Malagasy Precious Hardwoods

Scientific and technical assessment to meet CITES objectives

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Cover Photo: Rosewood logs stockpiled along the Onive/Ankavanana River that empties out at Ambohitralanana south of Antalaha/east of Maroantsetra. Photo courtesy of Annah Peterson, 2010.

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1. INTRODUCTION

Over the last 20 years, illegal logging of precious woods, which includes rosewood and ebony tree species, has emerged as a recurrent issue in Madagascar, severely threatening Madagascar's ecosystems and unique biodiversity – an irreplaceable public good. In addition to severely impacting pristine ecosystems, such as a World Heritage Site (the Atsinanana Forest, in the past rich in *Dalbergia* and *Diospyros* tree species, was listed as a UNESCO endangered heritage site in July 2010), and plundering natural resources, in particular rare endemic species, illegal logging also deprives the country of important taxable revenues that a sustainable timber industry could generate and economic assets that could serve as the basis for future economic development in the country.

The inability of the government to curb illegal exploitation and trade, particularly in the aftermath of the 2009 political crisis, has led to the listing of the genera of *Dalbergia* and *Diospyros* in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), and the establishment of an Action Plan to facilitate the implementation of the listing.

This report, prepared by the World Resources Institute and the World Bank, in collaboration with ETH Zurich, the Missouri Botanical Garden, the Madagascar CITES Scientific Authority, and the University of Antananarivo, with financial support from the Program on Forests (PROFOR), aims to inform the implementation of the scientific and science-based work envisaged under the CITES Action Plan, along with priority activities that were identified by the Government of Madagascar. While some progress has been made in terms of other issues in the Action Plan, namely on stockpile management, enforcement and reporting, the scientific agenda remains largely unaccomplished. This shortfall runs the risk of becoming a constraint going forward since the capacity to identify species correctly and monitor their status in the field is a key factor for enforcement and for understanding whether or not sustainable exploitation and trade in Madagascar's precious wood species is possible.

The assessment presented in this report, which constitutes the first systematic effort in this direction, is based on a careful review of all available information along with input from recognized experts on the genera *Dalbergia* and *Diospyros*. Specifically, the assessment focuses on: 1) geographic range and population status of precious timber species of *Dalbergia* and *Diospyros* species; 2) species identification (ID) technologies; 3) silvicultural potential for regeneration of those species; and 4) private sector potential for developing a value chain for the sustainable exploitation of precious timbers. For each of these areas of inquiry, the assessment identifies at the end of the report: a) the physical/equipment infrastructure acquisition and maintenance requirements and costs; b) capacity building and training needs with respect to human resources; and c) promising options for international technical cooperation and donor financial assistance for implementing a capacity building program. The intended audience for this report includes the Government of Madagascar, the donor community, and international and national non-government organizations engaged in the management of the precious woods crisis and that would be in a position to implement the recommended activities.

Why are scientific and technical capacity essential to the sustainable management of precious hardwoods in Madagascar?

In the short-term, scientific and technical tools can provide a credible basis for enforcement of both Malagasy and international laws (e.g., the Lacey Act, CITES) that govern trade in precious hardwoods. Effective enforcement of the current export ban on *Dalbergia* and *Diospyros* spp. implies: a) preventing the illegal exploitation of standing stock; b) seizure of illegally harvested stock and taking appropriate actions to dispose of and/or manage the illegal stock; and c) implementation of penalties and sanctions for parties supporting the harvesting, transport, sale and export of illegally exploited stock.

The development of tools that could provide accurate identification of these species would enable scientists to offer training on identification methods to enforcement bodies and forest agents and to work more closely with them in the field. Accurate field identification could prevent illegal harvesting and export of precious woods, while also decreasing unnecessary costs for legal business activity.

In the medium and long-term, these tools can enable the reliable identification necessary for sustainable management of precious woods. Improved identification of *Dalbergia* and *Diospyros* species is an essential precursor to completing a study on non-detriment findings[1] for exploitable species in the two genera for CITES. Assuming that further scientific research provides the support for the development of sustainable exploitation and trade, providing accurate species identification of *Dalbergia* and *Diospyros* species has the potential to increase the trade value of exported species, promote innovative silvicultural approaches for regeneration and conservation, and support new, profitable industries within Madagascar.

Structure of the report

The report is organized as follows. Section 2 describes the international and national context and background on *Dalbergia* and *Diospyros*. It starts by presenting general facts about the ecology, general uses and trade of these hardwood species. The section also takes stock of the sector in Madagascar and the sequence of events that has led to the CITES Appendix II listings. Section 3 provides an assessment of the current scientific and technical capacity to identify and manage *Dalbergia* and *Diospyros* species from Madagascar. This section starts by describing the geographic range and population status of these two genera, drawing attention to the important

[1] "Non-detriment findings" refers to the level of exploitation of an Appendix II-listed species at which exportation would not be "detrimental to the survival of the species" nor disrupt the species' role with an ecosystem. Non-detriment findings are determined by the results of studies and issued by a country's CITES Scientific Authority. For more information on what constitutes non-detriment findings, see the CITES website. For more information on how to make non-detriment findings, see this checklist (https://cites.org/eng/cop/11/info/03.pdf).

gaps in knowledge, and continues by describing the current state of the art of technologies to identify *Dalbergia* and *Diospyros* species. Section 4 puts the assessment in perspective by outlining an agenda going forward. The scientific and identification agenda is described first, by looking at what key steps need to be taken to fill the technical and financial gaps to appropriately map, identify and manage *Dalbergia* and *Diospyros* species in Madagascar. The section concludes by describing a number of factors that could act as drivers of this agenda, in particular the silviculture and private sector potential to develop a precious woods industry.

2. GLOBAL AND COUNTRY CONTEXT

2.1 General Facts about *Dalbergia* and *Diospyros* worldwide

2.1.1 Ecology and general uses of Dalbergia and Diospyros species

The precious wood species of the genera *Dalbergia* and *Diospyros* play a critical role in ecosystems across their widespread range in tropical areas (Figure 1). Aside from timber products, species in these genera also provide significant economic resources as non-timber forest products and have high horticultural value. *Dalbergia* has over 250 species distributed across the tropics that play vital ecosystem roles from improving soil nutrients through their association with nitrogen-fixing bacteria (Rasolomampianina et al., 2005) to providing habitat and food for butterfly larva (*Dalbergia sisoo* and *Bucculatrix mendax*; Shah et al., 2015). *Dalbergia* species are also used for medicinal purposes: bark is used to treat gonorrhea, leaf extract to treat eye ailments, and wood to treat scabies and acne (Shah et al., 2015). The genus *Diospyros* consists of approximately 735 species worldwide that provide essential ecosystem services for fruit dispersers (Beech, Shaw, Rivers, & Schatz 2016), including birds, mammals (Wallnöfer, 2001), and even reptiles (Griffiths, Hansen, Jones, Zuël, & Harris 2011). Different parts of *Diospyros* species have medicinal properties and are used to treat urinary infections, skin and blood diseases, and as antibiotics to treat syphilis and malaria (Orwa, Mutua, Kindt, Jamnadass, & Anthony 2009). Two species of *Diospyros*, *D. kaki* and *D. lotus*, are cultivated for persimmon fruits, with China leading the world in producing over 3.6 million tons of persimmons in 2013 (FAO, 2016).

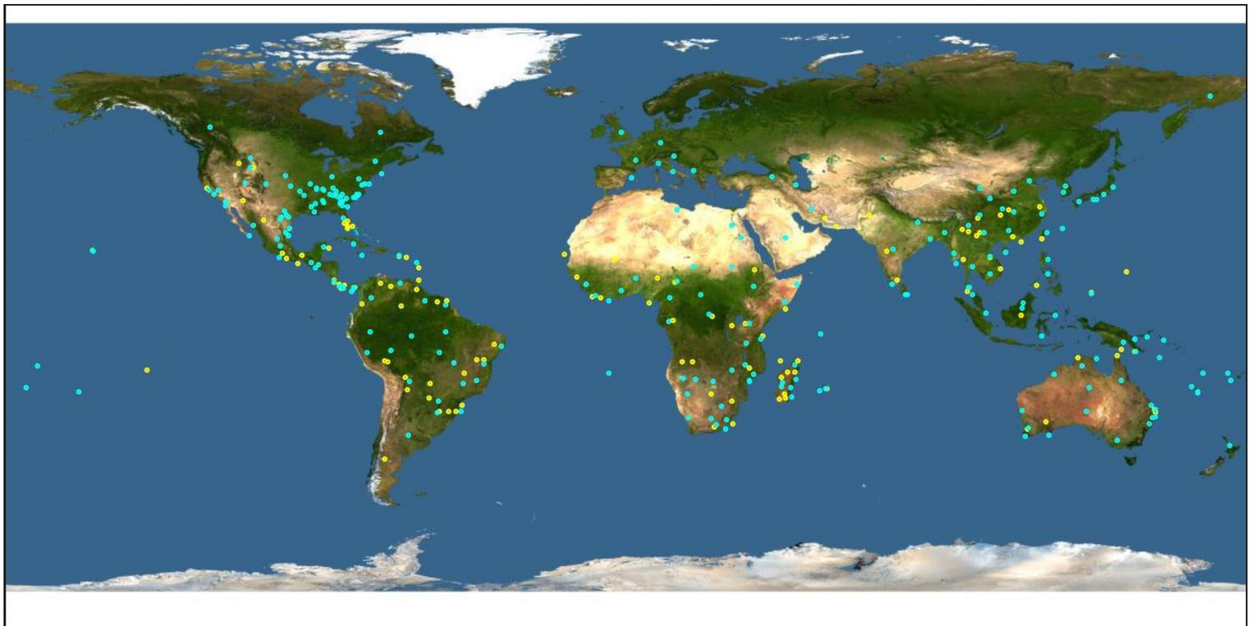

Figure 1. *Global distribution of* Dalbergia (*yellow points*) *and* Diospyros (*blue points*) *species* (GlobalMapper, 2016).

2.1.2 Global timber trade of Dalbergia and Diospyros species

One division of traded wood products are precious woods, in which the timber species belonging to the genera *Dalbergia* and *Diospyros* fall. Precious woods are "highly valued for a range of valuable inherent qualities including appearance, tone, physical, scent, chemical, medicinal or spiritual properties, and that is rare or of limited availability. The combination of inherent qualities and rarity usually results in higher trading prices than other categories or types of wood." (Jenkins et al., 2012). Obtaining accurate trade data for tropical hardwoods is very difficult due to a lack of standards in data compilation, discrepancies between importing and exporting countries, and basic data errors (Duery & Vlosky, 2006). Illegalities within the timber trade, ranging from bribery to document fraud and corruption, compound this problem (United Nations Office on Drugs and Crime, 2013).

Globally, *Dalbergia* species are traded internationally both legally and illegally. Reflecting the relatively poor quality of international trade data for tropical hardwoods, accurate data specifically for *Dalbergia* species are among the most difficult to track. The implementation of CITES within source and destination countries, though, does result in the publication of some trade data on *Dalbergia*. However, the CITES-listed *Dalbergia* species represent only a small proportion of all internationally traded species of these hardwoods (United Nations Office of Drugs and Crime, 2016).

Despite the difficulty of tracking tropical hardwood flows, China is widely considered to be the main importer of *rosewood*, the vernacular name often used to refer to a broad range of *Dalbergia* species, as well as species of other genera with similar commercial properties

(Treanor, 2015). Of China's raw imports of rosewood, approximately 99 percent by volume remain in the country (Treanor, 2015). Over the past fifteen years, as China's economy has grown rapidly, so too has the demand within the country for *hongmu* furniture, defined by its ornate, traditionally styled carvings of hardwoods (Treanor, 2015). Since 2000, the import volume of rosewood has increased 1,250 percent (Treanor, 2015). As a portion of total hardwood import value, rosewood accounted for just 3 percent in 2000 but represented more than one-third of all hardwood imports in 2014, according to official Chinese Customs trade data (Treanor, 2015).

