, there is still a deficiency in practical procedures to identify the origin of wood and its products. Tools are sought that can validate the origin of the harvest with the aim of legitimizing enterprises and ensuring that timber products have been harvested sustainably in accordance with the laws of the country of origin.

NIR technology (near-infrared spectroscopy, 800-2500 nm) and multivariate data analysis based on chemometric models (PLS-DA and SIMCA) have shown great promise in wood identification (Pastore et al. 2011). The work carried out with this project addressed some

basic problems, in field conditions, regarding the monitoring of commercial loads of mahogany (*Swietenia macrophylla*) and cedar (*Cedrela odorata*). NIRS technology was tested as a safe and rapid methodology for monitoring wood, from end to end, under field conditions, that is, without control of parameters such as temperature and ambient humidity, humidity and temperature of wood pieces, presence of fungi or xylophagous organisms, cutting orientation, surface roughness, surface contaminated by some other product, etc.

One limitation of NIR technology relates precisely to the moisture content of the wood, as water covers several information in the spectrum and provides non-coherent results. To mitigate this limitation, a new spot drying procedure, based on controlled hot air jet and rapid cooling, was applied in the areas of the wood surface where spectra readings were taken, aiming to minimize the interference of material and environmental moisture on the characteristic spectrum of each forest species.

In this context, the working method to be used was developed in the following stages: 1) monitoring the completion of laboratory studies on wood drying and cooling techniques on the spectrum collection surface; 2) establishing the protocol for collecting spectra; 3) defining and validating the planning of fieldwork; 4) enabling the execution of NIR spectrum collection work at the origin of the wood (industry yards), and at the port for export or end consumer, by the research team; and 5) preparing the final field report.

2.2.1. Monitor the completion of laboratory studies on drying and cooling techniques of wood, on the surface where spectra are collected.

Establishing a protocol for collecting spectra, considering the techniques of wood drying and cooling on the surface of the sample, to obtain diffuse reflectance spectra at distinct points of the sample is crucial for better control of variables such as moisture and temperature on the surface of the sample. At each point of spectrum collection (origin and port/final consumer), the wood samples from different individuals of the species *Swietenia macrophylla* King (mahogany) and the species *Cedrela odorata* (cedar), woods with similar anatomy, need to initially reach a dry condition (between 9 to 12% moisture) using pre-established drying and cooling techniques.

In the case of wood samples with moisture content above 15%, it is necessary to use drying techniques for these samples. However, this optimization procedure for drying wood samples aiming for greater control of sample moisture content, despite being effective, has the consequence of adding a new variable to the study, namely, an increase in sample

temperature.

Therefore, it was necessary to conduct laboratory studies and experiments on the techniques of drying and rapid cooling of wood samples in the spectral collection regions, aiming for greater control of this new variable. These studies aimed at optimizing the drying of wood samples were carried out at the Laboratory of Automation, Chemometrics and Environmental Chemistry at the University of Brasília (AQQUA - UNB) by the project team.

The initial procedures for collecting spectra in samples of wood with moisture content above 15% have been modified throughout this project, aiming to optimize the drying process so that during the sample cooling process, where a quick drying spray (contact cleaner) is used, temperature monitoring is also carried out using a thermocouple or digital infrared thermometer, seeking to evaluate the time for the sample temperature to return to the initial temperature condition or at least below 30°C.

The sample drying process used a heat blower, YAXUN® 880D equipment, over the previously sanded sample surface, with the equipment registering a heating temperature of 190°C, so that the air jet in contact with the sample would cause its heating, but the sample temperature should not exceed 105°C. Therefore, the distance from the heat focus to the sample surface was maintained at 8.0 cm and the estimated heating time of the sample was 2.0 to 3.0 minutes. After this period, the quick-drying spray (contact cleaner) was applied to the heated region of the sample until it reached a temperature of about 10°C, and then the sample temperature was allowed to return to the environmental equilibrium conditions, around 30°C.

This new procedure presented better results under laboratory conditions. Figures 3 to 6 show the equipment and instruments used for these tests in the laboratory.



Fig.03. Digital infrared thermometer, wood moisture meter, and ambient humidity and temperature meter.

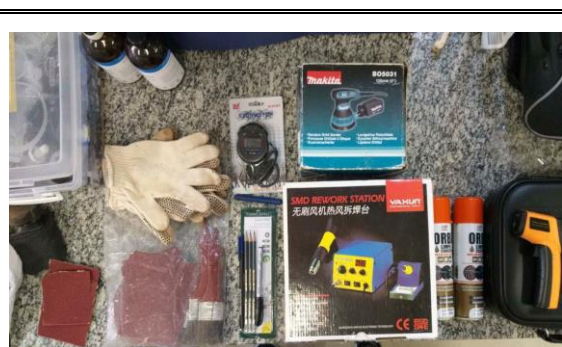


Fig.04. YAXUN® 880D heat blower, makita electric sander, digital timer, quick-drying spray, gloves, sandpaper, and brushes.

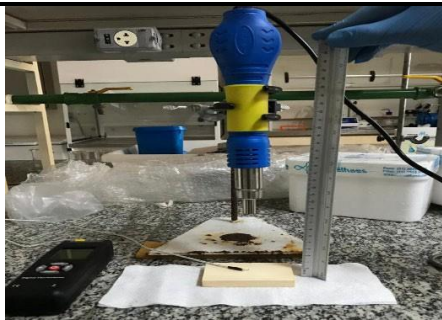


Fig. 05. Experimental setup with YAXUN® 880D heat blower, sample, and thermocouple.





Fig.06. Microphazir equipment for reading spectra on samples.

2.2.2. Establishing the protocol for collecting spectra

Table 02 below shows the standard procedure, after conclusive laboratory tests, to be adopted for drying and acquiring NIR spectra in wood samples collected in fieldwork.

Table 02. Standard procedure for collecting NIR spectra in wood samples in fieldwork.

STAGES	PROCEDURES
1. Sample preparation	<ol style="list-style-type: none"> 1.1. Wood sample analyzed by a wood anatomist and identifier, to confirm the species and guide the sample cut. 1.2. Sand the area of the sample where the spectra will be read with a n° 80 sandpaper and clean it with a brush. 1.3. Measure the initial moisture and temperature of the sample. 1.4. Record the humidity and temperature equilibrium of the environment where the spectra are being collected.
2. Methodology for drying and cooling the samples	<ol style="list-style-type: none"> 2.1. Position the sample at a distance of 8.0 cm between its surface and the hot air outlet of the YAXUN® 880D heat blower (Figure 3). 2.2. Adjust the blower to a temperature of 190°C. 2.3. Direct the hot air jet onto the sample for 2 minutes. 2.4. Monitor the temperature of the hot air jet under the surface of the sample with a thermocouple or digital thermometer so that it does not exceed 105°C. 2.5. For rapid cooling of the sample, apply a spray of quick-drying (contact cleaner) onto the surface where the spectra will be collected, at a distance of 5.0 cm for approximately 2.0 seconds. 2.6. Let the sample rest for 7.0 minutes, check the surface temperature, and if it is below 30°C or in equilibrium with the ambient temperature, take the spectra readings.
3. Turning on and calibrating the Microphazir equipment	<ol style="list-style-type: none"> 3.1. Press the Power On/Off . 3.2. Press the trigger to start the equipment. 3.3. Access the "Self Test" and press "Select". 3.4. Select the "Start Scan" option, wait for the equipment lamp to heat up and the test to be performed. 3.5. The message "Pass" should be displayed. If it shows "Fail", check the equipment battery level. 3.6. Select the "Return to Main Screen" option.
4. Method and batch selection for acquiring spectra	<ol style="list-style-type: none"> 4.1. In the initial menu, select the "Tools" option and then the "Acquire Signatures" option. 4.2. Click on the "Method" option and select a method already saved in the equipment or create a new one under "New". 4.3. Do the same for batch selection in the "Batch" option. 4.4. To start acquiring spectra, select the "Continue to Start Run" option.

