



PROJECT

RAPID-FIELD IDENTIFICATION OF *DALBERGIA* WOODS AND
ROSEWOOD OIL BY NIRS TECHNOLOGY

TECHNICAL NOTE

PANORAMA OF THE RESEARCH AND MARKET FOR *DALBERGIA* WOOD
IN BRAZIL: IMPLICATIONS ON THE PRESERVATION OF THE GENUS

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PANORAMA OF THE RESEARCH AND MARKET FOR *DALBERGIA* WOOD IN BRAZIL: IMPLICATIONS ON THE PRESERVATION OF THE GENUS

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Summary

The *Dalbergia* genus is a high-quality wood source, mainly for fine furniture, musical instruments, and sculptures. For that reason, it has been overexploited for hundreds of years in various regions of the world. Because of the significant number of species and difficulty distinguishing them from each other, in 2017, all the species, except *D. nigra*, were included in Cites Appendix II. In Brazil, two *Dalbergia* species are on the endangered flora list, *Dalbergia nigra* and *Dalbergia elegans*, both in the vulnerable (VU) category. *D. nigra* is one of the most worrying cases. The indiscriminate trade of *D. nigra* wood in the international market led in 1992 to the inclusion of the species in the most threatening degree, Cites Appendix I. These initiatives aim to preserve the species, but the control over the trade is very complex, and traffic continues to happen. The surveys carried out in this work indicate that the monitoring of wood trade, especially *D. nigra*, needs to be strengthened to understand supply and demand better. Also, it is crucial to improve silviculture research and development for this species to have a supply of quality wood from plantations in the medium and long-term. Over the past ten years, research on *Dalbergia* in Brazil has been focused mainly on studies about seed germination and seedling nutrition, in addition to genetics and diversity of natural populations. There are some initiatives for mixed-species plantations and agroforestry systems, in which *D. nigra* is always one of the promising species, but there are not yet mature plantings to evaluate the results. These plantations, based on prolonged scientific investigation, are of great importance for the species, and the expectation is that the future exploration and conservation of *D. nigra* may come from these plantations, coupled with public policies that promote gains from provided ecosystem services and more effective measures for enforcement mechanisms.

Key words

Dalbergia, *D. nigra*, wood, forestry market, tropical forestry.

***Dalbergia* at risk**

Over the past few decades, the genus *Dalbergia* sp. has been at risk from overexploitation. *D. nigra* is the most severe case (CITES Appendix I). Commonly known as Brazilian rosewood, *D. nigra* began to be extracted from the Atlantic Rainforest shortly after the arrival of the Portuguese in Brazil, around 1500, and continued intensely until the second half of the 20th century, with emphasis on the opening of the BR-101 Highway, which established a longitudinal axis along with the biome and increased the predatory exploitation of the vegetation (CASTRO, 2002).

The wood trade of *D. nigra* is still active, despite the international regulations fixed by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and the national regulations defined by the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA, 1992). The demand for musical instruments, sculptures, and small furniture drives a market for small pieces of reclaimed wood previously used in furniture and other instruments. This type of trade is not illegal since it is based on wood that was already processed before 1992, but monitoring it is quite complex. There is no guarantee that this supply of small samples will meet the demand, resulting in illegal logging. Such activities still happen, as verified by periodic seizures of *D. nigra* wood boards, veneers, and musical bows (G1, 2018). Also, a reasonable amount of that wood is exported, indicating that the CITES regulations alone cannot guarantee protection.

Currently, rosewood is the world's most trafficked natural commodity. In an investigative report for National Geographic, Guo (2019) warns of the situation in Guatemala, where illegal logging is decimating rosewood trees, which was verified by the apprehension of young individuals (DBH <40 cm). The primary demand is for the Chinese market, which has grown substantially since Asian rosewood stocks were exhausted. The trafficked volumes are significant; the estimated amounts for the smuggling of rosewood exceed 1 billion dollars. With this booming demand, illegal exploitation is now "worth" the risk.

The difficulty in differentiating species is another critical issue for the preservation of the genus. Timber of prohibited exploitation such as *D. nigra* was marketed under the names of other legalized ones, as *D spruceana*, for example. Identification requires rare specialists, specific protocols, and expensive equipment. Without a strict and rapid inspection, smugglers are even less afraid of the risk. The insertion of all species of the genus *Dalbergia* in the CITES list was found to alleviate the problem.

Initiatives to preserve the genus Dalbergia

The RAPID-FIELD IDENTIFICATION OF *DALBERGIA* WOODS AND ROSEWOOD OIL BY NIRS TECHNOLOGY project focuses on rapid identification and enforcement at the locality of the incursion, with the primary purpose of preserving the genus *Dalbergia* sp. and meeting the requirements for sustainable management and species conservation defined by CITES. To achieve this purpose and to complement the mentioned technological solutions, other actions are necessary. The demand for rosewood exists and will be extant. In addition to combating illegal trade, it is crucial to develop actions that meet this demand, whether by legally obtaining *Dalbergia* sp. wood or by indicating a substitute.

Therefore, it is necessary to learn the dynamics of the timber market of the genus *Dalbergia* sp.: who are the main actors (suppliers, buyers, beneficiaries, etc.), which species are most commercialized, and for what purposes (musical instruments, furniture, household utensils, sculptures, etc.), what is the demand (m³/year) and supply (m³/year). Another critical action is to analyze the physical-chemical and mechanical properties of wood intended for the production of musical instruments to understand which are the ideal characteristics for each group of instruments (wind, strings, and percussion) and thus be able to identify the wood species that meet these characteristics, substituting *Dalbergia* sp. Finally, it is necessary to learn the overview of tropical forestry. How developed is the plantation techniques with native species from the Atlantic Rainforest, what are the ongoing research for *Dalbergia* sp. germination, planting, and harvesting, where such research and developments in tropical forestry are happening, who are