Although we cannot estimate what proportion of rosewood imports into China is factually legal or illegal, the World Wildlife Seizures (World WISE) database indicates that between 2007-2015 China was listed on shipping documents as the destination country for 88 percent (by tonnage) of globally-seized rosewood, irrespective of the location of the seizure (United Nations Office of Drugs and Crime, 2016). At the same time, Malagasy rosewood accounted for 60 percent of seized rosewood around the world between 2005-2015 (United Nations Office of Drugs and Crime, 2016). As discussed in more detail below in section 2.2, domestic and export trading of rosewood products of Malagasy *Dalbergia* species has alternated between various legal statuses since at least 1975. Providing an accurate overview of the historical trade of Malagasy rosewood specifically is thus difficult.

Like rosewood, *Diospyros* species, or *ebony* as they are also referred to, is an internationally traded precious wood, often used for fine carvings, instruments, and furniture and produces both black wood (e.g., *Diospyros ebenum*) and pale-streaked wood (e.g., *Diospyros malabarica*; Beech, Shaw, Rivers, & Schatz 2016). Yet, when compared to rosewood, data on the international trade in ebony are even scarcer.

2.2 Precious woods industry in Madagascar and history leading up to CITES decision (how we ended up where we are now)

In Madagascar, "precious woods" refer to timber from *Dalbergia* species (including the commonly denominated rosewood and palissander) and *Diospyros* species (ebony). First introduced to the European and subsequently the world market hundreds of years ago, rosewood was central to the Brazilian timber industry, but was also exported from South East Asia and Madagascar, with the oldest recorded Malagasy rosewood export dating back to 1899. In 1992, Brazilian rosewood (*Dalbergia nigra*) was added to the first and most stringent Appendix of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which is likely to have led to increased pressure on the similar Malagasy rosewood species.

Industrial harvesting and export of precious woods in Madagascar has been documented since the beginning of the twentieth century (Randriamalala & Liu, 2010). At that time, France controlled Madagascar as a colony and French policy allowed for logging concessions. Lacking resources and political will, and prone to corruption, the French colonial government failed to regulate the logging effectively, allowing concessionaires to clear-cut land and extract resources outside of their concession boundaries (Raik, 2007).

Once Madagascar gained its independence in 1961, much of the mismanagement of forests that had occurred under French rule continued into the post-colonial period, with the government passing (yet often failing to enforce) a multitude of regulations over fifty years regarding forest use, governance, and management. Despite these laws and because of limited resources for management, widespread poverty, and pervasive corruption, illegal logging and slash-and-burn agriculture have persisted since then.

Although the first major attempt to curb illegal logging in the post-colonial period was the passage of the 1975 law banning the export of precious wood logs (Convention on International Trade in Endangered Species of Wild Fauna and Flora, 2016), it was in the subsequent twenty years that Madagascar began to attempt to overhaul management of the environmental sector. It was also during this period that the country started to open its doors more widely to scientists and conservationists, increased the involvement from foreign development agencies, and turned away from the political influences of the Soviet Union (Raik, 2007).

The immediate result of this overhaul was Madagascar's National Environmental Action Plan (NEAP), developed in the late 1980s and with a start date in 1991. Among the six objectives of Madagascar's NEAP were to "protect and manage the national heritage of biodiversity, with a special emphasis on parks, reserves, and gazetted natural forests," along with "establish[ing] mechanisms for managing and monitoring the environment" (The World Bank, 2007). Despite this surge of interest, commitment, and funds from the government and donor community, environmental degradation continued and even escalated over the decades after the introduction of NEAP. As a 2010 report from USAID stated, "the environmental crisis in Madagascar is far more acute now than it was at the outset of [NEAP Phase I]" (Freudenberger, 2010).

Specifically concerning precious woods, the Government of Madagascar imposed a moratorium in 2000[2] on the export of rosewood and ebony tree species, and their extraction from sensitive zones, including protected areas and their peripheral zones. The adoption of this moratorium was a legal covenant of the World Bank support project to the Second Phase of the NEAP. This ban was expected to be temporary, to give the Malagasy forest and environmental authorities time to develop an appropriate regulatory framework to manage this precious and rare natural capital, although to this day, such a regulatory framework is still lacking. Loopholes in the legal framework, the issuing of "exceptional" and often nominative export permits by the government and weak law enforcement facilitated the establishment of an extremely well organized network of illicit trade, giving the illegal logging industry a prime opportunity to harvest and export Madagascar's precious woods, often unabated. Cyclones, for example, have provided a pretext for illegal logging, with export permits awarded supposedly to clear fallen logs. This was the case in the aftermath of the Cyclone Gafilo in 2004-5, and led to loggers extracting quantities of

[2] Interministerial Decree n°11.832/2000 of 30 October 2000.

precious woods that were far greater than the real damage inflicted by the cyclone. An explicit ban on the exploitation of rosewood and ebony was issued only in 2006, by Interministerial Decree No. 16.030/2006 of 14 September 2006, related to the exploitation, commercialization of rosewood and ebony[3]. In 2009, when Madagascar suffered a coup d'état, illegal logging of precious woods came to a head. In addition to regulation and enforcement difficulties during the political crisis, the Government of Madagascar issued authorizations to allow for the export of both unfinished and semi-finished products (Convention on International Trade in Endangered Species of Wild Fauna and Flora, 2016). These regulations essentially gave amnesty to high-powered, politically connected businesspersons who traded in what had previously been illegal timber.

With pressure from civil society, international donors, and governments, Madagascar confirmed the ban on the harvesting of rosewood and ebony in 2010 (Decree No. 2010-141 of 24 March 2010, imposing measure to prohibit logging, exploitation, and exportation of rosewood and ebony in Madagascar). It also established penalties in 2011 (Ordinance No. 2011-001 of 8 August 2011 enabling punishment of offences related to rosewood and ebony), although this did not halt illegal export.

In September 2011, Madagascar sought unilaterally to restrict international trade in five *Dalbergia* species and 104 *Diospyros* species by placing all logs, sawn wood, and veneer sheets of these species on CITES

BOX 1. THE CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES (CITES)

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), which entered into force in 1975, is a voluntary, legally-binding agreement between national governments to ensure that the international trade of species does not threaten their survival. The Convention requires that member states implement CITES decisions for species protection with each state's domestic laws. CITES now counts 182 states as Parties to the Convention; Madagascar joined in 1975.

Complemented with the promotion of conservation and scientific research, the main activity of CITES and its Parties is to assess the threat to species posed by international trade, determine how to control international trade to ensure that the survival of species is not threatened by international trade, and to implement and evaluate the effectiveness of the international trade controls of those species.

The procedure for controlling the trade of species within the Convention is to list a species on one of three Appendices based on how threatened the species is. Species listed on Appendix I are threatened with extinction and are subject to the strictest trade controls. Appendix II species are those that may become threatened with extinction without the intervention of trade controls, which are less strict than Appendix I controls. Any CITES Party may propose that a species be listed on Appendix I or Appendix II. Species become listed on Appendix I or Appendix II when a two-thirds majority of Parties present and voting at a Conference of the Parties adopts a proposal to amend Appendix I or Appendix II to include the proposed species listing.

Species may be listed on Appendix III at any time and unilaterally by any Party who is restricting trade of the species within its jurisdiction to prevent or reduce the exploitation of the species and who is requesting cooperation of CITES Parties to control the trade.

[3] Article 1 of the Decree reads "L'exploitation du bois d'ébène et du bois de rose est interdite".

Appendix III, thereby requiring CITES permits for export and offering notice to other CITES countries that Madagascar was attempting to control the trade of these species (Convention on International Trade in Endangered Species of Wild Fauna and Flora, 2011 and Box 1 for more information on CITES). In 2013, all species of *Dalbergia* and *Diospyros* were placed on CITES Appendix II and embargoed from international trade until Madagascar made sufficient progress on the Precious Woods Action Plan presented at the CITES 16th Conference of Parties (Convention on International Trade in Endangered Species of Wild Fauna and Flora, 2013a). This embargo meant that thousands of logs of rosewood and ebony that had been confiscated during various precious wood bans could not leave Madagascar's shores. To date, stockpiles can be classified into three categories: (i) seized; (ii) declared and unseized; (iii) hidden (see Box 2).

This internationally agreed-upon action has, to some extent, raised the profile of enforcing the ban outside of Madagascar. Since 2014, authorities in several countries around the globe, including Kenya (Reuters, 2014), Mauritius (News Ghana, 2016), and Singapore (Chin, 2016), have seized shipping containers filled with rosewood from Madagascar. Yet, despite these bans and enforcement activities outside Madagascar's borders, illegal harvesting and trade persists, and the accelerated extraction of rosewood has degraded the landscape and depleted the resource even further. Indeed, in some areas the only standing rosewood trees are small, young specimens (Caramel, 2015), and because of the increasing scarcity of rosewood specimens of marketable size, many loggers have returned to exploited forests to retrieve stumps of previously-felled rosewood trees.[4] Illegal logging of ebony trees has also continued, but has received less

BOX 2. PRECIOUS WOODS STOCKPILE TYPES

Stockpiles in Madagascar (thus excluding those that have been seized by importing countries) can be classified according to the extent to which the Government has control over them, and comprise: (i) *Seized stockpiles*: these have been seized by the authorities and are stored either on Government property or on private property; (ii) *Declared stockpiles*: these been declared by operators in 2011 (following the dispositions in Ordinance No. 2011-001 of 8 August 2011), have not yet been seized, and are theoretically still stored on private property; and (iii) *Non-declared and hidden stockpiles*: these are either stored on private property, buried underground, sunk in rivers, or in other hidden locations. The seized stockpiles are currently stored at over 70 sites scattered across 11 regions (though mostly concentrated on the Northeast coast of Madagascar). The quantities of declared stockpiles are eight times higher than those of the seized stockpiles, i.e., 24,813 m^3 for 235,768 logs at 192 different sites. Stockpiles declared in 2011 by operators have never been verified, thus allowing them to serve as buffers to launder new logs (hence, the terms of 'elastic' stockpiles, which refers to the alleged temporary changes in volumes these stockpiles undergo as newly cut logs are added and new sales are subtracted). The Government has so far not verified the declarations and is not monitoring the stockpiles. Similar doubts were raised concerning the integrity of the seized stockpiles, however the Government has undertaken an audit in 2015 (see Section 2.3.2).

[4] *Personal communication*, as told to Charles Barber and Jonathan Mason, World Resources Institute (source names withheld due to safety and security concerns).

international attention and there are no data on the amount of timber being extracted and exported (Beech, Shaw, Rivers, & Schatz 2016).

2.3 CITES Action Plan and progress to date

2.3.1 Madagascar CITES Action Plan Summary of Main Points

As mentioned earlier, after intense pressure from foreign governments, civil society, and donors, Madagascar proposed to list all species of *Dalbergia* and *Diospyros* on CITES Appendix II at the Conference of the Parties in March 2013 (Convention on International Trade in Endangered Species of Wild Fauna and Flora, 2013b). With the adoption of these Appendix II listings, all logs, veneer sheets, and sawnwood of these genera became subject to stricter export controls.