<p>5. Acquisition of spectra</p>	<p>5.1. Position the sample to completely cover the beam output and press "Select" or press the equipment trigger. A warning that the lamp is being turned on will appear.</p> <p>5.2. Then, there will be a message that the background is being read and the spectrum of the first replicate will be acquired. If the spectrum is as expected, select "Select" to move on to the next one. Otherwise, select "Esc" and repeat the reading.</p> <p>5.3. Slightly change the position of the sample and press "Select" again or press the equipment trigger to acquire the spectra of the next replicate. Again, if the spectrum shows any undesired variation, select "Esc" and repeat the reading.</p> <p>5.4. At the end of acquiring the spectra of all replicates of the sample, the equipment will return to the acquisition menu, waiting for a new sample with the updated name in "Sample."</p> <p>5.5. At the end of reading all samples, select the "Esc" option to return to the main menu.</p> <p>5.6. In the main menu, select the "Logout" option and confirm by selecting "Yes."</p> <p>5.7. Press the Power On/Off button  until the "Powering Down" message appears. Wait until the screen turns off and the equipment will be properly turned off.</p>
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2.2.3. Define and validate the fieldwork planning.

The fieldwork in this project is essential, and it is important to properly define and validate its planning to ensure the proper execution of wood sample spectrum collection services. Another important aspect is that the project team's fieldwork approach will directly impact the results obtained.

Planning and executing fieldwork is not a simple task and should ensure compliance with established deadlines and achieve results that are compatible with the project's needs and the quality of the services to be performed. It can be said that the expected fieldwork in this project requires an effective and well-trained workforce to achieve the proposed objectives, increase team productivity, and, above all, optimize time and reduce costs. This will prevent the project from incurring higher costs due to unnecessary expenses such as personnel, equipment, transportation, and accommodations.

Fortunately, the project team is qualified and well-trained, with a defined standard operational protocol, important and fundamental aspects for achieving success in this type of work. Thus, the planning of field activities was based on establishing contacts with representatives of the timber industry (location of spectral collection), in order to gain

access to the study materials as well as logistic support for the work execution. Technicians and public managers from IBAMA and the Brazilian Forest Service were also contacted for project presentation, detailing, and support for fieldwork.

The planning, confirmation, and detailing of fieldwork (collection locations, project team physical displacements, dates, and work periods) were carried out based on weekly remote meetings of the project team and contacts made (public institutions and companies) through face-to-face meetings and phone calls. Table 03 presents the schedule of meetings and contacts made, with their respective participants and a summary of the main results obtained.

Table 03. Schedule of meetings and contacts held to define the planning and execution of fieldwork.

DATE	MEETING/CONTACT	PARTICIPANTS	RESULTS
11/17/2021	Remote meeting with the Project Coordination and LPF/DF	- Dr. Divino Eterno - Head of LPF - Dra. Tereza Pastore – Coordinator of Cites S 608 project – LPF - Dr. Paulo Fontes – Forestry Engineer	- Presentation of the project to the LPF Head, and - Negotiations for the execution of the Cites S 608 project.
01/18/2022	Remote meeting – Dalbergia Group	- Cites S 608 project team	- Getting to know the participants of the project team.
01/27/2022	Remote meeting – Dalbergia Group	- Cites S 608 project team	- Discussion about the standard protocol for conducting field tests.
02/09/2022	Remote meeting – Dalbergia Group	- Cites S 608 project team	- Project updates, and - Planning of laboratory assays.
02/14/2022	Remote meeting – Dalbergia Group	- Cites S 608 project team	- Discussion of the resumption of experimental work, trials to optimize drying.
02/23/2022	In-person meeting - with the Director of IBAMA	- João Pessoa R. Moreira Jr – Director of DBFLOR / IBAMA - Julianna Sampaio G. Oliveira – Advisor of DBFLOR / IBAMA - Paulo José P. Fontes – Consultant of Cites S 608 project – FUNTEC	- Talk to the IBAMA management about the project and request support. - IBAMA's participation in the 74th Cites Meeting and the mention of the project. - Meeting scheduled to present the project to the IBAMA team.
02/25/2022	In-person meeting - with LPF management	- Dr. Fernando Gouveia – Head of LPF - Dra. Tereza Pastore – Coordinator of Cites S 608 project – LPF - Dr. Paulo Fontes – Project consultant - FUNTEC	- Presentation of the project to the new LPF head and discussion about its importance - New negotiations for the project execution.
03/03/2022	In-person meeting - with the Director of IBAMA	- Ramiro H. Hofmeister – Coordinator of COUSF/DBFLOR/IBAMA - Daniel Santos Pinho – Coordinator of COMEX/DBFLOR/IBAMA - Victor Castro F Souza – Head of DATEC/DBFLOR/IBAMA - Julianna Sampaio G. Oliveira – Advisor of DBFLOR/IBAMA	- Presentation of the Cites projects to the technical team of DBFLOR/IBAMA. - Discussion and detailing of how IBAMA could support the Cites S 608 project. - Planning and initial contacts for the fieldwork with the mahogany wood, together with Agrocórtex, in the state of Acre.

		<ul style="list-style-type: none"> - Dr. Fernando Gouveia – Head of LPF - Dra. Tereza Pastore – Coordinator of Cites S 608 Project - Dr. Paulo Fontes – Consultant of Cites S 608 Project 	
03/07/2022	Phone call	<ul style="list-style-type: none"> - Ramiro H. Hofmeister – Coordinator of COUSF/DBFLOR/IBAMA. 	<ul style="list-style-type: none"> - Initial information about the mahogany wood at AgroCórteX - Acre. - Contact at Supes of IBAMA in Acre.
03/14/2022	Remote meeting – Dalbergia Group	<ul style="list-style-type: none"> - Cites S 608 project team - Dra. Vera Coradin – Consultant for the Cites Dalbergias Project 	<ul style="list-style-type: none"> - Results from the trip to the Botanical Garden and the Brazilwood project.
03/21/2022	Remote meeting – Dalbergia Group	<ul style="list-style-type: none"> - Cites S 608 project team 	<ul style="list-style-type: none"> - Discussion of the experiments carried out to optimize the drying of the samples.
03/23/2022	Phone call	<ul style="list-style-type: none"> - Luciano Arruda – Environmental Analyst and Cites Authority at the IBAMA/AC Superintendence 	<ul style="list-style-type: none"> - Confirmation of AgroCórteX's mahogany wood stocks in Acre. - Presentation of the field team and request for the company's support for the work to be carried out by the project.
03/25/2022	Remote meeting - with the project coordination	<ul style="list-style-type: none"> - Dra. Tereza Pastore – Coordinator of S 608 Project - Prof. Dr. Jez Braga – Professor / Researcher at UnB - Dr. Paulo Fontes – Consultant of Cites S 608 Project 	<ul style="list-style-type: none"> - Information about the mahogany wood (logs and sawn wood) that AgroCortex has in stock. - Discussion about the collection protocol and experiments conducted by researcher Mário Rabelo.
03/28/2022	Remote meeting – Dalbergia Group	<ul style="list-style-type: none"> - Cites S 608 project team 	<ul style="list-style-type: none"> - Discussion for conducting more experiments and optimizing the drying and cooling of wood samples
04/05/2022	Phone call	<ul style="list-style-type: none"> - Engineer Pamela Thuyany – Manager of AgroCórteX – Madeiras do Acre 	<ul style="list-style-type: none"> - Contact with AgroCórteX to discuss details of the fieldwork to be carried out by the project - Definition of the probable date for the field trip: April 26th to 30th.
04/11/2022	Remote meeting – Dalbergia Group	<ul style="list-style-type: none"> - Cites S 608 project team 	<ul style="list-style-type: none"> - Detailed planning of fieldwork at AgroCórteX, team displacement, accommodations, vehicle rental, tickets, and hotel daily rates.
04/12/2022	Phone call	<ul style="list-style-type: none"> - Engineer Pamela Thuyany – Manager of AgroCórteX – Madeiras do Acre 	<ul style="list-style-type: none"> - Confirmation of the fieldwork planning and the team's travel to the industrial unit in Manoel Urbano, Acre.
04/18/2022	Phone call	<ul style="list-style-type: none"> - Engineer Pamela Thuyany – Manager of AgroCórteX – Madeiras do Acre 	<ul style="list-style-type: none"> - Final arrangements for the execution of the work, condition of the woods, logistics, support, etc.
04/18/2022	Remote meeting – Dalbergia Group	<ul style="list-style-type: none"> - Cites S 608 project team 	<ul style="list-style-type: none"> - Checklist of all equipment and material necessary for the trip to Manoel Urbano, Acre.
04/27/2022	In-person meeting – with AgroCórteX management	<ul style="list-style-type: none"> - Engineer Pamela Thuyany – Manager of AgroCórteX – Madeiras do Acre - Dr. Paulo Fontes – Consultant and Fiel Team Coordinator - José Arlete Camargos – Wood Anatomist / Identifier, Msc - Daniele C. Kunze – Chemist, Msc - Hugo S. Rocha – Chemistry student. 	<ul style="list-style-type: none"> - Presentation of the field team and the work to be carried out. - Details and support for the execution of the work, access to the mahogany (<i>Swietenia macrophylla</i>) wood, and necessary logistics