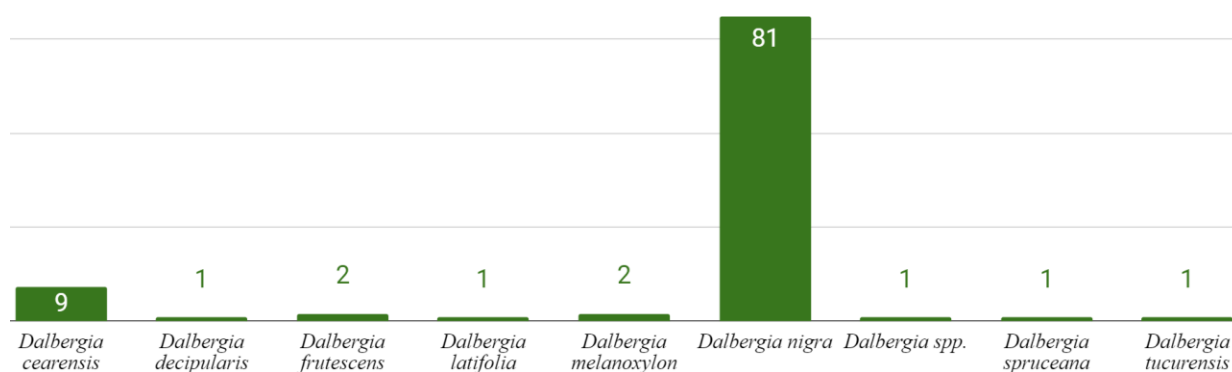
the researchers and what are the research centers and analysis of *Dalbergia* sp. originated from plantations.

Timber market of the genus Dalbergia

As it is an internationally protected genus, it is expected that the number of transactions and traded volumes will be reduced. The official numbers of the monitoring systems point to a few dozen transactions. For the monitoring of *Dalbergia* sp. supervision is done by the CITES database and, and in Brazil, by the Document of Forest Origin (DOF) managed by IBAMA.

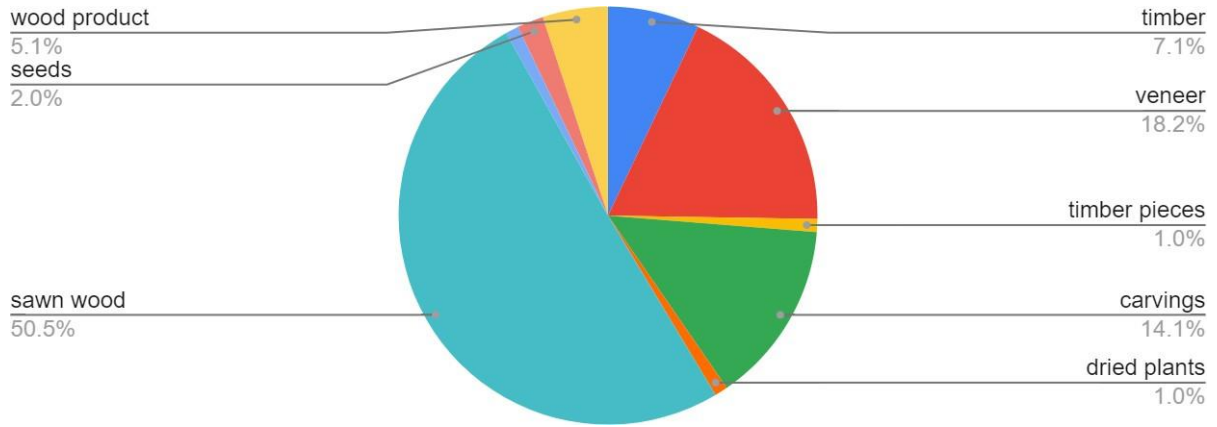
The CITES database compiles data on international trade in plant and animal products from all member countries. A survey carried out at the CITES database on the export of Brazilian *Dalbergia* sp. wood, from 1992 to 2019, returned 99 results. Most of them were represented by *Dalbergia nigra* (81%) among eight species (Figure 1).

Figure 1 - Occurrence of *Dalbergia* sp. exported from Brazil (1992-2019). Source: [CITES Trade Database](#).



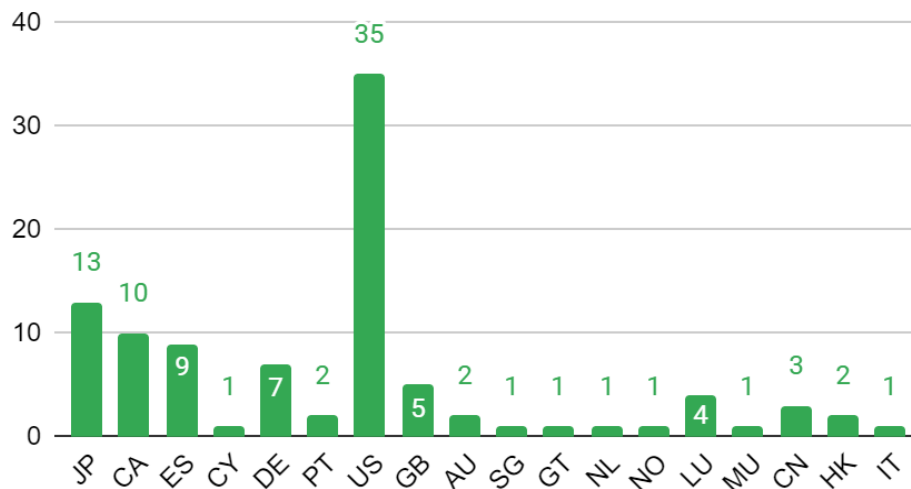
The most commercialized product is sawn wood (50%), followed by wood veneer (18%) of a total of nine types of products (Figure 2)

Figure 2 - Types of *Dalbergia* sp. wood products exported from Brazil (1992-2019). Source: [CITES Trade Database](#)



The most frequent destination for exports was the United States (35%), followed by Japan (13%) and Canada (10%), among a total of 18 destinations (figure 3). A peculiar fact is that China is in the 16th position, and the evidence pointed out by GUO (2019) indicates the country as one of the leading destinations for *Dalbergia* wood, probably illegally.

Figure 3 - Exports destinations of *Dalbergia* sp. wood products from Brazil (1992-2019). Source: [CITES Trade Database](#).