In addition to the listing of the genera, CITES members also decided to establish an Action Plan (Convention on International Trade in Endangered Species of Wild Fauna and Flora, 2013a) to support the implementation of the recent Appendix II listings. The Action Plan sets out seven action points that Madagascar is required to take. These points cover the science of managing precious woods, the handling of seized and declared stockpiles, and the establishment of effective enforcement measures. Perhaps the most significant of those points is the request to put in place an international trade embargo of *Dalbergia* and *Diospyros* logs, veneer sheets, and sawnwood, until CITES approves an audit of the existing stockpiles. The full text of Madagascar's Action Plan obligations is provided in Box 3.

2.3.2 Overview of current work being done by the Government of Madagascar

If the CITES action Plan were implemented, the outcome would be that with improved understanding of the taxonomy of *Dalbergia* and *Diospyros*, Madagascar would be able to carry out studies to determine proper export quota and controls for its precious woods industry, so that in the future, effectively regulated exploitation of the two genera are not detrimental to the survival of the species nor to the ecosystem within which they grow. Moreover, after approving an audit of the in-country stockpiles and an evaluation of the potential procedures for the export of the timber, CITES would lift the temporary international trade embargo on Madagascar's *Dalbergia* and *Diospyros* species. Since 2013, Madagascar, in concert with other parties, has taken several steps toward implementing the *Dalbergia* and *Diospyros* Action Plan.

In response to the scientifically-focused points outlined above, Madagascar has officially reported to CITES that: a) a remote sensing study (see Appendix 3) was carried out to assess standing stocks; b) eight *Dalbergia* and 11 *Diospyros* species are the most illegally traded; and c) a workshop was held to address the need to carry out a study on non-detriment findings (Convention on International Trade in Endangered Species of Wild Fauna and Flora, 2014). It should be noted, however, the validity of the remote sensing study and the naming of illegally traded species is called into question due to the underlying methodology and assumptions used for these studies. This report outlines the current state of the science on *Dalbergia* and *Diospyros* and further highlights why these studies are not currently feasible or valid.

Species identification and taxonomic studies are underway, along with the establishment of a wood conservatory for *Dalbergia* and *Diospyros* spp. (Convention on International Trade in Endangered Species of Wild Fauna and Flora, 2014). The progress and findings of these research initiatives are detailed in section 3 of this report.

BOX 3. CITES MADAGASCAR ACTION PLAN (2013)

The overall objectives of the Action Plan is to (i) improve the management of the standing stock of Madagascar's precious woods, (ii) to effectively control the international trade of those precious woods, and (iii) to determine the most appropriate method for earning revenue for the in-country stockpiles of harvested precious woods timber.

Science-based work

1) Establish, in collaboration with the CITES Secretariat, a science-based precautionary export quota for the listed taxa where an adequate non-detriment finding can be undertaken and clearly documented for any species planned for export;
2) Establish, as appropriate, and with key partners a process (research, information gathering and analysis) to identify the main species to be exported. Workshops should be organized for selected species to establish the adequate non-detriment findings required in paragraph 1;
3) Collaborate, as appropriate, and with key partners, as indicated in paragraph 2 above, to prepare identification material and tests for use in CITES enforcement to identify main taxa as they are traded;

Embargo and stockpile audit

4) Put in place an embargo on export of stocks of these timbers until the CITES Standing Committee has approved the results of a stockpile audit and use plan to determine what component of the stockpile have been legally accumulated and can be legally exported;

Enforcement

5) Collaborate, as appropriate, and with key partners, as indicated in paragraph 2 above, to establish enforcement mechanisms to assist in implementation of any export quota, stockpile control and opening of any legal and sustainable trade utilizing timber tracking systems and other technology as appropriate.

Reporting

6) Provide written reports on progress with the implementation of the plan to the Secretariat and Plants Committee, in compliance with document deadlines for meeting of that Committee;
7) Provide a document outlining progress with the implementation and any required adjustments to the Action Plan at the 17th meeting of the Conference of the Parties.

Responding to Action Plan Point 4, in January 2016, at the CITES 65th Standing Committee Meeting, Madagascar presented preliminary findings from an ongoing stockpile audit financed through a project financed by the World Bank and which involved a contract with SGS[5] to professionally mark audited logs. The audit focused on the seized stockpiles, leaving declared and hidden stockpiles for a follow up operation. The preliminary audit findings estimated that the Madagascar government had seized 3,193 cubic meters of rosewood and ebony, representing an estimated value of €11,035,678 (Convention on International Trade in Endangered Species of Wild Fauna and Flora, 2016). As mentioned, these figures, however, do not include thousands of cubic meters of stockpiles declared to exist (but not seized) within Madagascar, nor do they include thousands of cubic meters of timber seized outside of Madagascar.[6] As of December 2015, 27,725 logs, veneer sheets, and sawnwood pieces had been inventoried and secured, representing 97 percent of the total number seized by the forest administration. Of these, 64 percent had been bar-code marked and thus loaded on a database owned by the Ministry of Envirnment (presentation made by the Executive Secretary of the Inter-Ministerial Committee on Precious Woods).

With regard to enforcement, Madagascar has reported that the government carried out a series of land inspections and has taken steps, with the support of the World Bank, to use satellites to track shipments and monitor trade routes, including at sea (Convention on International Trade in Endangered Species of Wild Fauna and Flora, 2014). These efforts have allowed, through international cooperation, the seizure of rosewood shipments in Singapore, in 2014, and Hong Kong, in 2015. In addition, as part of The World Bank's Additional Financing to Madagascar's Third Environmental Program, which ended December 31, 2015, the government had been working with the World Bank to combine satellite imagery with the use of patrol boats to track and deter shipments of precious woods (Convention on International Trade in Endangered Species of Wild Fauna and Flora, 2014).

In addition, USAID has been funding a Sustainable Conservation Approaches in Priority Ecosystems (SCAPES) project in Madagascar entitled "Preserving Madagascar's Natural Resources Program." The program funding of US$2.25 million from October 2013 through September 2016 has been divided among four of the major international non-profit organizations operating in Madagascar: Worldwide Fund for Nature (WWF), Wildlife Conservation Society (WCS), Conservation International (CI), and Traffic. WWF's component has focused on increasing the engagement of civil society to combat illegal practices; WCS, through the use of the Spatial Monitoring And Reporting Tool (SMART) software, has focused on improving capacity to monitor illegal logging, especially within the Makira Natural Park; CI has led an effort to train local journalists on investigative practices and to increase media coverage of

[5] Société Générale de Surveillance (SGS) is an FSC-accredited inspection, verification, testing and certification company.

[6] For more information see Convention on International Trade in Endangered Species of Wild Fauna and Flora. (2016). Standing Committee 66 Document 46.2, paragraphs 32-37.

Madagascar's illegal timber trade; and Traffic has worked to develop a legal framework of Madagascar's forestry laws to improve understanding of Madagascar's forestry laws and illegalities associated with environmental degradation and, in partnership with University of Antananarivo experts, to train seaport agents on identifying rosewood species. A workshop on macroscopic and microscopic wood ID on some African wood species and Malagasy rosewood, pallisandre, and ebony was held for custom agents, as well as regional forest agents, international NGOs, forest concessioners, military control agents, and the managers of protected areas across Madagascar.[7]

3. ASSESSMENT OF SCIENTIFIC AND TECHNICAL CAPACITY

3.1 Geographic Range and Population Status of Malagasy *Dalbergia* and *Diospyros* species

The assessment presented in this section is based on a careful review of all available information along with input from recognized experts on these genera. Recent studies have demonstrated that the taxonomy of some *Dalbergia* species is inaccurate and that others may actually represent more than one species. For *Diospyros*, as many as 120 species may be large enough trees to be of potential commercial value for ebony wood products, but only half of them have been named, whereas the remainder do not yet have scientific names and can only be recognized by two botanical specialists working on this group[8]. Furthermore, none of the species of *Dalbergia* or *Diospyros* have been evaluated using the IUCN red list criteria, the worldwide standard to identify species conservation status and their extinction risk. This information is essential to determine which species require protection and conservation actions, and which might be suitable for sustainable management and exploitation.

3.1.1 Dalbergia: Number of exploitable species, geographic range and population status

Little if any reliable information is available on which species of *Dalbergia* are exploited in Madagascar. The genus encompasses several species of Malagasy rosewoods and palissanders. The same species of *Dalbergia* can be classified as rosewood or palissander depending on the coloration of the heartwood and the overall quality of wood. The term "rosewood" is used in this report for species displaying dark red and black patterned heartwood, whereas the term "palissander" is used to identify more lightly and brownish colored precious wood in Madagascar. Though the international demand is largely for rosewood (see section 4.3), palissander wood is one of the most preferred woods by Malagasy consumers for furniture (Ramananantoandro, Ramanakoto, Rajemison & Eyma, 2013) and sets the highest price in the Antananarivo timber market (Rajohnson, Gérard & Ramananantoandro, 2013). Currently 47 species (63 total taxa when subspecies and varieties are included) are known to occur exclusively

[7] Worldwide Fund for Nature, Wildlife Conservation Society, Conservation International, and Traffic. Presentation at the Embassy of the United States of America, Antananarivo, Madagascar, 31 March 2016.
[8] P.P. Lowry II and G.E. Schatz, *Pers. Comm.*

in Madagascar, out of a worldwide total of 140 (250 total taxa when subspecies and varieties are included) (Bosser & Rabevohitra, 2002; Klitgaard & Lavin, 2005). The species of *Dalbergia* occurring in Madagascar can be distinguished from one another by characters of their flowers and fruits but even expert scientists are unable to tell species apart without these reproductive structures (i.e., when only leaves are available; see Figure 2 for examples of *Dalbergia* flowers and fruits). Moreover, recent studies involving DNA sequence data from field-collected material (Hassold et al., unpublished data) and careful examination of herbarium specimens (Phillipson et al., unpublished data) have shown that some of the species defined in the most recent taxonomic treatment of the genus in Madagascar (Bosser & Rabevohitra, 2002) appear to represent several distinct entities and that at least some of the subspecies and varieties they described should be recognized as separate species (see Box 4 for a description on how plant species are formally named and described). Wood features are helpful for recognizing some species or species groups, but require specialist knowledge. As a consequence, the names used in published sources and on commercial export permits are frequently incorrect or wrongly assigned.

Figure 2. *(Left) Flowers of* Dalbergia monticola *(photo courtesy of John Cadle, Centre ValBio); (Right) Fruits of* Dalbergia bracteolata *(photo courtesy of Sonja Hassold).*

The number of potentially exploitable species of *Dalbergia* in Madagascar can be estimated based on tree size. Data on tree height are available for all 63 endemic taxa of *Dalbergia* (Bosser & Rabevohitra, 2002). Table 1 summarizes the number of species by height class.

Table 1. *Number of currently recognized Malagasy taxa of* Dalbergia *(including species, subspecies, and varieties) by height classes (DBH data not available for all species[9]).*

Height class	**Number of Taxa**
Maximum height ≥ 20 m	7
Maximum height = 15-19.9 m	14
Maximum height = 10-14.9 m	21
Maximum height < 10 m	21
Totals	**63**

If one assumes that *Dalbergia* trees with a height of at least 15 m (Bosser & Rabevohitra, 2002) are large enough to be potentially exploitable[10], Table 1 indicates that a total of 21 species meet this size criterion. DBH and sapwood measurements are needed to confirm this potentially exploitable size because some species may remain small in diameter or only have little heartwood developed and therefore reduce the amount of commercially valuable heartwood. More than half of the taxa (42) are smaller than 15 m in height and are therefore of limited potential for commercial exploitation.