05/18/2022	Remote meeting – Dalbergia Group	- Cites S 608 project team	- Reporting to the entire project team the results obtained from the field work carried out at Agrocórtex - Madeiras do Acre, in Manoel Urbano - AC.
05/23/2022	Remote meeting – Dalbergia Group	- Cites S 608 project team	- Update the reports on the project execution activities.
05/27/2022	Phone call	- José Humberto Chaves – General Coordinator of Forest Monitoring and Audit – SFB / MAPA	- Meeting with the Forest Monitoring and Audit Coordination of SFB, scheduled.
05/30/2022	Remote meeting – Dalbergia Group	- Cites S 608 project team	- Preparatory meeting for the visit to JB Madeiras in Taguatinga-DF for NIRS spectra collection.
05/31/2022	In-person meeting - with the Coordination of Forest Monitoring and Audit of SFB / MAPA	- José Humberto Chaves – General Coordinator of Forest Monitoring and Audit – SFB / MAPA - Claudio B. Cavalcanti – Engineer of the Forest Monitoring and Audit Coordination of SFB / MAPA - Dr. Paulo Fontes – Consultant of Cites S 608 Project.	- Presentation of the project to the SFB / MAPA Monitoring Coordination - Support for the execution of fieldwork with the SFB concessionaire, the company MADEFLONA - Contacts and presentation of the team to carry out fieldwork with MADEFLONA.
06/06/2022	Phone call	- Evandro José Muhlbauer – Engineer and Director of MADEFLONA	- Initial arrangements to plan the field team's trip to the MADEFLONA company.
06/06/2022	Remote meeting – Dalbergia Group	- Cites S 608 project team	- Discussion and detailing of the fieldwork planning in the MADEFLONA timber industry, located in Rondônia/RO, a concessionaire of SFB.
06/09/2022	Phone call	- Evandro José Muhlbauer – Engineer and Director of MADEFLONA	- Final preparations for the trip and information on identifying rosewood (logs) and the equipment to be used.
06/13/2022	Remote meeting – Dalbergia Group	- Cites S 608 project team	- Preparations for the trip to Itapuã do Oeste - RO, at MADEFLONA. - Discussion about the sampling system to obtain spectra in logs and planks of cedar (<i>cedrela odorata</i>)
06/20/2022	Remote meeting – Dalbergia Group	- Cites S 608 project team	- Last preparations for the trip to Rondônia, with a checklist of tickets, hotel reservations, car, equipment, and necessary materials.
06/27/2022	Face-to-face meeting - with the management of MADEFLONA company	- Evandro José Muhlbauer – Engineer and Director of MADEFLONA - Álvaro Patrick Soares – Engineer and Field Manager of MADEFLONA - Dr. Paulo Fontes – Consultant and Coordinator of the field team - José Arlete Camargos – Wood anatomist / Identifier, Msc. - Hugo S. Rocha – Chemistry student - Gabriel Calil – Chemistry student.	- Presentation of the field team and the work to be carried out. - Detailed explanation of the execution of the work at the company's industrial unit and access to cedar (<i>Cedrela odorata</i>) woods. - Logistic support for the movement of cedar logs in the industry's yard and their processing for obtaining samples.
07/04/2022	Remote meeting – Dalbergia Group	- Cites S 608 project team	- Presentation and discussion of the results obtained and the drying tests performed with the fieldwork at MADEFLONA.
07/11/2022	Remote meeting – Dalbergia Group	- Cites S 608 project team	- Update the standard procedure for collecting spectra of woods in the field.

08/01/2022	Remote meeting – Dalbergia Group	- Cites S 608 project team	- Preparations for the second trip to Rondônia, checklist for tickets, hotel reservations, equipment, car, and necessary materials.
08/08/2022	Meeting with the Management of MADEFLONA Company	- Evandro José Muhlbauer – Engineer and Director of MADEFLONA - Dr. Paulo Fontes – Consultant and Coordinator of the field team - Gabriel Calil – Chemistry student - Anelisa G. Sousa – (scholarship holder)	- Presentation of the field team and the work to be performed - Details of the execution of the work at the industrial unit and access to the 07 lots of cedar wood (<i>Cedrela odorata</i>) - Logistics support for moving the wood lots in the industry yard and obtaining samples.
08/15/2022	Remote meeting – Dalbergia Group	- Cites S 608 project team	- Discussion and evaluation of the results obtained and drying tests with the new protocol, carried out in the second collection at MADEFLONA
08/22/2022	Remote meeting – Dalbergia Group	- Cites S 608 project team	- Initial discussions to plan the field team's trip to the city of Ubatuba-SP.
08/29/2022	Remote meeting – Dalbergia Group	- Cites S 608 project team	- Preparations for the trip to Ubatuba-SP, checklist of tickets, hotel reservations, equipment, car, and necessary material.
08/31/2022	Meeting with the management of the company MADEIRO	- Mr. Jairo (owner of the company) - Dr. Paulo Fontes – Consultant and Coordinator of the field team - Gabriel Calil – Chemistry student / scholarship holder - Anelisa G. Sousa – Chemistry student / scholarship holder.	- Explain the objectives of the work to be carried out by the team on the company's premises and the logistical support needed to carry out the work. - Inspection of the 07 lots of sawn cedar, arranged in the company's warehouse.
09/05/2022	Remote meeting – Dalbergia Group	- Cites S 608 project team	- Brief discussion of the results obtained with the collection of spectra, carried out at MADEIRO company, in Ubatuba-SP.
09/12/2022	Remote meeting – Dalbergia Group	- Cites S 608 project team	- Meeting for information gathering about project execution.
09/19/2022	Remote meeting – Dalbergia Group	- Cites S 608 project team	- Meeting for information gathering about project execution.
09/26/2022	Remote meeting – Dalbergia Group	- Cites S 608 project team	- Information on the trip to Malaysia and request to prepare a summary for a conference.
10/31/2022	Remote meeting – Dalbergia Group	- Cites S 608 project team	- Discussion of the results obtained at MADEIRO company in Ubatuba. - Proposal to develop a more robust model for the data with the species <i>Cedrela odorata</i>

Thus, five field works were planned, detailed, and carried out for NIRS spectra collection, in four different lumber companies, namely:

- 1) Agrocórtex - Madeiras do Acre, located in Manoel Urbano – Acre;
- 2) JB Madeiras, located in Taguatinga - Distrito Federal;
- 3) Madeflona, located in Itapuã do Oeste - Rondônia; and
- 4) MADEIRO, located in Ubatuba - São Paulo.

3. EXECUTION OF NIRS SPECTRUM COLLECTION WORKS AT THE WOOD ORIGIN (wood industry yards)

3.1. Collection of spectra at Agrocórtex - Madeiras do Acre sawmill.

The field trip to the facilities of Agrocórtex - Madeiras do Acre, based and operating in the municipality of Manoel Urbano - AC, was carried out with the aim of relocating part of the project team to collect NIR spectra from samples of mahogany wood (*Swietenia macrophylla*) from different individuals/logs. The collection of NIR spectra was carried out from 04/26 to 05/01/2022 in samples of mahogany wood, already processed by the company and ready to be commercialized.



Figure 7. Field team.

All work was carried out by the field team consisting of 4 people: Paulo Jose Prudente de Fontes (Field team coordinator), José Arlete A. Camargos (Anatomist / identifier), Daniele C. Kunze (Chemist / researcher) and Hugo S. Rocha (Chemist / intern).

The team traveled from Brasília (DF) to Rio Branco (AC) by air and from Rio Branco (AC) to Manoel Urbano (AC) by road, through the BR-364, in a vehicle rented for this purpose. The industrial unit of the Agrocórtex company is located near the city of Manoel Urbano (AC), about 10 minutes away by car, on the left bank of the Purus River (Figure 8).

The company, Agrocórtex Madeiras do Acre Agroflorestal Ltda., has one of the largest sustainable forest management plans in the Brazilian Amazon, in the states of Amazonas (AM) and Acre (AC), with a total area of 190,201.00 hectares, located on the Seringal Novo Macapá Farm, in the municipalities of Boca do Acre/AM, Pauini/AM and Manoel Urbano/AC, on the left bank of the Purus River, Brazil. It is a certified sustainable management project with reduced impact, by the Forest Stewardship Council® - FSC.