These transactions represent a total volume of approximately 30 m³. The value is approximate because many occurrences do not present the volume sold. For comparison, in the IBAMA operation carried out in 2018 in São Paulo, Espírito Santo and Minas Gerais, the seized volume was 83 m³ of *Dalbergia nigra* (G1, 2018).

For monitoring the national timber market of *Dalbergia* sp., DOF is the official system in Brazil. For comparison, in 2017 (last year available on the IBAMA website), the numbers are very different from CITES, mainly because they are domestic transactions, with only one exportation occurrence.

In the DOF system, there are seven species: *D. brasiliensis*, *D. cearensis*, *D. foliolosa*, *D. frutescens*, *D. miscolobium*, *D. nigra*, and *D. spruceana*. Figure 4 shows the relative occurrence of them. The most-traded species by the number of DOFs is *D. nigra* (30 DOFs issued), followed by *D. cearensis* (10 DOFs). However, in volume, *D. cearensis* surpasses *D. nigra*, with 75 m³ and 43 m³, respectively, out of a total of 155 m³. This difference is because most of the products of *D. nigra* are wood veneers (19 DOFs), therefore of reduced volume (0.12 m³).

Figure 4 - Relative occurrence of *Dalbergia* sp. commercialized in Brazil (2017). Source: [DOF](#).

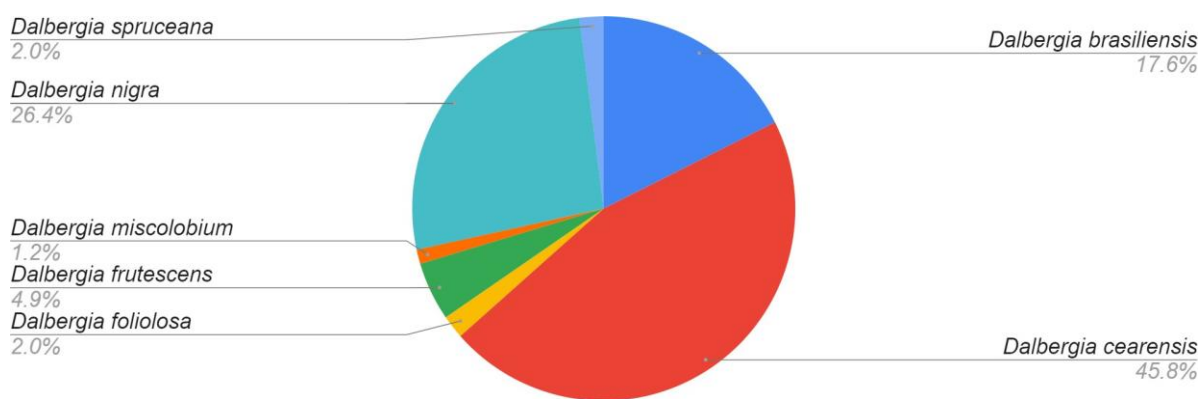


Figure 5 shows the occurrence of DOFs by product types (9) from the seven traded species. Most are for veneer (36%), but the first log processing products, called sawn wood, are more

representative if grouped. Plank (14%) is the main product of the sawn wood group. Logs (17%) are the highlight with a significant number of DOFs.

Figure 5 - Types of *Dalbergia* sp. wood products traded in Brazil (2017). Source: [DOE](#).



The large number of DOFs issued for knife-cut wood veneers explains the musical instrument market's importance, mainly for *D. nigra*. For logs, the DOFs issued refer mainly to the commercialization of *D. brasiliensis* (10 DOFs).

The origin and destination of *Dalbergia* sp. indicate regional concentrations. Considering *D. brasiliensis*, occurring in the south and southeast of Brazil (CARVALHO, 2004), the transactions were carried out in the same region. As for *D. cearensis*, endemic to the semi-arid region (NOGUEIRA et al., 2013), commercialization took place in the south, southeast, and northeast regions, especially in the state of Paraná. *D. nigra* was traded basically in its region of occurrence (southeast), with few cases of destination for the midwest region. The most representative state for the species is São Paulo, with emphasis on the municipality of Americana.

Trade values vary widely, even for transactions of the same type of product. *D. brasiliensis* was only sold as log in 2017, and the values vary between R\$ 0.10 and R\$ 300.00 (US\$ 0.02-US\$ 56, quoted in January 2021) per cubic meter. As there is no more information about the products beyond the type and species, it is impossible to understand the reasons for such discrepancy.

As previously mentioned, the products with the highest DOF emission were *D. nigra* veneers. The transaction values for these products vary between R\$ 151/m³ (US\$ 28/m³) and R\$ 710/m³ (US\$ 132/m³), an average of R\$ 410/m³ (US\$ 76/m³). In this case, too, there are no more details to infer the reasons for this variation. It also surprises this product's low value since it is known that the square meter of decorative wood veneers is sold at high prices.

Another option for analyzing the trade of *Dalbergia* sp. is by following general e-commerce platforms. In such search systems, it is possible to select products made of *Dalbergia* sp. wood. A survey was conducted on three well-known e-commerce platforms (one international: eBay and two national: OLX and Mercado Livre) with the term "*Dalbergia*" alone, and each site returned a few hundred results. There are furniture, household items, musical instruments, seeds, and wooden pieces. The analysis continued to be restricted only to the international platform (EBAY, 2020) due to the quality of its search system that returns specific results to the defined term, unlike the others that bring several results without any relation to the term.

On the international platform, among the various offers, *D. nigra* stands out with 44 occurrences. The offers refer to polyhedral pieces in suitable sizes for the production of musical instruments, especially guitars. Prices range from just over R\$ 100.00 (US\$ 19.00) for small pieces to more than R\$ 17,000.00 (US\$ 3,161.00) for larger pieces for guitars. A curious fact is that the origin of most offers is the United States (22). Figure 6 illustrates two extreme offers concerning the prices indicated.

Any inferences based on the results on these platforms are unreliable, as there is no certainty about the veracity of the provided information and the assurance of the indicated species. A more in-depth analysis could indicate a greater precision on how much of the offers reflect the reported species and, thus, a better understanding of the demand for this type of product would be possible.