Malagasy *Dalbergia* occupy a diversity of habitats, ranging from arid steppe-like areas to perhumid evergreen rainforests, and exhibit a range of growth forms from lianas and shrubs to trees (Bosser & Rabevohitra, 2002). Although the taxa grow in a diversity of habitats, they do not occur above 1600-1800 m.a.s.l (Bosser & Rabevohitra, 2002). There are 27 taxa (incl. infraspecific entities) growing exclusively in humid areas, 22 occur in dry areas, and 14 in both habitats (Bosser & Rabevohitra, 2002). Micro-endemism, known in other groups in Madagascar (Vences, Wollenberg, Vieites, & Lees 2009), is also found in some taxa of *Dalbergia* found in very limited areas.

The population status of *Dalbergia* taxa in Madagascar remains almost totally unknown. No information (published or otherwise) has been found and given the difficulty of identifying

[9] DBH data is only available for nine species from eastern Madagascar and was therefore not included in this table.
[10] The rationale behind formulating this assumption is that some species of *Dalbergia* never become large enough trees to produce exploitable wood. It should be noted that the total height of the tree is not the same as the height (length) of the straight part of the trunk (bole) that is generally taken when a tree is exploited. A 10 m tall tree might have a bole of just a few meters, depending on the structure of the individual (amount of branching, height of the branched part of the crown, etc.). This would explain why some logs look short; their length does not provide a reliable indication of the total height of the tree.

sterile trees[11] in the field combined with the outdated geographic range information available for many taxa, reports containing potentially useful data would be of questionable value. Such data would, however, be highly valuable if collected correctly by trained professionals and would complement the information and reference collections gathered using the protocol outlined in Appendix 2. Such information would also be important for distinguishing widely abundant species from those that are rare and potentially threatened, which must be taken into consideration when determining which are potentially exploitable.

3.1.2 Diospyros: Number of exploitable species, geographic range and population status

Little if any reliable information is available on which species of *Diospyros* are exploited in Madagascar. Moreover, because more than 60 percent of the ca. 215-230 species currently recognized by specialists working on the genus remain to be named and described (Schatz & Lowry, 2016), many of which have been regularly confused with other members of the group, the names used in published sources as well as unpublished reports are frequently incorrect and cannot be verified. The number of potentially exploitable species can be estimated based on tree size. Data on diameter at breast height (DBH) and tree height are available from authoritatively identified herbarium specimens of 165 species of *Diospyros*, including 81 that have names and 84 newly recognized species that have not yet been formally named and described (Appendix 1). Table 2 summarizes the number of species by size class.

If one assumes that *Diospyros* trees with a DBH of at least 30 cm or a height of at least 15 m are large enough to be potentially exploitable, Table 2 indicates a total of 48 species (only half of which have published names) meet these size criteria. In addition, at least 50 species lack sufficient DBH or height data to evaluate their placement on this list, and if the proportion of large trees (29 percent) is the same for them, this would increase the total to about 63 species. If the criteria for potential exploitability are set somewhat lower (DBH ≥ 20 cm or height ≥10 m), the total for species of known DBH/height increases to 90 (only 48 of which have published names) and to ca. 117 when all species are taken into consideration.

[11] Sterile trees refer to individuals with no flowers or fruits, the reproductive structures of flowering plants.

Table 2. *Number of currently recognized Malagasy species of* Diospyros *(described and undescribed) by DBH size class and by height class for species lacking DBH data.*

Diameter/height class	**Species Status**		
	Described	Undescribed	Total
Species for which DBH data are available			
Maximum DBH ≥ 40 cm	9	9	18
Maximum DBH = 30-39.9 cm	12	8	20
Maximum DBH = 20-29.9 cm	12	15	27
Maximum DBH = 15-19.9 cm	8	5	13
Maximum DBH = 10-14.9 cm	7	11	18
Maximum DBH < 10 cm	4	13	17
Subtotals	52	61	113
Species for which DBH data are not available			
Maximum height ≥20 m	1	4	5
Maximum height = 15-19.9 m	2	3	5
Maximum height = 10-14.9 m	6	9	15
Maximum height < 10 m	20	7	27
Subtotals	29	23	52
Totals	**81**	**84**	**165**

Figure 3. *Twelve species of* Diospyros *fruiting simultaneously on Nosy Mangabe island in northeastern Madagascar, seven of which are new to science.*

Authoritatively identified herbarium material provides information on the geographic distribution and commonness/rarity (number of documented localities) of *Diospyros* species in Madagascar. This information is available for all published species (including as on-line maps) through the *Diospyros* page on the Madagascar Catalogue (The Madagascar Catalogue, 2016). For species that remain to be formally named and described, data on geographic range have been compiled by the two specialists working on the genus (see Box 3 for more information on how species are formally named and described). Some species of potentially exploitable size that can reach 40-60 cm DBH are widespread, such as *D. haplostylis*, *D. sakalavarum* and *D. tropophila*, while others, including *D. bemarivensis*, *D. antongilensis* and *D. taikintana* (the latter two unpublished), have much more restricted ranges. Most Malagasy forests contain multiple species of *Diospyros*, almost always including some that have large enough trunks to produce commercially valuable wood. At least half of the co-occurring species shown in Figure 3 are large trees and Figure 4 shows an example of a potentially exploitable species in the wild.

The population status of *Diospyros* species in Madagascar remains almost totally unknown. No information (published or otherwise) has been found, and given the taxonomic complexity of the genus, the number of newly identified species, and the limited number of experts capable of recognizing members of the genus, any reports containing potentially useful data would be of little or no value. Such data would, however, be highly valuable if collected correctly by trained professionals and would complement the information and reference collections gathered using the protocol in Appendix 2.

3.2 Species Identification Technologies of Malagasy *Dalbergia* and *Diospyros* species

3.2.1 Development of reference collections and database

Development of reliable tools for accurate species identification requires a comprehensive, authoritative reference library, just as in forensic fingerprinting. A protocol for collecting the necessary material and compiling the associated data in an integrated database platform has been established and is now being initiated, tested and refined in the field (see Appendix 2). The library is necessary for two related processes: 1) to provide the material required by both the Malagasy and international scientific communities to build the set of identification tools listed in Table 3; and 2) to serve as a reference for Malagasy and international technical experts when they use these identification tools to support management and enforcement. The taxonomic delimitation and naming of *Dalbergia* and *Diospyros* species provides the foundation for the development of any accurate, reliable identification tool.

BOX 4. HOW PLANT SPECIES ARE DEFINED AND NAMED

Photo caption: Original specimen housed in the Paris herbarium collected by H. Perrier de la Bâthie in 1903 in Mahajanga, Madagascar. This specimen was used to describe and recognize the species, *Dalbergia tsiandalana* (Viguier, 1951).

Plant species are defined and named through a two-step process. First, species are recognized and distinguished from one another on the basis of differences in morphology (characters of their leaves, flowers, fruits and other organs) as well as aspects such as their ecology and geographic distribution, often supplemented with information from other sources (e.g., genetics, anatomy and chemistry). This involves the careful examination of herbarium specimens, which provide samples from populations occurring at multiple sites, to determine which collections belong to a given species and to identify its distinctive characters. The second step involves naming these species, which is done according to an internationally recognized set of rules (Taxonomy, International Association for Plant, 2012). Over the last two and a half centuries botanists have published names for many plant species and the rules of nomenclature determine which name applies to which species. In groups such as *Dalbergia* and especially *Diospyros*, however, many of the species recognized by today's botanists do not yet have formally published names, either because the species was not collected until recently (a situation often encountered in Madagascar, where dozens of new plant species are discovered each year) or because taxonomists working decades ago did not have adequate material to enable them to distinguish these species. Each newly recognized species must be carefully measured, described and given a formal scientific name in a peer-reviewed publication that indicates how it differs from other species, a process that can require a year or two.

Figure 4. *Fruits on the trunk of a tree of* Diospyros labatiana, *a newly identified species that can reach 16 m tall and almost 30 cm in diameter.*

The current taxonomic information and the available identification tools are both seriously inadequate. For instance, individual logs that belong to the same species of *Dalbergia* could be classified, using today's tools, as either palissander or rosewood, depending on the definition of these two categories and the knowledge of the person identifying the logs. Without reproductive structures, wood samples cannot be assigned with certainty to a species. In its current implementation, the TRAFFIC wood identifier can only classify wood as ebony, palissander or rosewood in the field and cannot identify the corresponding *Dalbergia* or *Diospyros* species.[12]

3.2.2 Methods for identifying species and origin from (dead) wood samples (e.g., anatomy, genetics and chemical composition)

The CITES convention assumes that species listed on any one of the three appendices are taxonomically described and readily identifiable by trained individuals using tools that are

[12] Ratsimbazafy, C. Presentation of the USAID SCAPES project, U.S. Embassy, Antananarivo Madagascar, March 31, 2016. The TRAFFIC wood identifier is a printed booklet that includes photos to help guide identification of logs as ebony, palissander, or rosewood, but does not enable identification to the species level.

widely available. Unfortunately, for timber, and more specifically for exported timber originating in Madagascar, this is not the case. The fallacy in this assumption, and subsequently part of what is compromising the adherence to the CITES Madagascar Action Plan, is that species in the genera of *Dalbergia* and *Diospyros* are not all officially named and described and further, as stated above, are mostly unknown and cannot readily be identified.

Apropos to the situation in Madagascar, the quote below from the most recent University of Adelaide/UNODC publication (Dormontt, et al., 2015) – to which many of the leading scientists working on wood identification contributed – lays out some of the hurdles faced by Malagasy scientists with regard to *Dalbergia* and *Diospyros* species identification:

> *"New requirements for forensic timber identification tools arise each time a timber species is listed on the CITES appendices. At present, no consideration is given to the availability of identification tools when new listings are made, and there are no requirements for signatories of the convention to provide reference material or facilitate its acquisition. We contend this presents an unacceptable arrangement, whereby sole responsibility for reference material collection falls to underfunded xylaria. Adding to these difficulties is the paucity of taxonomic clarity in many groups of timber species; without solid taxonomic foundations, it is not possible to develop the required forensic identification tools."*

The highly respected, internationally trained, Malagasy botanists and wood scientists working on these issues are up against a lack of human and monetary resources, close partnerships with international experts, and essential lab equipment, all of which are necessary if they are to play the leading role in a collaborative effort to resolve the existing taxonomic questions surrounding *Dalbergia* and *Diospyros* species.

Many technologies, tools and methodologies currently being used in human and animal forensics are quickly being adapted and further developed to aid in the forensic identification of illegal timber and wood-based products. In more developed countries where illegal logging legislation has been enacted, there is clear motivation to fund the development of these tools to improve the monitoring and enforcement of legislation pertaining to timber legality. Unfortunately, because of the lack of resources available, the few technologies that are being employed by Malagasy scientists are still under development and none yet are adequate to be scaled.

Below is a brief overview of existing and new technologies currently being used by Malagasy scientists and their international partners to resolve questions surrounding taxonomic issues in the genera *Dalbergia* and *Diospyros*. Table 3 summarizes the different identification tools and their current status of development.

<u>Species-level Taxonomy</u>: Malagasy staff of the Missouri Botanic Garden have joined international botanists in St. Louis and Paris in conducting a comprehensive taxonomic review of species within the genera *Dalbergia* and *Diospyros* that occur in Madagascar. Initial work has

shown that traditional taxonomic approaches such as the analysis of leaf, flower and fruit morphology provide a useful and highly informative basis for identifying species in both genera.

Wood Macroscopy/Microscopy: Dr. Harisoa Ravaomanalina, professor of Botany, directs the wood anatomy lab at the University of Antananarivo. She was internationally trained as a wood anatomist and has extensive experience using macroscopy (hand lens) and light microscopy for wood identification (Ravaomanalina, Crivellaro, & Schweingruber, In press).