Figure 08. Log yard, at Agrocórtex sawmills, on the left bank of the Purus River, in Manoel Urbano (AC).

The logging of timber that occurs within the areas of forest management follows ecological, social, and economic standards that make up the sustainable management plan, with its economic aspect being given by the exploitation of only a few trees. Only trees above 60 cm in diameter can be removed. In addition, if the forest is very good, there is a limitation of removing a maximum of up to 25.0 m³ per hectare/year.

Figure 09. Forest management area of Agrocórtex.





Fig. 10. Wood log storage yards, in the forest management area, and marking of the logs.



Figure 11. Log yard at Agrocórtex company, where logs are processed and refined, with an estimated annual production of 150,000 m³ of logs from around 40 different species.

As the first activity, as soon as the team arrived at the company, they held a brief meeting with Engineer Pâmela Thuyany, the company's manager, for introductions and to explain the work to be done. After the meeting, the team proceeded to visit part of the company's facilities and the warehouses where the mahogany woods were stored and ready to be sold (Figures 12 to 15).



Fig. 12. Field team coordinator in the company's log yard.



Fig. 13. Stacking of wood for road transport.



Fig. 14. Lot 100689, with 96 pieces of mahogany used in the sampling for road transport.



Fig. 15. Lot 098434, with 130 pieces of mahogany used for NIRS spectra collection.

During the fieldwork, the NIR spectra collection protocols were carried out, as recommended in Table 02, considering the wood drying and cooling techniques on the collection surface, with the longitudinal surface cleaning of each sample (using P80 sandpaper), to obtain three diffuse reflectance spectra at distinct points of each sample. 94 samples and 164 collection points were used, totaling 492 spectra. Figures 16 to 19.

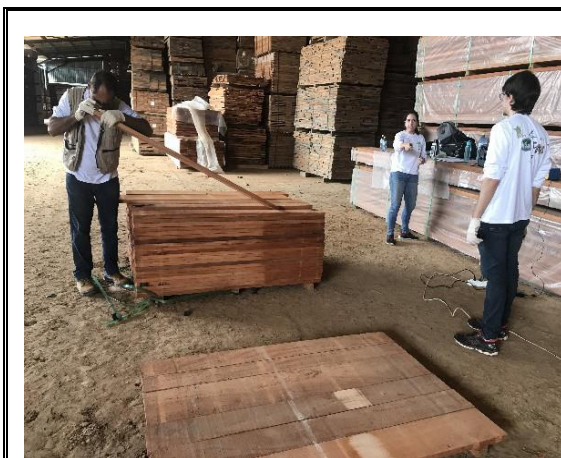


Fig. 16. Anatomist checking the mahogany samples.



Fig. 17. Disassembling the lots to collect spectra.



Fig. 18. Field team in the log yard of the company.



Fig. 19. Field team with the manager of Agrocórtex company.

3.2. Spectra collection at JB Madeiras.

The field visit, carried out at JB Madeiras company, located in Taguatinga (DF), on 06/02/2022, despite not being a spectra collection in the origin of woods, i.e., in the industry's yards, has its importance for being a collection in commercial woods, as they are presented in the consumer market. In fact, it was the project team's second visit to this company, and the first occurred in 09/2021 and was considered the project team's first visit to a sawmill to test the wood sampling protocol in a commercial environment, outside the laboratory environment.

In this first visit, important results were obtained for the project, to demonstrate that in environments with uncontrolled variables (outside the testing laboratory and xylotec environment), such as wood moisture content, temperature and humidity of the environment, etc., are variables that can affect NIR spectra readings and consequently, alter the identification results. Therefore, with this second visit, it was possible to better evaluate the behavior of these variables as well as test the application of the standard operational protocol for field collections.

This visit was carried out by the project team consisting of 6 people: Tereza Pastore (Project Coordinator), Jez Braga (Professor / Researcher at UnB), Paulo Jose P. Fontes (Field Team Coordinator), Alexandre (Anatomist/identifier), Hugo da Silva Rocha (Student / scholarship holder), and Gabriel Calil (Student / scholarship holder). For the spectra collection, the standard protocol was applied, as presented in Table 02. The sampled species were: Cedar (*Cedrela odorata*); Cedrinho (*Erisma uncinatum*), and Curupixá (*Micropholis melinoniana*).



Fig.20. Sanding sample for NIR spectra collection.



Fig.21. Applying drying protocol on samples for NIR spectra collection.

3.3. First spectra collection at Madeflona company

The displacement of the CITES S 608 project field team: “Identification of the origin and wood species of mahogany and similar through NRIS technology” to the facilities of the Madeflona timber company, based in the municipality of Itapuã do Oeste, occurred from Brasília (DF) to Porto Velho (RO) by air and from Porto Velho (RO) to Itapuã do Oeste (RO) by land, also on BR-364, in a vehicle rented for this purpose. The main objective of the field trip was to collect NIR spectra from 22 logs of cedar (*Cedrela odorata*) and subsequently, also from the sawn wood (boards/planks) of this same lot of logs, from 10 distinct trees of this species. Due to the opportunity to access these wood logs, before they were processed, it was possible to collect samples from the 22 cedar logs to be sent to the wood collection (xylarium) of the Laboratory of Forest Products – LPF, in Brasília/DF.

The project team accompanied the processing of the logs, at the Madeflona industrial unit, collecting three samples of boards, from each processed log, to obtain new NIR spectra.

As soon as the team arrived in Itapuã do Oeste city, they went to the Madeflona company, located in the urban area of the city. A meeting was held with Mr. Jonas (Owner), Eng. Evandro José Muhlbauer (Director) and Eng. Álvaro Patrick Soares (Field Manager) of the Madeflona company for the necessary introductions, to explain the project's objective, as well as to request logistical support from the company to carry out the work.

In the afternoon, the team moved with Eng. Álvaro Soares to the Jamari National Forest, to visit the log yard of the timber species exploited by the company, coming from its forest management area. In this yard, among other woods, were stored the 22 cedar logs (*Cedrela odorata*), which would be the object of the work to be performed, as shown in Figures 22 to 25. After a brief inspection of the logs, the team returned to the company's industrial unit, in the urban area of Itapuã do Oeste (RO), to visit the facility and better plan the way to carry out the work, aiming at starting the collection of NIR spectra as soon as the inspected logs on the yard were transported from the forest to the yard of the industry, which happened the next morning.



Fig.22. Log yard at FLONA JAMARI (RO).



Fig.23. Timber logs from Madeflona forest management.



Fig.24. The 22 cedar logs in the yard used in the collection of NIR spectra.



Fig.25. Selected Angelim logs for processing in the industry.

With the cedar logs already in the yard of the industry, the protocols for collecting NIR spectra were carried out on each of the 22 logs, and also, samples (wood wedges) were removed from each log to be sent to LPF. As shown in Figures 26 to 29.



Fig.26. Cedar logs, in the yard of the industry, ready for spectra collection.



Fig.27. Collecting samples (wood wedges) from each cedar log.



Fig.28. Tracing codes of the forest management logs.



Fig.29. Applying standard procedure for collecting NIR

After collecting the spectra of the logs, the sawing and processing of the logs into planks and boards (Figures 30 and 31) began. For each sawn log, three pieces (boards) were collected as samples of sawn wood, and NIR spectra were collected for each piece, considering the techniques of drying and cooling the wood on the surface of the collection. The longitudinal surface of each sample was cleaned using P80 sandpaper to obtain three diffuse reflectance spectra at different points of each sample. A total of 66 sawn cedar wood samples (planks and boards) were provided, and 540 spectra were collected.



Fig.30. Beginning of log sawing.



Fig.31. Cedar logs being sawn into planks and boards.

During the spectra collection, it was observed that the sample drying protocol being used was not efficient in reducing the moisture content of the wood. The moisture content remained in the range of 25-27%, while the ideal moisture content for collecting spectra is below 15%.

Therefore, the team, considering that they already had a comprehensive sampling of the wood from the 10 different trees and samples taken from the 22 logs, decided to use the last day in the field to carry out some tests related to the sample drying and cooling protocol to optimize the drying process and improve the collection protocol. As a result, an additional 60 spectra were obtained from four samples (boards) in nine different regions. Each region of the sample was analyzed in triplicate before and after the proposed drying, and different drying times (5, 8, 10, 15, 18, and 20 minutes) were tested. To better control the drying process, an improvised apparatus (a wooden box) was added to direct the heat flow better onto the sample surface (as shown in Figure 32).