Figure 6 - Results of two searches for the term *D. nigra* in an international e-commerce platform. Source: [ebay](#)



R\$ 104,91 (US\$ 19,51)



R\$ 17.264,46 (US\$ 3210,38)

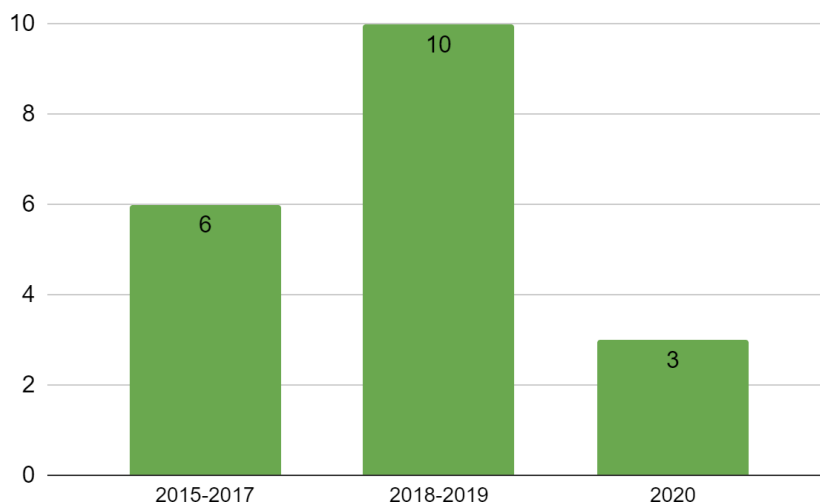
The precise knowledge about *Dalbergia* sp. market dynamics, especially *D. nigra*, is a potential indicator of how much such a market may be served by illegal wood because forest exploitation for this species is forbidden. There is no illegal forest exploitation if there are no buyers interested in the other end of the chain. However, there is not enough information to know whether such a market is stable, growing, or decreasing.

Seizures of Dalbergia wood

Considering that there is an established market, the offer can (or should) cause illegal exploitation. This situation is happening in Guatemala, according to an investigation by Guo (2019) presented earlier. It is also occurring in Brazil, as verified by apprehensions carried out by IBAMA. Analyzing the seizures results, it is evident that *Dalbergia* wood continues to be illegally traded, mainly for export attempts. Figure 7 shows the number of seizures carried out between 2015 and 2020. Of 19 apprehensions, most of them took place in São Paulo, at Guarulhos international airport, with only two cases in Minas Gerais and one in Espírito Santo. The seized materials were mainly pieces of sawn wood (175 pieces), in addition to seeds and

utensils such as statues and bowls (CGU, 2020). Almost all seizures were of *D. nigra*, only one case of *D. cearensis*.

Figure 7 - Seizures of *Dalbergia* wood carried out by IBAMA



The frequency and volume of *Dalbergia* wood seized denote an active clandestine market. The seizures likely represent very little compared to the actual values that are being traded illegally. Most seizures result from denouncement or inspection at the end of the chain, such as those carried out at airports. When seizures are not supported by society or carried out in a centralized manner, the harvested and illegally traded timber inspection becomes very difficult.

Therefore, to meet the demand legally, the sector needs to offer sufficient volumes of wood, whether from *Dalbergia* or other species with similar properties, to please the needs of the musical instruments manufacturers, the furniture producers, or any other use in which the *Dalbergia* wood stands out. Research and development must provide information and technologie to identify substitute species and implement competitive commercial plantations on time.

Research on the genus Dalbergia

Obtaining high added-value wood that does not come from extractivism in natural forests is still incipient for most forest species. The growing conditions in natural forests, which generate high-quality wood specimens, are challenging to reproduce in plantations.

Research and development for tropical wood have been developed for some decades and have shown very significant results. One example is *Eucalyptus*, an exotic tropical genus adapted to Brazil's edaphoclimatic conditions (mainly Midwest and Southeast), with yields much higher than in its original continent, Oceania.

Perhaps Brazilian forest science has been intensely focusing on exotic species (eucalyptus and pine) at the expense of driving the research on native species. This statement is based on the fact that there are few plantations with native species, in general rubber (for rubber production), paricá, and araucaria, adding up to just over 500 thousand hectares (in addition to little information available) compared to the area of more than seven million hectares planted with eucalyptus and pines (IBÁ, 2019).

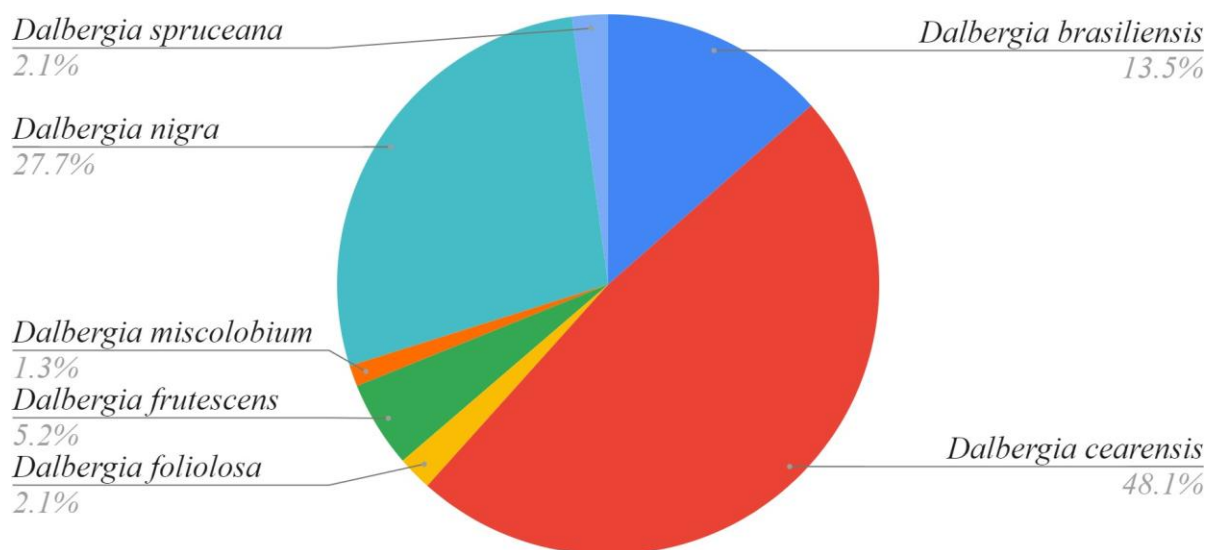
However, several Brazilian species have high added-value potential, being used in the recovery of degraded areas or the restoration of legal reserves, with a perspective of exploitation in the future (for areas subject to exploitation). One example is the *Dalbergia* species, specifically *D. nigra*, which commercial value was previously informed in this study.