Working on the wood anatomy aspect of the Madagascar ITTO-CITES project (directed by Dr. Sonja Hassold), Dr. Ravaomanalina employs light microscopy to identify differences in the cellular structure of wood from species of *Dalbergia* (and *Diospyros*). Ultimately, these anatomical data will be collated with the morphological and genetic data in the hope of resolving the historically described, problematic species groupings within *Dalbergia*.

Portable, Handheld NIRS (under development): Dr. Tahiana Ramananantoandro is a wood science professor and directs the wood science lab at the Water and Forest department of the School of Agronomy (ESSA-Forêts) department at the University of Antananarivo. She was internationally trained as a wood scientist and uses traditional and innovative NIRS methods to analyze multiple properties of wood (Rakotovololonalimanana et al., 2015). Because of the lack of funds to purchase a Bruker MPA FT-NIR unit (cost: USD 70,000), she is testing a handheld near infrared spectrometer (MicorNIR Pro 1700 ES – USD 18,000) in hopes of developing a database of discriminatory characters that can provide resolution among species of *Dalbergia* and *Diospyros*. Past studies have shown that the NIRS methodology can discriminate between different species of Brazilian timbers (Braga, Pastore, Coradin, Camargos & da Silva, 2011) that are difficult to tell apart by eye and can distinguish between geographic regions (for example, between timber originating from Finland, northern and southern Poland and Italy; Sandak, Sandak & Negri, 2011). For application to the *Dalbergia* species, *Dalbergia cochinchinensis* (a species listed in Appendix II of CITES), can be distinguished from three other *Dalbergia* species (*D. retusa*, *D. bariensis* and *D. oliveri*) using the FT-IR spectrometry discriminating between the composition of extractives in the wood (Zhang et al., 2016). The team at ESSA-Forêts, in collaboration with Cirad Montpellier and ESALQ Brazil has used NIRS to distinguish the geographical origin of wood of *Eucalyptus robusta*. Thus, based on NIR spectra, they determined whether the eucalyptus wood was collected in the region of Fianarantsoa, Manjakandriana, Anjozorobe, Andasibe or Mahela (Ramananantoandro, Rakotovololonalimanana, Razafimahatratra & Mevanarivo, 2016).

DNA: In partnership with University of Antananarivo, Dr. Sonja Hassold and Mr. Simon Crameri under the supervision of Prof. Dr. Alex Widmer of ETH Zurich, have carried out the only molecular studies to date on Madagascar *Dalbergia* species[13]. Using traditional DNA barcodes as well as DNA microsatellites, their preliminary studies have shown that groups of species can be distinguished and that it may be possible to differentiate between material from

[13] Microsatellite/barcoding work done by Sonja Hassold (Hassold et al. *submitted*)

Madagascar and from other areas. The current work is funded by the CITES ITTO project and will continue through October 2016. The only molecular work involving *Diospyros* species from Madagascar is that being conducted Mr. Alex Linan at the Missouri Botanical Garden and St. Louis University, which is focusing primarily on the population genetics of species from the Mascarene Islands (Mauritius, Reunion, and Rodrigues).

Mass Spectrometry: Dr. Edgard Espinoza, Deputy Director of the United States Fish and Wildlife Service, Forensics Laboratory, has been working in partnership with Dr. Ravaomanalina and Dr. Hassold to build a reference database of chemical signatures unique to *Dalbergia* species in Madagascar (currently, no comparable database for *Diospyros* exists). Using Mass spectrometry, Dr. Espinoza has successfully been able to distinguish many different species of *Dalbergia*, globally, but work to resolve Madagascar species is still under development (Espinoza, Wiemann, Barajas-Morales, Chavarria, & McClure 2015; McClure, Chavarria, & Espinoza 2015; Lancaster & Espinoza 2012).

Table 3. *List of wood identification tools currently available to Malagasy scientists, along with type of material (e.g., standing tree, logs and planks, finished products) and the developmental state of each tool with respect to identifying species of* Dalbergia *and* Diospyros *from Madagascar. For more background information on these tools, see Dormontt et al., 2015.*

ID tool	Standing trees	Logs and planks	Finished products	Current application to *Dalbergia* spp.	Current application to *Diospyros* spp.
Flowers/fruits	Yes	N/A	N/A	Experts can ID some species[14]	Experts can ID all species[15]
Leaves	Yes	N/A	N/A	Experts can ID some species[16]	Experts can ID all species[2]

[14] Most *Dalbergia* species flower and fruit irregularly (some appear to initiate flowering only after a cyclone) and there are not enough botanical collections with flowers or fruits for these species for proper description and identification (*unpublished data).*

[15] Only two botanical experts are currently able to identify all *Diospyros* species occurring in Madagascar, primarily using flowers/fruits, although identification based on leaf characters is regarded as something that could be developed (P.P. Lowry II and G.E. Schatz, *Pers. Comm.*).

[16] The work of Simon Crameri and Sonja Hassold on the potential of identification based on leaf morphological characters (Hassold et al. unpublished results).

DNA	Yes	Yes	Possible. Typically very challenging due to the degraded nature of processed DNA	Barcode and Microsatellite databases have been built for some species within unique geographic regions of Madagascar[17]	Not developed
Wood Macroscopy[18]	Yes	Yes	Possible, with challenges	Technician can be trained to ID genus but not species. With contextual information[19], expert **may** be able to ID species	Technician can be trained to ID genus but not species. With contextual information, expert **may** be able to ID species
Wood Microscopy[20]	Yes	Yes	Yes	Expert can ID genus and can potentially ID species with contextual information	Expert can ID genus and can potentially ID species with contextual information
Handheld Near Infrared Spectroscopy tool[21,22]	*Potentially: technique under development*	*Potentially: technique under development*	*Potentially: technique under development*	Expert can potentially ID genus and species	Expert can potentially ID genus and species
Mass Spectrometry	Yes	Yes	Yes	Reference data exists for many *Dalbergia* species, globally. Reference data for Madagascar species are still being gathered[23,24,25]	Not developed

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[17] Microsatellite/barcoding work done by Sonja Hassold (Hassold et al. submitted)
[18] Ravaomanalina, Crivellaro, & Schweingruber, In press
[19] Contextual information includes additional information from the collected specimen: geographic location, habitat information, habit (tree, shrub etc), name in local language among other salient details.
[20] Ravaomanalina, Crivellaro, & Schweingruber, In press
[21] Sandak, Sandak, & Negri, 2011
[22] T. Ramananantoandro, Professor ESSA-Forets, University of Antananarivo, *Personal Communication*
[23] Espinoza, Wiemann, Barajas-Morales, Chavarria, & McClure, 2015
[24] McClure, Chavarria, & Espinoza, 2015
[25] Lancaster & Espinoza, 2012

4. MOVING FORWARD AND PUTTING SCIENCE TO WORK

As noted in section 2, science plays an important role in the CITES Action Plan for Malagasy *Dalbergia* and *Diospyros* species. The previous section showed that while the knowledge gap is substantial, there is a significant basis of expertise, both nationally and internationally, on which to build. This section delineates an agenda for action across two key dimensions: (i) making progress on science; and (ii) promoting the enabling environment, particularly from the point of view of silviculture and private sector potential. These two dimensions are closely linked together. Scientific progress cannot happen without either a public sector impulse or a business rationale. In the case of Madagascar's precious woods, the major public sector impulse comes from the CITES listing and associated embargo on international trade – implementing the CITES listings effectively is a priority for both the Government of Madagascar and the Parties to CITES. There is also a potential private sector impulse deriving from private sector entities who would like to see appropriate protection efforts capable of leading to the development of sustainable commercial exploitation and trade in precious woods. The private sector increasingly realizes that this will not be possible without up-front investment in the science for species identification, species distribution and abundance, silvicultural aspects, and other matters discussed in this report.

4.1 Needs assessment and funding opportunities to support science-based work

Recent and current investment in the science of precious hardwoods in Madagascar has focused on assessing the standing stocks of potentially exploitable precious timber species (see summary in section 2.3.2 of this report) and has largely neglected the taxonomic work and the development of identification tools that are foundational to evaluating the science-based points under the CITES Action Plan. Appendix 3 lists previous and ongoing projects that cover either some of the work identified in the CITES action plan or further work outlined in section two of this report.

To support the development of reference collections and identification tools, the authors of this report, in partnership with scientists at the University of Antananarivo, have outlined the essential infrastructure and resource needs that are currently not funded, which are further detailed in Table 4. Specific resources needed are outlined in Appendix 4. Moreover, capacity building and training of Malagasy scientists and students should play a significant role in future projects to ensure the long-term sustainability of this work. A clear example is the necessary transfer of knowledge by international experts to Malagasy scientists for both genera. As stated above, only two international botanists are currently capable of identifying all *Diospyros* species, which is an untenable situation for any future work on the genus in Madagascar. Potential sources of funding for these projects include the European Union Financing Cycle Fed11, which is accepting proposals to support scientific and technical assistance and investment in Madagascar, and the National Geographic Society, Committee for Research and Exploration, which could possibly support some fieldwork to develop the reference collection of *Dalbergia* and *Diospyros* species.

Additionally, because of the immense global attention being placed on *Dalbergia* within the CITES process, there is now an opportunity to harness the attention of the international community and secure financial support to aid Malagasy scientists in building the needed capacity through close partnerships with international scientists developing, testing and implementing tools to combat the trafficking of illegal timber and wood-based products. The Malagasy scientists have already established a few key relationships with international scientists, but many more scientists from the international community are interested in aiding their Malagasy colleagues. Through our outreach during this assessment period, the team received very positive feedback from multiple scientific bodies who understand the gravity of this situation and have expressed their commitment – once funding is made available – to aid their fellow Malagasy colleagues in this effort.

The botanical specialists at the Missouri Botanical Garden are keenly interested in training and passing on their expertise on the taxonomy and identification of *Dalbergia* and *Diospyros* species to Malagasy students and/or botanists to ensure the needed level of in-country capacity. The Missouri Botanical Garden opened an official office in Madagascar in 1984 and currently employs over 75 Malagasy staff across Madagascar in their botanical research and plant conservation programs. Furthermore, the team has communicated with the recognized leaders in wood anatomy (based at the USFS Forest Products Lab and Royal Botanic Gardens, Kew) and has received confirmation that they would be interested in leading a Madagascar-based training and pilot some of the newest wood anatomy tools for future on-the-ground use in Madagascar in collaboration with Malagasy expert wood scientists identified in section 3.2.2 of this report. Moreover, the USFWS Forensics lab (which currently has a role in the Madagascar ITTO-CITES project using mass spectrometry) has expressed an interest in becoming more deeply engaged with the Malagasy scientists so as to provide usable data to their Malagasy colleagues who have no expertise in this field. Lastly, and to drive the point home, this is exactly what the Malagasy scientists have expressed they need; a close, collegial, well-coordinated international collaboration of scientists employing multiple methodologies in order to deal with the overarching issues that exist around the identification and illegal trafficking of rosewoods and ebonies from Madagascar. The budget and timeline in Tables 4 and 5 are suggestions based on consultations with experts in each of these fields and are realistic given the status of ongoing work in each area. With regards to the timeline, the various components of the proposed activities indeed need to be implemented concurrently as they are synergistic and progress will be iterative. The preliminary results already obtained were based on sampling in a limited number of areas done for Sonja Hassold's PhD. research; the recently developed sampling protocol now being implemented is generating a significantly broader and deeper set of material for taxonomy, wood anatomy, DNA work, etc., which will enable each of these ID tools to move to the next level. The continuation of field sampling will then lead to obtaining the comprehensive sample set needed to finalize the various tools, but waiting until the full sample is available before pursuing the development of the tools would be not be efficient and would delay the entire process unnecessarily. Evaluating the conservation status of the species in each genera against the IUCN Red List criteria should be a priority to establish which species should never be exploited commercially (e.g., critically endangered and endangered species) and the species that should be examined further for the possibility of sustainable exploitation (e.g., species of least concern).