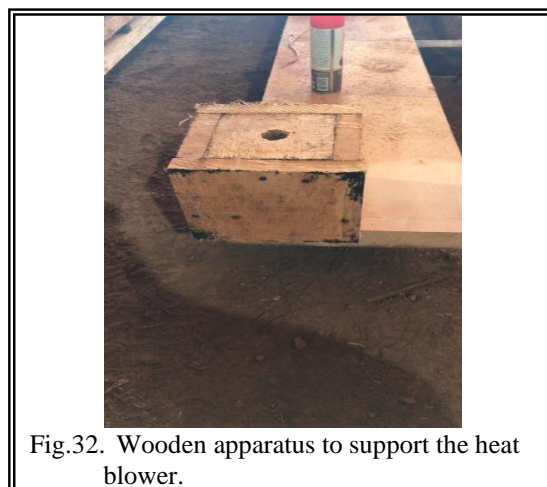
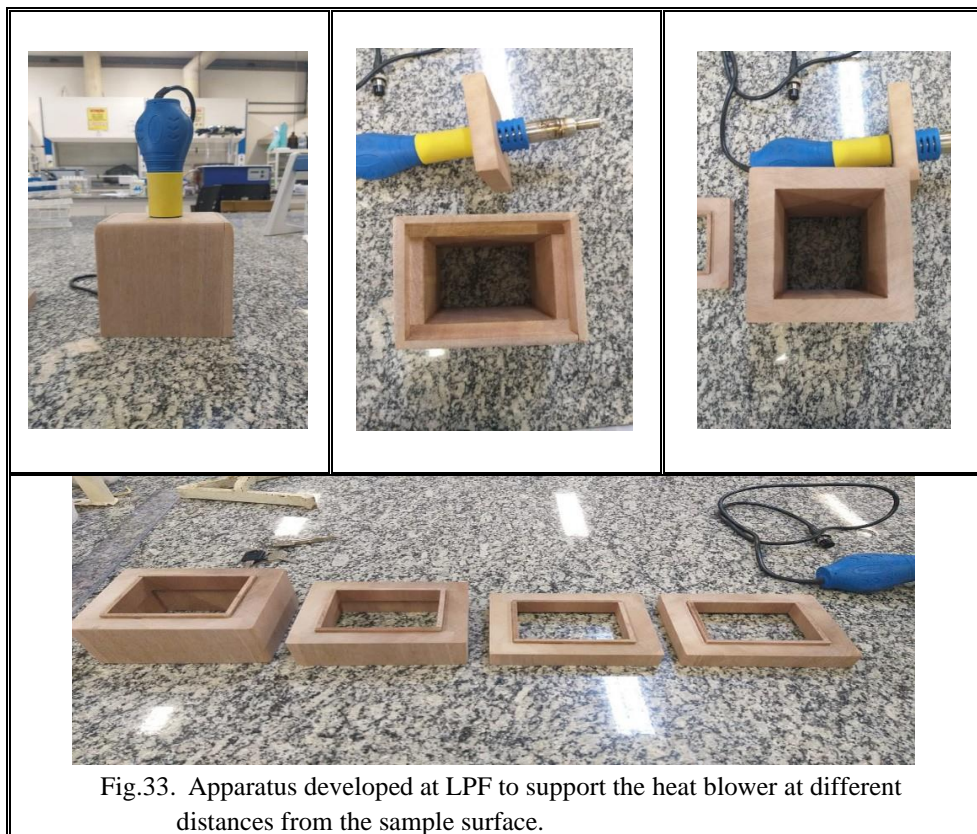


Fig.32. Wooden apparatus to support the heat blower.

After completing the fieldwork, the team returned to Porto Velho (RO) via the BR364 highway, a journey of approximately 120 km. The team then took flights to Brasília and São Paulo, but the wood samples could not be transported due to the lack of authorization from the competent authority, IBAMA. This requirement was made by the airline, AZUL, at the time of boarding. Thus, after the other team members boarded their flights, the coordinator went to the IBAMA Superintendence in Porto Velho to obtain the required authorization to transport the wood samples. With the authorization in hand, the coordinator returned to the airport, but the samples could no longer be shipped that day. Later, the cedar samples were sent to LPF/DF.

After the fieldwork team returned to Brasília (DF), two remote meetings were held on July 4 and 11 with the entire project team (Table 03) to present and discuss the results obtained from the spectra collection in the fieldwork at MADEFLONA. The results of this discussion showed that the last drying and cooling tests carried out by the fieldwork team indicate the need for adjustments and the inclusion of a new apparatus to the collection instruments, resulting in a new standard procedure for collecting spectra of wood in the field. This new apparatus, based on the wooden box (Figure 32) improvised in the last fieldwork, was improved in the carpentry workshop of LPF (Figure 33) and is ready to be tested in future fieldwork.



This new apparatus, based on the wooden box (Fig. 32) that was improvised in the last fieldwork, was improved at LPF's carpentry workshop (Fig. 33) and is ready to be tested in the next fieldwork.

3.4. Second collection of spectra at Madeflona company

The second fieldwork of the CITES S 608 project: “Identification of the origin and wood of mahogany and similars by NRIS technology”, at the Madeflona timber company, located in the municipality of Itapuã do Oeste, took place from August 07th to 11th, 2022. The team traveled by air from Brasília (DF) to Porto Velho (RO), and then by land to Itapuã do Oeste (RO), in a rented vehicle for this purpose. The objective of this fieldwork was to collect NIR spectra from seven commercial lots of sawn *Cedrela odorata* (cedar) wood, originating from the same batch of logs from ten trees measured in the previous trip.

It was necessary to make this second trip to Madeflora to verify the moisture range in which the commercial load of cedar wood was after natural drying in the company yard for approximately 45 days before being dispatched to the end consumer. Also, to verify if the constructed NIRS models remain valid under these new moisture conditions of the cedar wood cargo and to evaluate the efficiency of the new drying procedure, with hot air blowing followed by cooling.

The fieldwork was conducted by a team of three people: Paulo Jose Prudente de Fontes (fieldwork coordinator), Gabriel Calil (student/scholarship holder), and Anelisa Granato de Sousa (student/scholarship holder). Upon arrival at Madeflona, the team met with Engenheiro Evandro (co-owner) of the company to explain the objectives of this second fieldwork and request logistical support for the work. In the afternoon, a brief inspection of the seven lots of sawn cedar wood in the company yard was carried out to better plan the work and start collecting NIR spectra on the following day (Fig. 34 and 35).



Fig. 34. The 07 lots of sawn cedar wood, in the industry yard.



Fig. 35. Equipment for rapid drying being used on the wood sample.

For each of the 7 lots of sawn wood (boards), 3 pieces were collected as wood samples per lot and then the NIR spectrum collection protocols were performed, considering the wood drying and cooling techniques on the collection surface, with the cleaning of the longitudinal surface of each sample (using P80 sandpaper), to obtain three diffuse reflectance spectra at different points of each sample. 21 sawn cedar wood samples were made available, and 126 spectra were collected (Fig. 36 to 38).

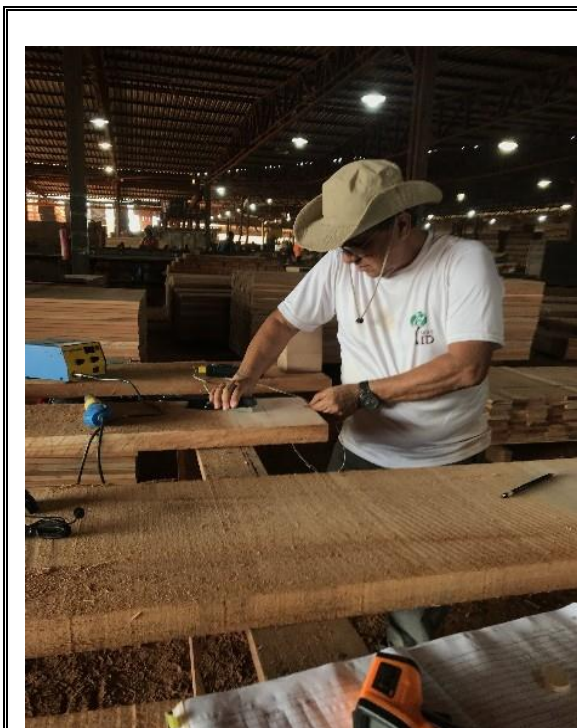


Fig. 36. Preparing the sample for rapid drying process.