A systematic bibliometric analysis made on Google Scholar presents some peculiarities of research and development on the *Dalbergia* genus over the years. To this end, we considered only the last ten years. A search for the term "dalbergia" alone returns approximately 17,300 results. When related to the term "brazil," the results decrease to approximately 7,300 (~ 42%). Adding the term "nigra" (dalbergia + brazil + nigra), approximately 2,450 results are obtained, equivalent to about 14% of the research produced for the genus in the mentioned period and 33% of the research in Brazil.

For comparison, the same research was carried out with the following most transported species in the country according to the 2017 DOF report. *D. nigra* continued to be the highest result,

followed by *D. brasiliensis* (~ 2,200), from *D. miscolobium* (~ 1,010), *D. frutescens* (949), *D. foliolosa* (666), *D. cearensis* (619) and *D. spruceana* (203). Figure 8 shows the relative results.

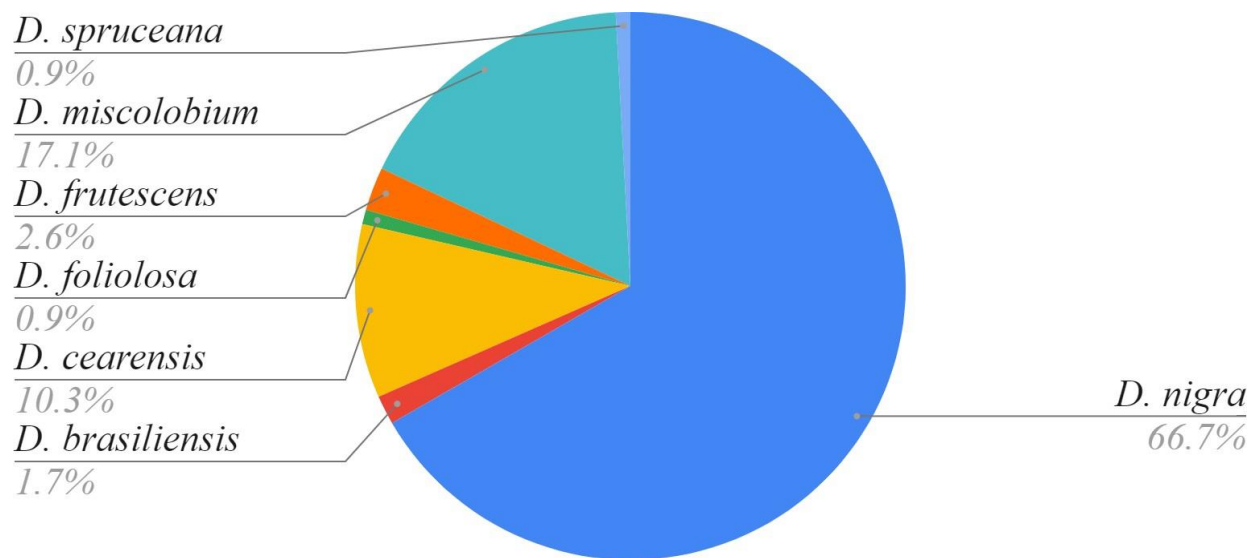
Figure 8 - Most studied *Dalbergia* species in Brazil according to those highlighted in the DOF 2017 report. Source: Google scholar.



The search focused on the terms presented in the articles' titles, returning a result even more favorable to *D. nigra*: we found 78 publications in the last ten years. For the other species present in the DOF report, the result was: *D. miscolobium* (20), *D. cearensis* (12), *D. frutescens* (3), *D. brasiliensis* (2), *D. foliolosa* (1), and *D. spruceana* (1). Figure 9 shows the relative results.

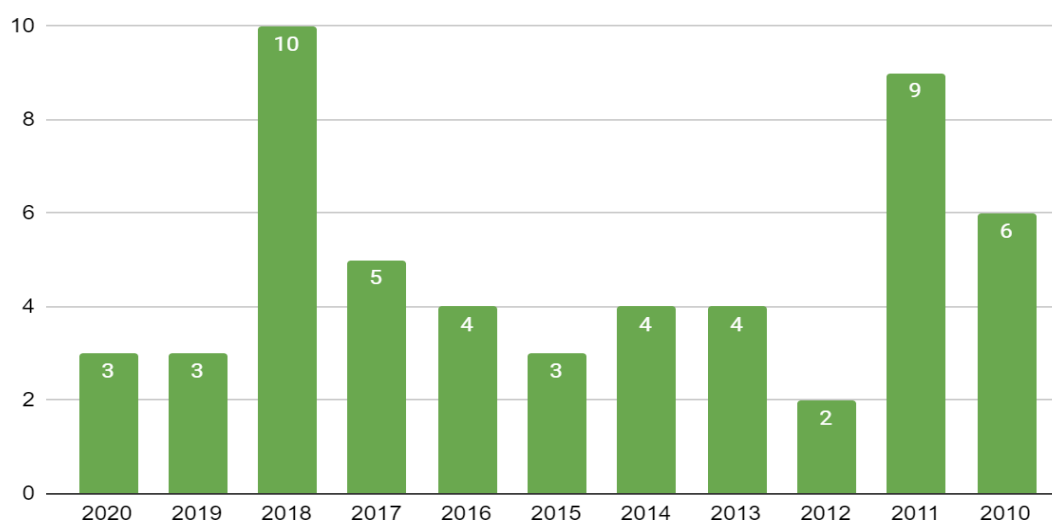
Due to the expressive results of *D. nigra*, the analysis continued to focus on this species. The results of the types of research conducted with *D. nigra* are presented below.