Table 4. *List of recommended work, activities, financial need and timeline to address the scientific needs identified in section 3.*

Recommended work	**Activities**	**Financial Need (USD)**	**Timeline**
Standardized field sampling of *Dalbergia* and *Diospyros* to generate source reference collection for identification tools and living material for *ex-situ* conservation and seed banking	The sampling protocol developed and piloted by ETH, MBG and the Univ. d'Antananarivo (Appendix 2) will be implemented in order to compile a comprehensive reference collection and living material (seeds, seedlings, cuttings) representing all potentially exploitable species, with representative population sampling spanning the geographic range of each species. This will support taxonomy, wood anatomy, DNA barcoding, mass spectrometry, and conservation assessments, as well as for *ex-situ* conservation and seed banking (see below). The pilot integrated database platform will be refined and finalized, and all relevant data will be incorporated, providing access to all stakeholders.	60,000	2 years
Taxonomy of potentially exploitable *Dalbergia* species	Botanists from MBG who have initiated a preliminary assessment of taxonomic problems in the genus (P. Phillipson, M. Rabarimanarivo) will collaborate with botanists from a Malagasy institution to review and update the delimitation of *Dalbergia* species, incorporating the methods and results of S. Hassold and S. Crameri (ETH Zurich). This will involve 2 months of work by the full team in the Paris herbarium, which holds by far the largest and most complete collection of herbarium specimens from Madagascar. This includes developing field guides and conducting training workshops.	60,000	2 years
Taxonomy of potentially exploitable *Diospyros* species	The recognized experts on Malagasy *Diospyros* (G. Schatz & P. Lowry) will collaborate with 2 Malagasy botanists to delimit and describe the ca. 50 potentially exploitable species that do not currently have names. This will utilize material (specimens, photos) generated by the standardized sampling protocol, and will involve 6 months of field work by the Malagasy botanists and 3 months of work by the full team in the Paris herbarium.	100,000	2.5 years

	This includes developing field guides and conducting training workshops.		
Conservation status of potentially exploitable *Dalbergia* and *Diospyros* species	MBG-Madagascar's Red Listing team and the IUCN-mandated Madagascar Plants Specialist Group will apply the IUCN Red List criteria to assess the risk of extinction of each of the ca. 160 potentially exploitable species of *Dalbergia* and *Diospyros*	50,000	1 year
Malagasy Xylarium: Infrastructure and future development	Provide human and monetary capacity to grow and curate Malagasy reference collections for *Dalbergia*, *Diospyros* and look-a-like species at the Univ. d'Antananarivo. Also provide for training of future Malagasy wood scientists by international experts	200,000	3 years
Development of DNA identification tools	Develop DNA tools for identification, including extraction, analysis, and training of Malagasy scientists.	100,000	2-3 years
Macro/Microscopic/ handheld tools for wood anatomy	Using Malagasy reference material, develop handheld wood ID screening tool to be deployed by enforcement officials. Also to bring international experts to develop and scale wood anatomy training in Madagascar.	200,000	1 year (tool in ports by 1.5 years)
Near Infrared Spectroscopy	Purchase Bruker MPA FT-NIR unit for University of Tana Wood Science lab to aid Dr. Ramananantoandro in obtaining robust data that will corroborate other ID technologies and validate the handheld NIRS. To provide lab infrastructure to run analyses and maintain samples.	200,000	1.5 years
Mass Spectrometry	Continue to send samples to USFWS Forensics lab to build reference database of *Dalbergia*, *Diospyros* and look-a-like species	100,000	1.5 years

4.2 Silvicultural Potential for Regeneration of Malagasy *Dalbergia* and *Diospyros* species

The successful conservation of species threatened by extinction requires both *in situ* management plans of existing populations and *ex situ* silvicultural programs to protect the remaining genetic diversity of species and provide the material and methods for restoration opportunities and plantations of economically valuable species. Currently there are no restoration projects, timber plantations, or native plant nurseries that focus exclusively on ebony, rosewood or palissander species in Madagascar. Although a few Malagasy precious timber species have been included in some restoration projects and nurseries, data on germination protocols and requirements, seed dormancy and viability, and preferred growing conditions have not been assessed systematically and are not publicly available.

For collections of seeds and plant germplasm, the National Silo of Forest Seeds (*Silo National des Graines Forestières*, SNGF) and the Kew Millennium Seed Bank Partnership are working together to collect, store, test the viability/germination ability, and manage the seeds of plant species at the greatest risk of extinction in Madagascar, including some *Dalbergia* and *Diospyros* species. Their holdings currently include seeds of several *Dalbergia* and *Diospyros* species, although the exact numbers are not available. At the SNGF campus in Antananarivo, specialists have successfully grown *Dalbergia* species and report no strong seed dormancy or difficulties with germination[26]. However, tests in the green house done by scientists at the ETH Zurich have revealed difficulties in growing *Dalbergia* plants from seeds that were collected in Madagascar. The seeds germinate very easily and grow to seedlings 15cm in height but then die after a few weeks. This difficulty may be due to the absence of specific nitrogen-fixing bacteria that are necessary for the growth of all legume species and may only exist in Malagasy soils. The only published study to examine Malagasy *Dalbergia* species for their associated nitrogen-fixing bacteria found high levels of diversity and new strains of bacteria that have never been documented before to fix nitrogen in association with legume species[27]. Field observations show that stumps of cut *Dalbergia* trees coppice easily and generate vigorous sprouts, but only anecdotal information is available on whether they will eventually grow into potentially exploitable trees[28]. *Diospyros* species are less prone to coppice. There are no published data available on growth rates or potential yield of exploited *Dalbergia* and *Diospyros* species. Cut logs have not been formally tested for their age, though anecdotal observations put the largest logs at over 100 years old.

The Conservation Unit of Missouri Botanical Garden's Research and Conservation program has begun to establish field gene banks at community-based conservation sites across Madagascar. This program focuses on collecting seeds to capture the extent of genetic diversity in populations of selected *Diospyros* species in protected forests as well as in targeted populations in surrounding unprotected areas. These seeds are then sown in the communities' native plant nurseries and the resulting seedlings can be used for local restoration projects. Moreover, at five of the conservation sites where MBG is working with local communities, local *Dalbergia* species have also been successfully germinated and grown in the native plant nurseries as part of the restoration program of protected forests.

Building on existing activities and experience, we recommend the establishment of a coordinated program of *ex-situ* cultivation and conservation of potentially exploitable species of *Dalbergia* and *Diospyros* using a combination of field-based nurseries for growing and multiplying living plants, and seed banking to preserve genetic diversity. Nurseries should be established at protected areas and other sites that have permanent on-site personnel with expertise in growing plants (such as MBG's community-based conservation sites and the Madagascar Fauna and Flora

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[26] L. Ramamonjisoa, Directice de SNGF, *Pers. Comm.*
[27] Rasolomampianina et al., 2005
[28] S. Hassold, *Pers. Comm.*, Reports one instance of seeing a coppiced *Dalbergia* tree reach an exploitable size.

Group's site at Ivoloina). This work would have two main goals: 1) test and develop protocols to propagate/multiply *Dalbergia* and *Diospyros* species so that sufficient quantities can be produced for an extensive sylviculture program; and 2) ensure the conservation of genetic diversity of these species through *ex-situ* cultivation. Living material of *Dalbergia* and *Diospyros* species should also be grown at Parc Botanique et Zoologique de Tsimbazaza (PBZT) and SNGF. In parallel, seeds of each species, collected during the standardized field-sampling program, should be deposited into the seed bank maintained at SNGF in Antananarivo and to the Kew Millennium Seed Bank in the UK, through their partnership with SNGF. This will provide an additional, complementary means of *ex-situ* conservation. The resource needs for this program, which are currently not funded, are presented in Table 5

Table 5. *List of recommended work, activities, financial need and timeline for* ex-situ *cultivation and conservation identified in section 4.2.*

Recommended work	**Activities**	**Financial Need (USD)**	**Timeline**
Ex-situ cultivation and conservation of potentially exploitable species of *Dalbergia* and *Diospyros*	Establish collections of living plants at ca. 6 sites covering the ecological and geographic ranges of *Dalbergia* and *Diospyros* species (e.g., protected areas with staff experienced in growing plants) to test and develop the techniques required to grow and multiply each species (required for later up-scaling), and to maintain genetic diversity of threatened species whose wild populations are being impacted or are under pressure. Experienced specialists in growing Malagasy trees (e.g., from MBG, SNGF) will work with a dedicated nurseryman/women at each site. Living material will also be grown at PBZT, the Ivoloina Zoo (where the Madagascar Fauna and Flora Group is conducting *ex-situ* plant conservation work) and other appropriate sites.	200,000	3 years
Seed banking of potentially exploitable species of *Dalbergia* and *Diospyros*	Deposit viable seeds, collected during the standardized field sampling program, in the SNGF seed bank and the Kew Millennium Seed Bank Partnership to support the conservation of the genetic diversity of *Dalbergia* and *Diospyros* species.	50,000	1.5 years

4.3 Establishing the Scientific Basis for Sustainable Exploitation of and Trade in Madagascar's Precious Woods

Madagascar's precious woods constitute an important natural resource. To date, it has been unsustainably and illegally exploited, causing significant ecological harm and providing few benefits for the Government and people of Madagascar. Ideally, *Dalbergia* and *Diospyros* could be sustainably harvested, creating jobs and income, and providing incentives for maintaining the forest ecosystems in which these species occur. What policy changes are necessary to allow that to happen? What can be done in terms of investment in scientific research and human scientific and technological capacity to facilitate these policy changes?

It is widely recognized that the first, crucial step is reducing external demand for Madagascar's precious woods, which is nearly entirely driven by Chinese market for *hongmu* furniture, traditionally styled furniture carved from richly colored, dense woods, such as rosewood. This requires much stronger national-level enforcement, and international cooperation pursuant to effective implementation of the CITES listings of Madagascar's *Dalbergia* and *Diospyros*. Much of the basic scientific work proposed in this report can directly support efforts to detect and deter this trade, which is, at present writing, illegal under the agreed terms of the Madagascar Action Plan.

Apart from enforcement concerns, development of basic scientific methodologies (e.g. species identification) and baseline information (e.g. population distribution and abundance) is an essential step for development of responsible private sector investment and trade in Madagascar's precious woods.

Madagascar rosewood, for example, is highly prized by the musical instruments industry. In 2008, a delegation from Greenpeace's MusicWood Coalition (representing the Gibson, Martin, and Taylor guitar companies) carried out a fact-finding mission to Madagascar to determine if the country's logging practices could be improved in order to comply with the standards of the Forest Stewardship Council (FSC), an international voluntary timber certification body (Greenpeace, 2008). This initiative was cut short by the 2009 unconstitutional change in Government and subsequent boom in illegal rosewood logging. In addition, Gibson's premises were raided in November 2009 by U.S. federal agents, who confiscated allegedly illegal Madagascar ebony. The company reached a settlement with the U.S. in 2012.