Fig. 37. Rapid drying and cooling protocols being applied to the samples.



Fig. 38. Collection and reading of spectra using the NIR equipment.

On the last day of fieldwork, the team, considering they already had a comprehensive sampling (126 spectra collected), decided to use this last day of fieldwork to carry out a technical visit in the forestry exploration area of the company, located in the Jacundá National Forest, about 80 km from the company's industrial unit. Cutting areas, dragging and log yards were visited inside the forest.



Fig. 39. Log yard within the exploration area, in Flona Jacundá.

Fig. 40. Cut of a century-old faveira tree, in the management plan of Flona Jacundá.

4. EXECUTION OF NIRS SPECTRA COLLECTION WORK AT THE FINAL DESTINATION OF COMMERCIAL WOOD CARGO (export port or end consumer)

4.1. Collection of NIR spectra in mahogany (*Swietenia macrophylla* King) cargo at the port.

The field work for the collection of NIR spectra in the commercial mahogany cargo, which was supposed to have been sent by the company Agrocórtex do Acre to a port in the country for export, has not yet been possible. Unfortunately, the company has not yet obtained the CITES licenses from IBAMA for the sale and export of the wood. Therefore, we do not currently have the possibility of sending the project's field team to collect NIR spectra in the commercial mahogany cargo at a port, in order to complete our cycle of monitoring wood cargos using NIR technology.

4.2. Collection of NIR spectra in cedar (*Cedrela odorata*) cargo, end consumer.

Unlike what happened with the commercial mahogany wood cargo, the commercial cedar wood cargo was sold and sent by the company MADEFLONA from Itapuã do Oeste-RO to the buyer (end consumer), the company MADEIREIRO based in the city of Ubatuba, in the

state of São Paulo (SP). The wood traveled about 3 thousand kilometers to its final destination (Fig.41).

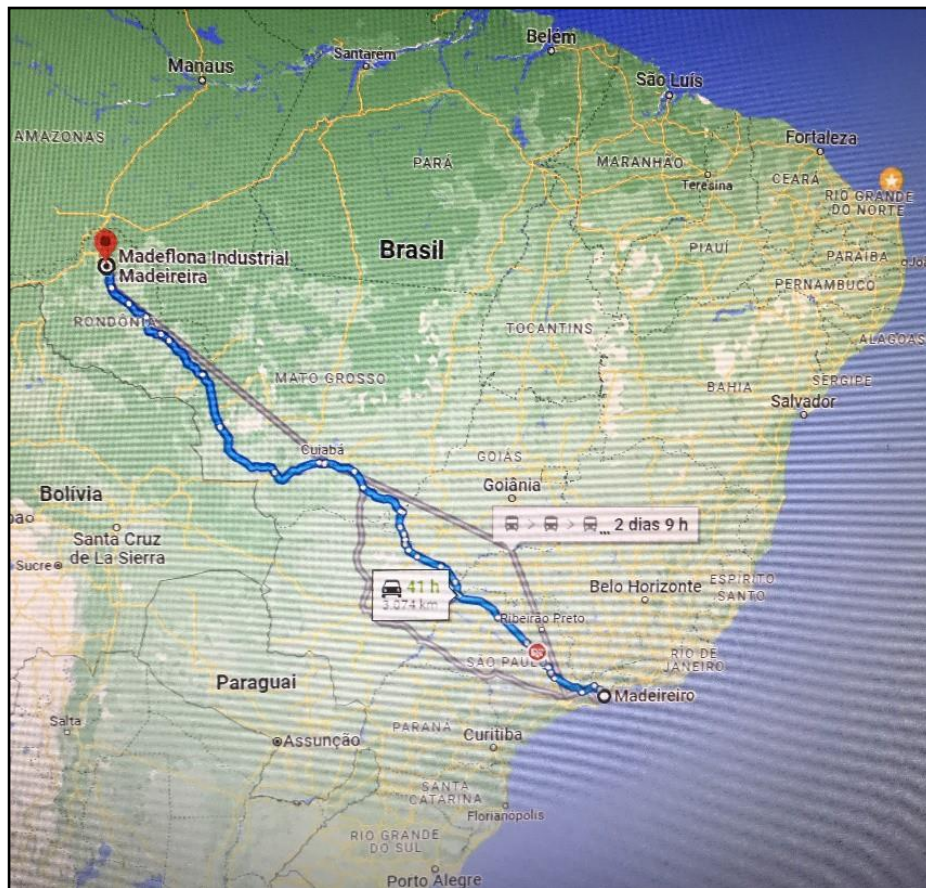


Fig. 41. Route taken by the shipment of cedar wood.

Therefore, the objective was to send part of the field team from the project "CITES S 608: Identification of the origin and wood of mahogany and similar by NRIS technology" to the facilities of the MADEIREIRO company in Ubatuba, in the state of São Paulo (SP), from August 31 to September 2, 2022, and collect NIR spectra in the commercial sawn cedar wood cargo, which had recently arrived from the Northern region, in order to obtain new NIR spectra and thus verify the practicality and efficiency of NIR technology in monitoring transported wood cargos. The experimental procedure was carried out where the wood cargo was located (Fig. 42 and 43), aiming to follow the wood from origin to destination, from end to end.



Fig. 42. Shipment of cedar wood sent by Madeflona company from Rondônia (RO).



Fig.43. Disassembling of the wood shipment to begin NIR spectra collection.



Fig.44. Cleaning the location for NIR spectra collection on the wood samples.



Fig. 45. Checking the collected NIR spectra on cedar wood samples in Ubatuba-SP.

For each of the 7 lots of cedar wood (boards), 3 pieces were collected as wood samples per lot, and then the protocols for collecting NIR spectra were performed, with the cleaning of the longitudinal surface of each sample (using P80 sandpaper) to obtain three diffuse reflectance spectra at different points of each sample (Fig. 44 and 45). In total, 126 spectra were collected. Table 04 shows a summary of all field work carried out, with dates, locations, sampled species, number of spectra collected, and participating team.

Table 04. Summary of field work carried out.

PERIOD	LOCATION	SPECIES	Nº. OF COLLECTED SPECTRA	PARTICIPATING TEAM
04/26 to 05/01/2022	AGROCÓRTEX – MADEIRAS DO ACRE Manoel Urbano - AC	Mahogany (<i>Swietenia macrophylla</i>)	489	- Paulo Jose Prudente de Fontes (Team Coordinator) - José Arlete Alves Camargos (Anatomist/identifier) - Daniele Cristina Kunze (Chemist/researcher) and - Hugo Rocha (Chemistry student)
06/02/2022	JB MADEIRAS Taguatinga – DF	Cedar (<i>Cedrela odorata</i>) Cedrinho (<i>Erismia uncinatum</i>) Curupixá (<i>Micropholis melinoniana</i>).	70	- Tereza Pastore (Project Coordinator/Researcher) - Jez Braga (Professor/ Researcher at UnB) - Paulo Jose Prudente de Fontes (Project Consultant) - Alexandre (Anatomist/identifier) - Hugo Rocha (Chemistry student) - Gabriel Calil (Chemistry student)
06/26 to 07/01/2022	MADEFLONA Itapuã do Oeste – RO	Cedar (<i>Cedrela odorata</i>)	540	- Paulo Jose Prudente de Fontes (Team Coordinator) - José Arlete Alves Camargos (Anatomist/identifier) - Daniele Cristina Kunze (Chemist/researcher) and - Hugo Rocha (Chemistry student) - Gabriel Calil (Chemistry student)
08/07 to 08/11/2022	MADEFLONA Itapuã do Oeste – RO	Cedar (<i>Cedrela odorata</i>)	126	- Paulo Jose Prudente de Fontes (Team Coordinator) - Gabriel Calil (Chemistry student /scholarship holder) - Anelisa G. Sousa (Chemistry student /scholarship holder).
08/31 to 09/02/2022	MADEIRO Ubatuba – SP	Cedar (<i>Cedrela odorata</i>)	126	- Paulo Jose Prudente de Fontes (Team Coordinator). - Daniele Cristina Kunze (Chemistry/researcher) and - Anelisa G. Sousa (Chemistry student /scholarship holder).