Figure 9 - *Dalbergia* species most studied in Brazil (in the title of the publication) according to those indicated in the DOF 2017 report. Source: Google scholar.



To this end, we analyzed publications made in Brazil with the compound term "*Dalbergia nigra*" in the title of the publication, from 2010 to 2020. Figure 10 illustrates the distribution of publications over the mentioned period.

Figure 10 – Publications about *Dalbergia nigra* from 2010 to 2020.

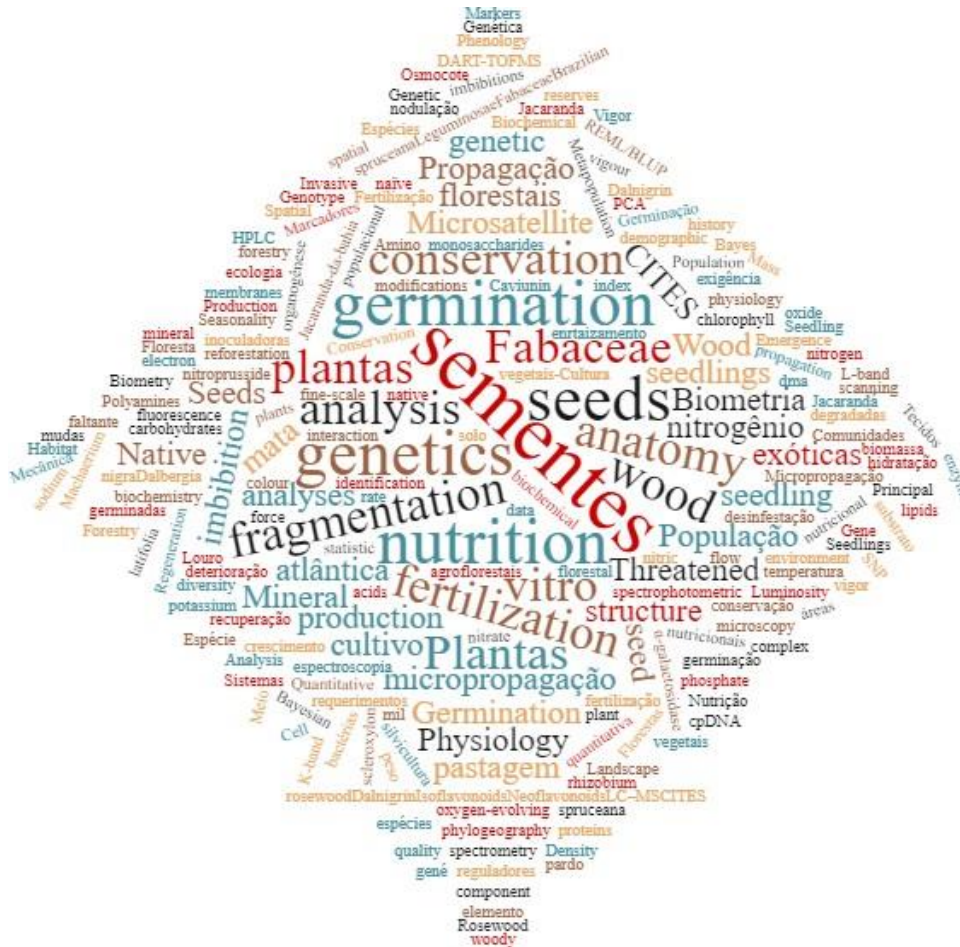


Among the 78 publications returned from the survey, 53 were considered valid for analysis since some documents appeared twice (same document returned in Portuguese and English). Among the remaining 53, keywords were analyzed to identify the main topics addressed in the surveys. Some keywords were removed because they indicate the analysis's primary object (*dalbergia*, *nigra*, *jacarandá*, *jacarandá-da-bahia*, *Brazil*, *Brazil*), therefore common to all documents. A total of 200 keywords were used to analyze the themes. Therefore, the larger the word in the picture, the more often it appears in the selected group. There are some cases in which the same word occurred several times but was presented differently (starting with uppercase and lowercase, in Portuguese and English, etc.). The word cloud is shown in figure 11.

The word cloud brings some characteristics of the research on *D. nigra* in Brazil in the last ten years. The most frequent words are germination, genetics, seeds, nutrition, fragmentation, and conservation. Therefore, most research deals with obtaining seedlings, their genetic characteristics, the nutritional demands of seedlings, and the effects on native populations, caused by changes in natural habitats.

The germination and seed studies are logically coincident. They represent most of the research conducted in the period in question. There are 22 publications (42%) that deal with the subject in several aspects, such as the influence of fruits and substrate harvesting and processing conditions (REGNIER, 2019) and in-vitro germination needs (SANTOS et al., 2019; SANTOS et al., 2010; MALAQUIAS et al., 2017; CANTO, 2011), the effects of hydration (ATAÍDE et al., 2016; ATAÍDE et al., 2013, CARRIJO et al., 2011), storage (ATAÍDE et al., 2016; AGUIAR et al., 2010), temperature (MATOS et al., 2015; MATOS et al., 2014; ATAÍDE et al., 2013), vigor (ATAÍDE et al., 2015; GUEDES et al., 2011), the effect of sugars (RIOS et al., 2015), seed deterioration (SISTON, 2013) and population ecology (COSTA, 2011).

Figure 11 - Word cloud with the occurrence of keywords in publications with *Dalbergia nigra* in the title. Source: Google scholar + [Wordcloud](#).



The second most recurrent theme was genetics, with nine publications (17%). Genetics was addressed with clonal mini-gardens (SANTOS et al., 2019), interactions with the environment (SANTOS et al., 2018), regeneration of secondary forests (LEITE et al., 2014), seed deterioration (SISTON, 2013), diversity in primary forests (BUZATTI et al., 2012, BARRETO, 2010), phylogeographic structure (RIBEIRO et al., 2011) and connectivity between populations (RESENDE et al., 2011).