However, the instrument industry continues to be interested in determining if sustainable and legal precious wood can be purchased from Madagascar. In September 2015, Bedell Guitars visited Madagascar with WRI to understand more clearly the causes and impacts of illegal rosewood harvesting and to evaluate whether the present situation offered any options for legal and sustainable sourcing. In the spring 2016, Martin Guitar returned to Madagascar to assess the feasibility of establishing a site for sustainable management of precious woods and visited a forest in the southeast of Madagascar managed by EtcTerra, a France-based NGO active in Madagascar. Considering site-specific challenges and the overall precious woods crisis in Madagascar, both Bedell and Martin concluded that legal and sustainable sourcing in the short-term were not possible. However, the continued interest from the private sector indicates the potential involvement of and investment from the tonewood industry in future sustainably managed production forests where the value chain can be secured and the wood can receive FSC certification.

In northeastern Madagascar, near Makira Natural Park, the Wildlife Conservation Society and Zoo Zürich have initiated community projects that integrate rosewood plantings with recently established cocoa crops (Wildlife Conservation Society, 2015). The cocoa trees would produce fruit as a cash crop within the medium-term of three-to-five years, while the rosewood trees would offer shade (making for a higher value cocoa fruit harvest) and a long-term source of timber revenue. Given the slow growth rates of rosewood species, however, this is a quite long-term prospect.

An alternative proposal, developed in the course of discussions held pursuant to this study, could involve identifying pilot sites in a limited number of regions of Madagascar to test and implement a sustainable exploitation protocol of appropriate (unthreatened) species of *Dalbergia* and *Diospyros*. Such piloting would not only help develop some of the recommendations above but would serve as a platform to test collaboration between scientists, forest enforcement agents, local authorities, the central Government and the private sector. An assessment of the resources available in each plot (tree by tree) would be required, and a long-term, sustainable harvesting plan that provides regular economic benefits, including to the local community, would have to be developed. For obvious security reasons, information on the location of inventoried trees would need to be kept strictly confidential. It would be necessary more broadly to ensure careful control and monitoring of the pilot sites using proven tools, and the wood extracted from them would have to be tracked along the entire value chain in a verifiable and enforceable manner. Potential private sector investors have expressed an interest in supporting initiatives of this type in Madagascar provided that robust monitoring and enforcement can be guaranteed in order to ensure FSC certification.

Similar projects have reported success in other countries (e.g., Martin Guitar's community forests for mahogany exploitation in Guatemala), but the governance conditions are significantly weaker, and the exploitation pressures stronger in Madagascar than they are in Guatemala.

As previously noted, there are presently no data available to determine which, among the various species of rosewood and ebony, are "endangered" or not, since there has been no IUCN Red List assessment for the *Dalbergia* and *Diospyros* genera in Madagascar. A first step in support of this pilot would therefore be an acceleration of the relevant scientific work that would provide baseline information on: (i) which commercially-viable species are of least concern and are not likely to be endangered; (ii) what are their growth and production characteristics.

In short, there is a considerable amount of preparatory scientific work needed before such a pilot could be implemented. In addition, there are urgent management and enforcement risks that will also need to be mitigated, to ensure the physical security of pilot plots, and the scientific integrity of pilot results. Bearing in mind these risks, however, the establishment of a prospective private sector driver for sustainable management and harvest of precious woods may serve as exactly the type of incentive that is required to both accelerate needed scientific work, and invigorate management and enforcement issues by government. Piloting such a model also holds out the promise to local communities that conserving Madagascar's precious woods can be more than just pure "protection", and on the contrary can be linked to sustainable economic growth and development.

It is beyond the scope of this report to provide detail on the design of such a sustainable use pilot program. The authors recommend, however, that relevant stakeholders from Government, the private sector, and scientific and forest management institutions rapidly begin a process to develop such a pilot project, including a crash program to complete the baseline scientific and management requirements that are laid out above.

5. CONCLUSIONS

While this report has revealed significant gaps in the knowledge and available tools needed to implement the CITES Action Plan and to support the sustainable management of precious hardwoods in Madagascar, it has also revealed that a solid foundation exists for overcoming each of these gaps – ***if*** donor and technical partners step up to work with relevant institutions and authorities in Madagascar. Malagasy and international experts in each of the key areas (taxonomy, field collection and identification, development and management of a reference collection and a database, wood anatomy, DNA barcoding, and mass spectrometry) have conducted promising pilot initiatives and are working in close collaboration with a shared vision of how to address the most pressing issues and to develop the needed knowledge and tools. Now is the time to scale these efforts up.

Madagascar faces significant challenges in its effort to maximize the benefits derived from commercial exploitation of its precious hardwood resources, and to do so in a way that is legal, equitable and sustainable. At the same time, the country has a unique opportunity to harness the engagement and commitment of Malagasy experts and their international partners in a coordinated effort to develop the information base and tools that will be required to help transform the government's aspirations into a structured and organized industry that makes a significant contribution to the national economy. If the required resources can be mobilized, the successful establishment and implementation of such a program would be the first of its kind in the developing world.

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7. APPENDIX 1: Currently recognized Malagasy species of *Diospyros* (described and undescribed) by DBH size class (and height class for species lacking DBH data)

Species	Described	Diameter (cm)		Height (m)		Voucher collection
		min	max	min	max	
Species for which DBH data are available						
Maximum DBH ≥ 40 cm -- 18 species (9 undescribed)						
Diospyros bemarivensis H. Perrier	✓		60.0		13.0	SF 19797
Diospyros sakalavarum H. Perrier	✓		60.0		15.0	SF19356
Diospyros toxicaria Hiern	✓		60.0		20.0	SF 18323
Diospyros Mucronata sp. 6			60.0		14.0	Randriamampionona 234
Diospyros sp. 4 Maba aff. toxicaria			60.0		20.0	SF 18323
Diospyros tropophylla (H. Perrier) G.E. Schatz & Lowry	✓		50.0		15.0	SF 14130
Diospyros haplostylis Boivin ex Hiern	✓		45.0		30.0	Rakotovao 2635
Diospyros aculeata H. Perrier	✓	30.0	40.0	8.0	10.0	SF 20738
Diospyros cupulifera H. Perrier	✓	30.0	40.0	6.0	7.0	SF 22434
Diospyros fuscovelutina Baker	✓		40.0		12.0	Rakotondrajaona 161
Diospyros sclerophylla H. Perrier	✓		40.0		7.0	SF 16168
Diospyros amborelloides ined.	□		40.0		18.0	SF 21889
Diospyros antakaranae ined.			40.0			SF 5795
Diospyros taikintana ined.			40.0		18.0	Humbert 24919
Diospyros antongilensis ined.			40.0		10.0	SF 17883
Diospyros Platyclayx sp. 8			40.0	8.0	10.0	SF 27296
Diospyros sp. 5 branched female infl.			40.0		16.0	SF 19186
Diospyros brevipedicellata ined.			40.0	5.0	24.0	
Maximum DBH = 30-39.9 cm -- 20 species (8 undescribed)						
Diospyros occlusa H. Perrier	✓		35.0		23.0	Ravelonarivo 3486

Diospyros Maba sp. 5			35.0		15.0	Birkinshaw 1017
Diospyros calophylla Hiern	✓		32.0		25.0	Bernard 1658
Diospyros maculata ined.			31.5			Vasey 284
Diospyros bernieriana (Baill.) H. Perrier	✓		30.0	5.0	6.0	SF 24537
Diospyros bezofensis H. Perrier	✓		30.0		17.0	Gautier 3234
Diospyros ebenifera (H. Perrier) G.E Schatz & Lowry	✓	25.0	30.0		7.0	Decary 5239
Diospyros ferrea (Willd.) Bakh.	✓		30.0		5.0	SF 19681
Diospyros humbertiana H. Perrier	✓		30.0	8.0	10.0	SF 20742
Diospyros lanceolata Poir.	✓		30.0		7.0	Ramison 133
Diospyros manampetsae H. Perrier	✓		30.0	8.0	10.0	SF 20741
Diospyros platycalyx Hiern	✓	25.0	30.0	8.0	10.0	SF 6879
Diospyros vescoi Hiern	✓		30.0			SF 23282
Diospyros ramisonii (sp. 6 Subsessilifolia)			30.0		12.0	Ramison 94
Diospyros Mucronata sp. 3			30.0		15.0	SF 18318
Diospyros sp. 34 (decaryana)			30.0		20.0	SF 770
Diospyros Bernieriana sp. 12			30.0	8.0	10.0	SF 23322
Diospyros sp. 6			30.0		6.0	SF 25-R-303
Diospyros gracilipes Hiern	✓		30.0	2.0	12.0	
Diospyros lewisiae ined.			30.0	4.0	20.0	

Maximum DBH = 20-29.9 cm -- 27 species (15 undescribed)						
Diospyros squamosa Bojer ex A. DC.	✓		29.0		25.0	Bernard 1667
Diospyros labatiana ined.			28.0	2.0	16.0	
Diospyros parifolia H. Perrier	✓		25.0		16.0	Rakotonandrasana 924
Diospyros perrieri Jum.	✓		25.0		8.0	SF 12735
Diospyros urschii H. Perrier	✓		25.0		18.0	Rakotonandrasana 903
Diospyros sp. 28			25.0		20.0	SF 988

Diospyros Maba sp. 1		25.0		20.0	Schatz 2617
Diospyros chitoniophora ined.		25.0		12.0	Randrianaivo 1350
Diospyros subenervis (H. Perrier) G.E. Schatz	✓	25.0	1.5	10.0	
Diospyros velutipes (H. Perrier) G.E Schatz & Lowry	✓	25.0	3.0	13.0	
Diospyros dolichopoda ined.		25.0	3.0	15.0	
Diospyros mapingo H. Perrier	✓	24.0		25.0	Ratovoson 364
Diospyros analamerensis H.Perrier	✓	22.0		8.0	Ranirison 1150
Diospyros Subsessilifolia sp. 3		20.2		8.0	Malcomber 2068
Diospyros clusiifolia (Hiern) G.E. Schatz & Lowry	✓	20.0		18.0	Lehavana 174
Diospyros masoalensis H. Perrier	✓	20.0		14.0	Antilahimena 2649
Diospyros myriophylla (H. Perrier) G.E. Schatz & Lowry	✓	20.0		8.0	Guatier 5033
Diospyros quadrangularis ined.		20.0		10.0	Antilahimena 2876
Diospyros rubripetiolata ined.		20.0		18.0	Antilahimena 1316
Diospyros andohahelensis ined.		20.0		6.0	Randriamampionona 232
Diospyros mandenensis (Maba sp. 12)		20.0		5.0	Ramison 217
Diospyros Mucronata sp. 10		20.0		10.0	Rakotovao 3147
Diospyros Mucronata sp. 11		20.0		12.0	Rakotoarivelo 152
Diospyros sp. 29 aff. toxicaria		20.0		12.0	Rabenantoandro 833
Diospyros ankaranensis ined.		20.0	5.0	15.0	
Diospyros baroniana H. Perrier	✓	20.0	5.0	10.0	
Diospyros micrograciliples ined.		20.0	5.0	10.0	

Maximum DBH = 15-19.9 cm -- 13 species (5 undescribed)					
Diospyros Mucronata sp. 1		18.5		11.0	Randrianaivo 24
Diospyros mangabensis Aug. DC.	✓	18.0		16.0	Bernard 1636
Diospyros mahaboensis ined.		18.0	4.0	10.0	
Diospyros sp. 26		16.0		14.0	Antilahimena 2547