5. ACHIEVED RESULTS

5.1. Spectra collection in the Agrocórtex – Madeiras do Acre timber industry.

The collection of spectra in samples of mahogany (*Swietenia macrophylla*) was carried out on pieces of sawn wood, already conditioned in batches/packages for commercialization, as shown in Table 05. There were 03 batches totaling 336 pieces, of which 94 pieces were taken for samples and the collection carried out in 164 points, corresponding to 492 spectra, with and without the application of the sample drying protocol.

Table 05. Collecting the mahogany spectra at Agrocórtex sawmill (Acre).

Characteristics	Lot 100689	Lot 100691	Lot 098434	TOTAL
Number of pieces	96	110	130	336
Thickness of pieces (cm)	2,80	2,80	2,80	-
Length of pieces (m)	3,35	2,75	1,50	-
Nº of samples	25	25	44	94
Volume of lot (m ³)	2,26	1,85	1,03	5,14
Drying protocol	Sim	Não	Sim	-

5.2. Spectra collection at Madeflona sawmill (Rondônia).

The collection of NIR spectra in cedar wood (*Cedrela odorata*) was carried out from 22 logs from 10 different individuals (trees) of the species. This was a unique opportunity to start collecting spectra before the wood was processed, that is, before being sawn into planks and boards. As shown in Table 06, these 10 trees, when cut down, gave rise to a lot of 22 logs, with some trees providing up to 3 logs (identified with A, B, and C, according to their position in the tree trunk). Before the logs were processed, spectra were collected with and without the drying protocol.

It is important to note that high moisture content was expected in the logs, considering that they were practically freshly cut (1 month from cutting in the forest). As can be seen in Table 06, the moisture content of the logs ranged from 22% to 38%, and even after the application of the rapid drying protocol, it continued to vary from 21% to 33%, a maximum reduction of 5.0 percentage points. This was an excellent opportunity to test the rapid drying protocol in the field. In the case of the logs, it did not prove to be very effective.

Table 06. Collection of NIR spectra in cedar logs.

Number and Code of Trees	Position of logs in the trunk	Pre-drying collection		Post-drying collection	
		Moisture (%)	Temp. (°C)	Moisture (%)	Temp. (°C)
01 - 47949	A	30	8,0	33	22,0
	B	38	32,5	30	26,1
02 - 44881	A	22	25,7	22	22,9
	B	35	20,4	33	24,0
03 - 44791	A	38	14,0	33	25,0
04 - 47173	A	29	22,9	22	38,0
	B	35	30,0	29	24,8
05 - 43081	A	30	27,7	30	17,0
	B	31	23,6	21	23,2
06 - 42942	A	27	28,6	21	31,0
	B	30	22,2	25	22,6
	C	31	19,0	26	31,0
07 - 43456	A	25	24,9	30	21,6
	B	29	20,2	32	29,0
	C	29	16,6	21	29,7
08 - 55170	A	27	23,1	28	25,7
	B	33	25,3	27	21,0
	C	31	16,6	27	23,0
09 - 43633	A	27	28,8	28	22,3
	B	23	20,3	26	32,4
	C	23	27,0	23	18,6
10 - 47698	A	27	24,2	26	22,1

The field team accompanied the sawing of the 22 logs into planks and boards at the Madeflona sawmill. From each processed log, 3 samples of boards were taken and spectra were collected (readings) at two points on each sample, at the center and at the ends (C and P). Spectra were also collected before and after the application of the drying protocol. The cutting orientations (Radial or Tangential) in which each sample was processed were identified (Table 07).

The data presented in Table 07 also shows that the moisture content in the processed wood pieces (boards) still remained high, ranging from 24% to 33%, and even after the drying procedure, the decrease was not significant, ranging from 18% to 29%, considering that the ideal would be to stay below 15%. Therefore, the drying protocol, when applied to pieces with high moisture content, above 24%, was not effective.

Table 07. Collection of NIR spectra on sawn wood (boards) of cedar.

Number, Code and log position	Position of logs and boards	Pre-drying collection		Post-drying collection		Cut orientation
		Moisture (%)	Temperature (°C)	Moisture (%)	Temperature (°C)	
01-47949 B	1.1 C	31	24,4	28	28,8	100% R
	1.1 P	29	23,9	27	29,0	
	1.2 C	27	24,4	28	28,0	50% R
	1.2 P	28	24,6	22	28,7	
	1.3 C	27	25,5	25	29,0	80% R
	1.3 P	29	24,9	28	28,0	
02-44881 A	2.1 C	26	30,0	27	26,2	100% T
	2.1 P	24	26,3	27	25,0	
	2.2 C	33	27,0	29	27,3	90% T
	2.2 P	32	27,0	27	25,2	
	2.3 C	31	27,0	25	28,0	90% T
	2.3 P	31	25,0	28	26,2	
02-44881 B	3.1 C	29	25,2	26	25,5	Unoriented
	3.1 P	28	24,9	29	26,1	
	3.2 C	28	24,8	26	27,1	100% T
	3.2 P	29	24,3	23	28,1	
	3.3 C	31	24,4	18	27,8	100% T
	3.3 P	30	24,5	25	28,6	
03-44791 A	4.1 C	29	24,3	27	27,8	Unoriented
	4.1 P	29	24,0	28	25,5	
	4.2 C	28	25,3	25	28,3	Unoriented
	4.2 P	31	25,0	28	27,2	
	4.3 C	32	25,6	29	26,3	100% T
	4.3 P	28	25,3	29	26,8	
04-47173 B	5.1 C	28	26,1	26	28,9	100% T
	5.1 P	30	26,6	29	28,2	
	5.2 C	27	25,0	26	26,5	100% T
	5.2 P	28	27,0	27	28,9	
	5.3 C	28	27,0	27	27,2	100% T
	5.3 P	27	30,0	25	28,5	
05-43081 B	6.1 C	28	25,7	27	27,4	100% T
	6.1 P	29	26,3	25	27,0	
	6.2 C	26	26,3	25	27,4	100% T
	6.2 P	27	27,4	24	28,1	
	6.3 C	28	26,1	26	28,0	100% T
	6.3 P	27	25,8	27	24,3	
04-47173 A	7.1 C	30	27,0	27	25,2	70% T
	7.1 P	31	25,0	20	26,0	
	7.2 C	30	27,0	27	26,2	60% T
	7.2 P	30	25,0	25	26,0	
	7.3 C	31	28,0	24	26,8	100% T
	7.3 P	32	27,0	28	28,3	
06-42942	8.1 C	28	24,6	24	28,3	Center
	8.1 P	24	25,5	26	25,0	

B	8.2 C	29	24,8	25	24,6	90% T
	8.2 P	30	25,4	26	26,9	
	8.3 C	27	24,8	21	28,2	90% T
	8.3 P	27	25,5	26	25,5	
05-43081 A	9.1 C	28	25,6	23	28,7	100% T
	9.1 P	25	25,2	23	27,5	
	9.2 C	26	25,6	25	27,0	100% T
	9.2 P	27	25,5	22	27,5	
	9.3 C	24	26,1	24	26,1	100% T
	9.3 P	28	26,1	21	27,3	
06-42942 C	10.1 C	26	26,3	24	26,1	100% R
	10.1 P	25	26	24	27,5	
	10.2 C	33	27,9	26	26,1	90% T
	10.2 P	30	26,8	28	26,9	
	10.3 C	30	26,9	27	28,6	100% T
	10.3 P	25	26,2	21	27,7	
01-47949 A	11.1 C	29	25,5	26	28,8	100% T
	11.1 P	26	25,6	22	28,1	
	11.2 C	29	25,4	21	27,8	60% T
	11.2 P	26	24,8	23	28,5	
	11.3 C	30	26,2	26	27,7	100% T
	11.3 P	28	25,4	23	29,5	
07-43456 C	12.1 C	27	24,8	24	25,7	100% T
	12.1 P	25	26,2	21	28,8	
	12.2 C	27	25,4	26	26,5	70% T
	12.2 P	27	25,8	24	27,3	
	12.3 C	27	25,8	27	25,8	70% T
	12.3 P	26	25,5	26	28,6	
08-55170 B	14.1 C	28	26,3	21	27,5	100% T
	14.1 P	27	25,5	26	28,9	
	14.2 C	24	25,7	26	28,6	70% T
	14.2 P	27	25,5	27	28,3	
	14.3 C	28	26,2	26	26,7	100% T
	14.3 P	25	25,7	26	25,7	
09-43633 A	17.1 C	28	25,7	25	28,3	100% T
	17.1 P	30	25,4	27	26,2	
	17.2 C	30	26,3	28	29,3	100% T
	17.2 P	31	26,4	24	25,0	
	17.3 C	26	26,8	26	27,8	Unoriented
	17.3 P	28	28,2	23	28,3	
10-47698 A	20.1 C	27	26,6	24	27,0	100% T
	20.1 P	27	26,9	26	27,3	
	20.2 C	29	26,1	27	26	60% T
	20.2 P	27	26,6	27	24,4	
	20.3 C	28	26,3	26	23,9	100% T
	20.3 P	28	26,5	27	25,8	

This condition of wood with high moisture content is actually a very particular condition due to the fact that the pieces are freshly sawn. In general, we will not encounter this situation in everyday cargo transport. But it was interesting to know that the drying protocol needs further adjustments. In this sense, we took advantage of the last day at the company to perform some tests aimed at optimizing the drying protocol. We conducted tests varying the drying time from 5 to 20 minutes, starting from an initial moisture content of 27% and reaching 10% with a 20-minute drying time and a heat jet on the sample (Table 08).