Another prominent topic was nutrition, appearing in seven publications (13%). The theme appeared in conjunction with propagation (SANTOS et al., 2020), clonal mini-garden (SANTOS

et al., 2019), seedling quality (CARLOS et al., 2018), phosphorus (MAIA, 2018), nitrogen (VALLE, 2018), NPK (GONÇALVES et al., 2014), calcium, magnesium, and sulfur (GONÇALVES et al., 2014), potassium (REIS et al., 2012) and nutritional requirements (FARIAS et al., 2010).

The other most recurrent themes - fragmentation and conservation - coincide with the references already presented, mainly with the results of genetics. Some understandings emerge from this analysis:

- Studies on germination have been constant over the proposed period. Such condition denotes an advance in the understanding of obtaining quality seedlings in different situations;
- Genetic evaluation has been used repeatedly to understand the behavior of *D. nigra* populations in natural areas. This approach helps to identify the conditions in which trees fully develop;
- The nutritional demand for seedlings has been studied for various elements and conditions. The results of these surveys support the development of more vigorous seedlings.

However, these results also point to a critical issue regarding the purpose of this project. During the period under analysis, there was little research focused on developing silvicultural systems that include *D. nigra*. To achieve the objective of conserving the genus *Dalbergia*, especially *D. nigra*, it is necessary to know the technical and economic viability of tropical forestry.

***Panorama D. nigra* tropical forestry**

Tropical forestry is not new in Brazil. There are reports of research being carried out since the 1930s, especially in Paraná with *Araucaria angustifolia* (ROLIM & PIOTTO, 2018). The authors report a history of experiments carried out in the country, during the second half of the 20th century, with several native species, in most cases in monocultures. There are few experiments with more than two species intercropped for timber purposes. However, in the

northern region of Espírito Santo (Linhares), there is the Vale Natural Reserve (RNV), where around 700 ha have been used to conduct experiments with mixed plantings since the 1970s totaling almost 100 species of the Atlantic Rainforest. Plantations are monitored annually and biannually for some species after 20 years of age.

D. nigra is one of the species evaluated in these experiments. After 35 years, in a mixed plantation with *Paratecoma peroba* and *Zeyheria tuberculosa* with 1.5x1.5 m spacing, it reached a Diameter at Breast Height (DBH) of 30.5 cm, with an Mean Annual Increment (MAI) of 0.87 cm/year (ROLLIM et al., 2018). Among 35 species analyzed, *D. nigra* is the 11th in MAI. The authors highlighted its performance; even though it is a shade-tolerant species, it developed well in full sun and thinning. Planting started with 1,667 trees/ha and ended after 35 years with 438 trees/ha. Despite the promising numbers reported, the species heartwood takes a long time to form; therefore, the harvest is indicated after 50 years, when the planting density will be around 350 trees/ha. At the end of 35 years, there is an expectation of approximately 250 m³/ha.

A project entitled Economic Valuation of Reforestation with Native Species (VERENA), under the coordination of the World Resources Institute (WRI) together with several other institutions, was carried out with the greater purpose of making plantations with Brazilian species viable (BATISTA et al., 2017). The project evaluated 12 reforestation initiatives in consolidated monoculture, reforestation with multiple species, and agroforestry systems. Among these three models, probably the most challenging is reforestation with multiple species. Driving several forest species with different growth rates, cutting cycles, and edaphoclimatic requirements is quite complex, with long-term results.

Two of these initiatives include the planting of *D. nigra*. One of them is developed by the SYMBIOSIS company in the south of Bahia. There are 26 planted species divided into accessory species (cut up to 18 years old) and target species (cut up to 30 years old). Consortia go up to six species per plot with thinning and enrichment activities. *D. nigra* is among the 20 target species. The other initiative is from SUCUPIRA Agroflorestas, also in southern Bahia. The company develops a successional agroforestry system combined with 18 productive species and two

fertilizer species. *D. nigra* is one of the productive species planted (BATISTA, 2018). Figures 12 and 13 illustrate both companies' plantation programs.

Figure 12 - Aerial image of mixed-species plantations in southern Bahia. Source: [Symbiosis](#)



Figure 13 - Example of successional agroforestry with a consortium of fertilizer (banana) and productive (trees) species. Source: [Sucupira](#).



In both cases, there are still no results available on the success of the activities and the analysis of the development of *D. nigra* trees. However, Batista (2018) states that the profitability of silviculture with native species is proven, and the natural capital return and investment in R&D increase its competitiveness. The potential sale of carbon credits can increase up to 2% of the Internal Rate of Return (IRR). The return on investment in R&D can increase the IRR by another 5%.

There are encouraging projections for a subject that still faces more difficulties than traditional silvicultural systems that deal with monocultures with exotic species. The scalability challenge has yet to be met. The most extensive plans do not reach 10,000 hectares in the VERENA project, with silviculture with mixed-species covering 1,500 hectares and the successive agroforestry covering 45 hectares.

On the other hand, smaller plantations, intercropped, and biodiversity systems present themselves as a good alternative for small producers, both as an income supplement or as the main activity. The research returns a few hundred works being carried out with *D. nigra* intercropped in agroforestry systems. Nevertheless, there is no evidence of any economic return with wood in these analyzes, other than such encouraging projections. As indicated by the studies at RNV, the wood reaches a satisfactory condition for harvesting (heartwood formation) 50 years after planting. Besides the research carried out in this reserve, there was no evidence of plantations analyzed at this or older age.