Table 08. Drying tests.


Time (in minutes)	Sample moisture (%)	Temperature on sample (°C)
0	27	23,6
5	22	72,0
10	19	77,0
12	19	82,5
14	20	75,3
16	17	79,4
18	16	66,0
20	10	71,4


After these results, we included a wooden box to support the blower in the drying protocol (Fig. 32) and since this apparatus creates a closed environment for drying, we already had a more efficient drying with just 10 minutes, reaching 17%. The problem now is the cooling time of the sample until it reaches room temperature. In these tests, it took about 20 minutes of waiting. Subsequently, the model of the "little wooden box" (Fig. 33) was developed and improved in the carpentry of LPF/DF as a support for drying and became part of the apparatus for applying the new rapid drying procedure of samples.

5.3. New standard procedure for collecting NIR spectra in wood samples in fieldwork.

With the development of fieldwork and tests, some adjustments were necessary in the standard procedure for collecting NIR spectra, aiming to optimize the process of drying wood samples when necessary (Table 09).

Table 09. Standard procedure for collecting NIR spectra in wood samples in fieldwork

STAGES	PROCEDURES
<p>1. Sample preparation</p>	<p>1.1. Wood sample analyzed by a wood anatomist and identifier to confirm the species and cutting orientation. 1.2. Check if the surface of the sample is free of defects (cracks, splits, borers, fungi, etc.). 1.3. Sample should have a minimum size to cover the light beam of the device (minimum area of 1.5 x 1.5 cm). 1.4. The analyzed surface should be longitudinal (tangential or radial). 1.5. Sand the location where the spectra will be measured with n° 80 sandpaper, always in the direction of the wood fibers, and clean any sawdust with a brush. 1.6. Measure the initial moisture and temperature of the sample. 1.7. Record the humidity and ambient equilibrium temperature where the spectra are being collected.</p>
<p>2. Drying and cooling methodology of samples</p>	<p>2.1. Position the wooden support (box) for the YAXUN® 880D hot air blower nozzle on the surface of the sanded sample. 2.2. Turn on and adjust the blower to a temperature of 190°C, so that the hot air jet in contact with the sample is close to 105°C. 2.3. In open and hot environments, adjust the output temperature of the equipment to ensure that the sample temperature remains slightly above 100°C. This can be confirmed using a thermocouple, whose sensor should be positioned to touch the surface of the sample that receives the hot air jet, or an infrared thermometer. 2.4. Direct the hot air jet onto the sample for 10 minutes. 2.5. Monitor the temperature of the hot air jet under the surface of the sample, with a thermocouple or digital thermometer, to ensure that it does not exceed 105°C. 2.6. For rapid cooling of the sample, apply quick-drying spray (contact cleaner) jets to the collection surface of the spectra, at a distance of 5.0 cm, on the surface that received the hot air jet, until it reaches approximately 5°C (this temperature will be momentary and should quickly rise). 2.7. Position and direct the cold air jet onto the surface of the sample until the sample temperature is close to ambient. 2.8. Check the final temperature and moisture content of the sample. 2.9. Collect the NIR spectra readings with the MicroPHAZIR™ RX Analyzer (ThermoFisher Scientific™) equipment.</p>
<p>1. Turn on and calibrate the Microphazir equipment</p>	<p>1.1. Press the Power button to turn on/off the device . 1.2. Press the trigger to start the device. 1.3. Access the "Self Test" and press "Select". 1.4. Select the "Start Scan" option, wait for the device's lamp to warm up and the test to be performed. 1.5. The "Pass" message should be displayed. If it shows "Fail", check the battery level of the device. 1.6. Select the "Return to Main Screen" option.</p>
<p>2. Selection of the method and batch for spectra acquisition</p>	<p>2.1. In the main menu, select the "Tools" option and then select "Acquire Signatures". 2.2. Click on the "Method" option and select a method already saved on the equipment or create a new one by clicking "New". 2.3. Do the same for batch selection in the "Batch" option. 2.4. To start acquiring spectra, select the "Continue to Start Run".</p>

<p>3. Acquiring spectra</p>	<p>3.1. Position the sample to completely cover the beam output and press "Select" or trigger the equipment. A notice that the lamp is being turned on will appear.</p> <p>3.2. Next, a message that the background is being read and the spectrum of the first replicate will be acquired. If the spectrum is as expected, select "Select" to move to the next replicate. Otherwise, select "Esc" and repeat the reading.</p> <p>3.3. Slightly change the position of the sample and press "Select" or trigger the equipment to acquire the spectra of the next replicate. Again, if the spectrum shows any undesired variation, select "Esc" and repeat the reading.</p> <p>3.4. At the end of acquiring the spectra for all replicates of the sample, the equipment will return to the acquisition menu, awaiting a new sample with the name updated in "Sample".</p> <p>3.5. After reading all samples, select the "Esc" option to return to the main menu.</p> <p>3.6. In the main menu, select the "Logout" option and confirm by selecting "Yes".</p> <p>3.7. Press the Power On/Off button  until the "Powering Down" message appears. Wait until the screen turns off and the equipment will be properly turned off.</p>
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5.4. Collection of spectra at Madeireiro company (Ubatuba-SP).

For each of the 7 lots of pink cedar wood (boards) received by Madeireiro company in Ubatuba-SP, 3 pieces were collected as wood samples per lot. Then, the protocol for collecting NIR spectra was applied to these samples without using the rapid wood drying procedure. A total of 42 collections were performed, totaling 126 spectra, at ambient humidity.

For analysis and evaluation of the data, class analogy modeling (SIMCA) and discriminant analysis models (PLS-DA) developed within the project using NIR technology were used. The results were very promising and showed a compatibility rate, depending on the model used, ranging from 76.2% to 96.0%, validating the efficiency and practicality of the method for monitoring commercial wood loads.

6. FINAL CONCLUSIONS

The objective of this study was to trace commercial loads of mahogany and cedar wood from legal extraction areas in the Amazon region, under forest management plans, in private areas, in the case of mahogany in Manoel Urbano - AC, and under forest management plans in the Jamari National Forest, in the case of cedar in Itapuã do Oeste - RO, to an export port or final consumer.

In the case of mahogany, it was not possible to complete the cycle because the wood load has not yet reached its destination (export port). In the case of cedar, the wood reached its final destination in the city of Ubatuba-SP, in the southeast region of the country. This load of cedar wood, with a volume of 19.114 m³, traveled a distance of 3.074 km by land. At the final destination, new spectra were collected from the same load. Based on SIMCA and PLS-DA models for data evaluation, the presented results were promising, with a compatibility rate ranging from 76.2% to 96.0%, demonstrating the efficiency of the method and the practicality of the portable NIR instrument for monitoring and tracing wood loads in the field, validating the identification and origin of the species.

This final report on the field execution of the project seeks to show the development of the work carried out. Certainly, the results achieved in the project execution were very promising. Therefore, it can be said that the proposed objectives were achieved, and the main results are:

- ✓ Collection of 1,351 NIRS spectra performed in the field on four different wood species: Mahogany (*Swietenia macrophylla*); cedar (*Cedrela odorata*); Cedrinho (*Erisma uncinatum*) and Curupixá (*Micropholis melinoniana*);
- ✓ New Standard Operating Procedure (SOP) developed for wood sample collection in the field;
- ✓ Monitoring of a commercial load of 19,1124 m³ of cedar wood from its origin in Itapuã do Oeste - RO to the city of Ubatuba - SP, covering 3,074 km, crossing the country.

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