Potential implications for the preservation of Dalbergia

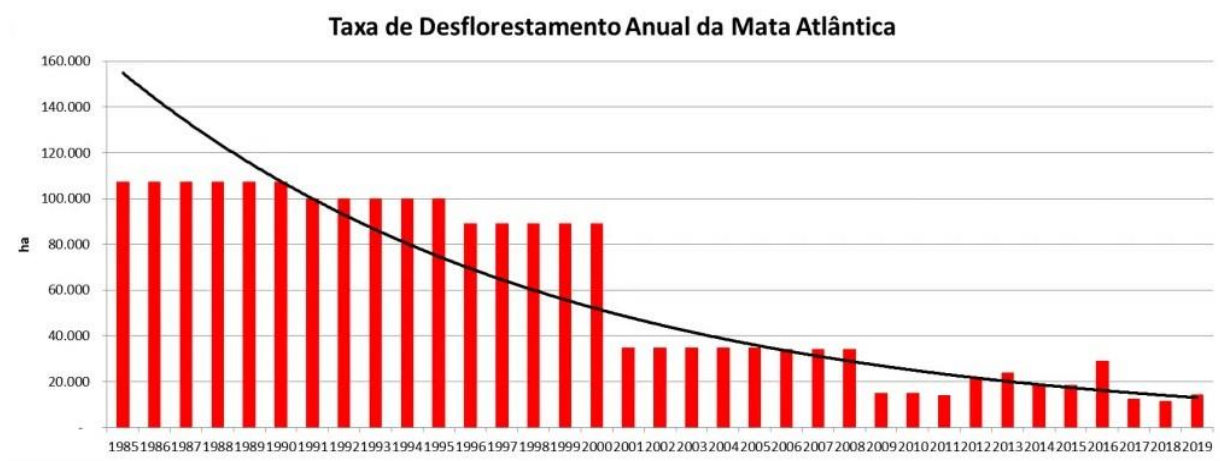
The difficulty in monitoring the commercialization of timber from *Dalbergia* species and the inspection of the protection of natural populations, especially *D. nigra*, results in a significant challenge for the preservation of the genus. Although there are several restrictions, commercial transactions continue to occur without the assurance that only wood harvested in the period before the restrictions are being handled.

In this sense, the command and control policies must be more effective, combined with awareness policies such as environmental education programs and R&D promotion. Every

supply and demand for *D. nigra* wood should be traceable, and its actors identified. The trade of these woods must be previously authorized and qualified to promote a mapping that identifies the stakeholders of this chain and the potential volume of wood demanded, offered, immobilized, and suitable for negotiation. In a way, this control is already done.

D. nigra is also on the red list of species threatened with extinction by the National Center for the Conservation of Flora - CNCFlora. Red Book of the Brazilian Flora (MARTINELLI and MORAES, 2013) also resulted in Ordinance MMA No. 443, of December 17, 2014, referring to the official list of flora species threatened with extinction (ICMBIO, 2014). The book considers *D. nigra* as vulnerable, a rare species in primary forests, with a loss estimate of approximately 30% and a projected loss of another 30% if there is no strict control of its habitat's size and quality. Such an analysis was carried out in 2013, deforestation in the Atlantic Rainforest has decreased, as can be seen in figure 14 (SOS Mata Atlântica, 2020), although unevenly in the states where the biome occurs.

Figure 14 - History of annual deforestation in the Atlantic Rainforest biome. Source: [SOS Mata Atlântica](#).



Few studies monitor the effects of deforestation on *D. nigra* populations. Such populations should be monitored continuously, through Long-Term Ecological Research (LTER), as is the case of research conducted by the Federal University of Minas Gerais in the Médio Rio Doce (UFMG, 2008). Botanical diversity was one of the themes of this research and evaluated the

effects of deforestation and the implantation of eucalyptus monocultures in the region on some species genetic diversity, among them *D. nigra*.

Another important initiative that can significantly increase the recovery of native vegetation in the biome is the Payments for Ecosystem Services (PES), also known as payments for environmental services (or benefits). They are incentives offered to those who promote ecosystem services or recover natural areas for this purpose. Brazil is advancing in this direction by processing the National Policy of Payments for Environmental Services (PNPSA) recently approved in the Federal Senate (BRASIL, 2020). The Atlantic Rainforest is the main target in this process due to its high degree of degradation and for the organization of the various sectors in this regard. An example of this is the Conexão Mata Atlântica project, which already pays small rural producers and, in its second call, will encourage 137 more producers to provide revitalization and forest restoration services, totaling another 778 hectares (INEA, 2020). For *D. nigra*, there is excellent potential since carbon sequestration is considered a profitable environmental service (climate regulation).

Next steps for the preservation of Dalbergia

The preservation of *Dalbergia* species remains a significant challenge. The commercialization of wood, mainly from *D. nigra*, continues to happen despite the impossibility of the entry of "new" wood into the market. Seizures continue to occur, indicating that the demand exists. The official monitoring data on wood transactions for this species indicates the type of wood product that induces it but does not give the actual dimension on the market dynamics: whether it is growing, decreasing, or stable.

Research on the genus and its "main" species in Brazil is focused on the initial stages of silviculture (germination, seedling nutrition) and natural populations' ecological conditions. There is little research dedicated to understanding the dynamics of planting for commercial purposes to provide the market with quality wood from legal activities. Therefore, there is a gap between the market and research, making it impossible in the short/medium term to provide enough volumes to meet the needs and to reduce illegal exploitation.

Plantations in biodiverse systems indicate reasonable projections and can continue their activities as they allow the generation of income in a few years (multiple wood species) or months (SAF), without relying exclusively on the wood of slow-growing species. Nevertheless, there is still no guarantee that even after decades, the wood will have the desired characteristics (heartwood) to be offered in place of native "competitors".

In Brazil, there is a great deal of natural vegetation, especially in the Atlantic Rainforest. Plantations to recover legal reserves, environmental compensation, and payments for ecosystem services, among other legal enforcement mechanisms in areas subject to future harvest, have the potential to generate data and information necessary to understand the ideal conditions for obtaining high-quality planted wood. Research on tropical forestry systems, especially with *Dalbergia* species, needs to move fast, at the risk of being overtaken by the illegal market, avid for wood at any cost.

Dalbergia nigra has been on CITES Appendix I for almost three decades. In so many years, very little has been done to get it out of this condition. Perhaps its situation is worse off now compared to when it entered the list. We must act now to change this situation. The opportunities and challenges were analyzed in this research. The next steps must be taken.

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