Diospyros boinensis (H. Perrier) G.E. Schatz & Lowry	✓		15.0	7.0	8.0	SF 6782
Diospyros cinnamomoides H. Perrier	✓		15.0		4.0	Amman 424
Diospyros lokohensis (H. Perrier) G.E. Schatz & Lowry	✓	10.0	15.0	8.0	10.0	SF 8863
Diospyros louvelii H. Perrier	✓		15.0		9.0	Ranaivojaona 539
Diopsyros myrtifolia H. Perrier	✓		15.0		6.0	Randriamampionona 295
Diospyros pruinosa Hiern	✓		15.0	10.0	12.0	Rabevohitra 4565
Diospyros subsessilifolia H. Perrier	✓		15.0		8.0	Randriamampionona 396
Diospyros noyesii (Diospyros sp. 3)			15.0		7.0	Noyes 1041
Diospyros sp. 30 Calophylla			15.0	8.0	10.0	SF 8871

Maximum DBH = 10-14.9 cm -- 18 species (11 undescribed)						
Diospyros parvifolia Hiern	✓		14.0		10.0	Antilahimena 2702
Diospyros Mucronata sp. 5			14.0		12.0	S. Randrianasolo 356
Diospyros Sclerophylla sp. 1			14.0		15.0	Andrianantoanina 1019
Diospyros birkinshawii ined.			14.0	2.0	15.0	
Diospyros olacinoides (H. Perrier) G.E. Schatz & Lowry	✓		13.0		8.0	Ramananjanahary 10
Diospyros boivinii Hiern	✓		12.0		7.0	Rakotovao 3701
Diospyros sp. 24 Pruinosa			12.0		8.0	Rakotovao 2846
Diospyros anosivolensis H. Perrier	✓		12.0	4.0	7.0	
Diospyros randrianasoloi ined.			12.0	2.0	20.0	
Diospyros Maba sp. 3			11.0		6.0	Razafitsalama 1077
Diospyros perreticulata H. Perrier	✓		10.0		3.0	Madiomanana 228
Diospyros pervillei Hiern	✓		10.0		12.0	Tahinarivony 267
Diospyros sphaerosepala Baker	✓		10.0		6.0	Antilahimanena 5489
Diospyros maxima ined.			10.0		6.0	Antilahimena 7607
Diospyros sp. 16			10.0		6.0	Ratovoson 808
Diospyros sp. 21 "aff. clusiifolia"			10.0		8.0	Razafitsalama 1069

Diospyros sp. 32		10.0		6.0	Antilahimena 2620
Diospyros Mucronata sp. 4		10.0		13.0	Antilahimena 596
Maximum DBH < 10 cm -- 17 species (13 undescribed)					
Diospyros Sclerophylla sp. 8		9.0		10.0	Birkinshaw 216
Diospyros randrianaivoi ined.		9.0	3.0	10.0	
Diospyros stenocarpa (H. Perrier) G.E. Schatz & Lowry	✓	8.5			Vasey 48
Diospyros sp. 17 "decaryoides"		8.0		12.0	Schatz 2546
Diospyros pseudovelutipes ined.		8.0	3.0	9.0	
Diospyros acutiflora ined.		7.0		7.0	Razakamalala 62
Diospyros betamponensis ined.		7.0		8.0	Bernard 2237
Diospyros callmanderi ined.		7.0		7.0	Callmander 519
Diospyros platyclada (sp. 9 Subsessilifolia)		7.0		8.0	C. Rakotonirina 9
Diospyros ratovosonii (Pruinosa sp. 1)		7.0		7.0	Ratovoson 19
Diospyros perglauca H. Perrier	✓	6.0		5.0	Leopold 151
Diospyros torquata H. Perrier	✓	6.0		3.0	SF 16713
Diospyros ravelonarivoi ined.		6.0		5.0	Ratovoson 653
Diospyros pervilleana (Baill.) G.E. Schatz & Lowry	✓	5.0		4.0	Raharimampionona 185
Diospyros Sclerophylla sp. 2		5.0		7.0	Nussbaumer 1442
Diospyros capuronii ined.		5.0	6.0	15.0	
Diospyros malcomberi ined.		5.0	3.0	10.0	
Species for which DBH data are not available, organized by maximum recorded height					
Maximum height ≥ 20 m -- 5 species (4 undescribed)					
Diospyros Sclerophylla sp. 6				30.0	Rasoavimbahoaka 186

Diospyros meyersii (Platycalyx sp. 3)			22.0	Meyers 125
Diospyros decaryana H. Perrier	✓	15.0	20.0	Randrianasolo 1373
Diospyros maxima ined.			20.0	Schatz 2847
Diospyros Mucronata sp. 9 (sp. 40)			20.0	McPherson 14621
Diospyros sp. 5 branched female infl.		15.0	20.0	SF 18266
Maximum height = 15-19.9 m -- 5 species (3 undescribed)				
Diospyros sp. 33 "schatzii"			18.0	Schatz 3064
Diospyros Bernieriana sp. 10			16.0	Andrianantoanina 175
Diospyros erinacea (H. Perrier) G.E. Schatz & Lowry	✓		15.0	Randriamampionona 40
Diospyros Bernieriana sp. 9			15.0	SF 3075
Diospyros subtrinervis H. Perrier	✓		15.0	Perrier 540
Maximum height = 10-14.9 m -- 15 species (9 undescribed)				
Diospyros erythrosperma H. Perrier	✓	10.0	12.0	SF 22219
Diospyros sclerophylla H. Perrier	✓		12.0	Razakamalala 846
Diospyros tampinensis H. Perrier	✓	10.0	12.0	SF 18077
Diospyros Platycalyx sp. 1			12.0	Malcaomber 1987
Diospyros Sclerophylla sp. 7			12.0	Schatz 1810
Diospyros sp. 40			12.0	Randriatafika 676
Diospyros latinervis ined.		3.0	12.0	
Diospyros hazomainty H. Perrier	✓	8.0	10.0	Perrier 2106
Diospyros quercina (Baill.) G.E. Schatz & Lowry	✓		10.0	Rakotoarivelo 81
Diospyros sphaerosepala Baker	✓		10.0	Rakotomalaza 1178
Diospyros makayensis (sp. 7 Subsessilifolia)			10.0	Razakamalala 5987
Diospyros tropophylloides ined.			10.0	Randrianarivony 132

Diospyros sp. 15		8.0	10.0	SF 20066
Diospyros sp. 36 "sahafariensis"		6.0	10.0	SF 24515
Diospyros zombitsiensis (Bernieriana sp. 11)		8.0	10.0	SF 11918
Maximum height < 10 m -- 27 species (7 undescribed)				
Diospyros coursiana H. Perrier	✓		8.0	Cours 765
Diospyros implexicalyx H. Perrier	✓	7.0	8.0	SF 22197
Diospyros obducta (H. Perrier) G.E. Schatz & Lowry	✓		8.0	Andrianjafy 834
Diospyros subfalciformis H. Perrier	✓	7.0	8.0	SF 24213
Diospyros sp. 32			8.0	McPherson 14729
Diospyros leucocalyx Hiern	✓	2.5	8.0	
Diospyros madecassa H. Perrier	✓	6.0	7.0	Rakotomalaza 782
Diospyros danguyana H. Perrier	✓	5.0	6.0	SF 27966
Diospyros geayana (H. Perrier) G.E. Schatz & Lowry	✓		6.0	Rabarimanrivo 61
Diospyros microrhombus Hiern	✓		6.0	Razakamalala 2579
Diospyros darainensis (sp. 2 Subsessilifolia)		5.0	6.0	Callmander 220
Diospyros sp. 23 opposite lvs. Ranomafana		5.0	6.0	SF 23908
Diospyros filipes H. Perrier	✓		5.0	Randriatafika 796
Diospyros laevis Bojer ex A. DC.	✓		5.0	Lehavana 364
Diospyros mangorensis H. Perrier	✓	3.0	5.0	Perrier 2042
Diospyros subacuta Hiern	✓		5.0	Evrard 11259
Diospyros tetraceros H. Perrier	✓	4.0	5.0	Perrier 1160
Diospyros beverleae ined.			5.0	Lewis 831
Diospyros pseudolanceolata ined.			5.0	N. Rakotonirina 423
Diospyros anjanaharibensis ined.			4.5	Ravelonarivo 427

Diospyros dicorphyeoides H. Perrier	✓	3.0	4.0	Perrier 17013
Diospyros mcphersonii G.E. Schatz & Lowry	✓	3.0	4.0	Perrier 8762
Diospyros thouarsii Hiern	✓	3.0	4.0	Bosser 16987
Diospyros patricei ined.			4.0	Antilahimena 1696
Diospyros meeusiana (H. Perrier) G.E. Schatz & Lowry	✓		3.0	Prance 30778
Diospyros enervis (H. Perrier) G.E. Schatz & Lowry	✓	1.0	2.0	Perrier 3010
Diospyros nidiformis G.E. Schatz & Lowry	✓		2.0	SF 422

8. APPENDIX 2: Summary of a newly-developed standardized sampling protocol to establish a reference dataset of Malagasy *Dalbergia* and *Diospyros*

The main purpose of the comprehensive, standardized protocol developed by ETH Zurich, MBG and University of Antananarivo is to provide a set of authoritatively identified reference samples of species of *Dalbergia* and *Diospyros* that can be used for a coordinated program to develop a set of reliable identification tools using material obtained along the value chain from standing trees to logs and finished products. Fieldwork conducted throughout the country will generate one or more samples of all members of *Dalbergia* and/or *Diospyros*. Each sample, taken from a single geo-referenced tree marked with a numbered tag and accompanied by a set of photos, includes a voucher herbarium specimen for identification, leaves for morphometric analysis, silica gel-dried leaf material and heartwood for molecular analysis, wood samples for anatomical analysis, and heartwood for mass spectrometry and chemical analysis. Field observations and data are also collected.

A) Samples to be collected per individual

a. Herbarium vouchers

To maximize accurate identification, a set of voucher herbarium specimens is collected if the tree is fertile (i.e., has fruits and/or flowers). If multiple individuals are available at a site, a minimum of six are sampled.

b. Tissue samples

A full set of samples (Table 7.1) are collected from the same individual as the voucher specimen and are named using its unique collection number.

Table 7.1

Tissue type	Analysis	Drying method
Entire leaves	Morphometric analysis	Pressed and stored in alcohol
Leaf tissue	Molecular analysis	Silica gel
Wood (bark, sapwood)	Wood anatomy	Alcohol
Heartwood	Mass spectrometry, chemical analysis	Air-dried or silica gel
Heartwood	Molecular analysis	Silica gel

c. Soil samples

A soil sample (ca. 50 ml) is also collected at each site for analysis in order to assess whether the distribution of species may be correlated with soil type.

B) Information collected for each sample

For each individual tree from which a set of samples is taken, the following information is recorded:

- General information: names of all the collectors, date and time of the collection, name and short description of the location
- Location: habitat description, GPS coordinates, altitude, vegetation type, bio-climate
- Herbarium vouchers and samples: a unique collection number, the scientific name if known, the local vernacular name, DBH, height, number of leaflets per leaf (for *Dalbergia*), what samples have been taken, how many photos have been taken

- Photos: to be taken of the sampling location, the entire tree, the tagged trunk, bark, flowers and/or fruits (macro lens), herbarium vouchers, leaves and wood samples
- Uses: local use of the species (construction wood, medicinal plant, ornamental plant, etc.)

C) Monitoring/re-visit

Sites will, in many cases, be re-visited in order to 1) collect fertile material (flowers and/or fruit) when the initial collection was made from a sterile tree, and 2) to monitor the status of tree and the site where it occurs. Individual trees can easily be re-located using the numbered tag attached to the trunk when the initial collection was made.

9. APPENDIX 3: List of studies and/or projects recently funded on *Dalbergia* or *Diospyros*

Population status and distribution studies:

- The University of Antananarivo was funded by the International Tropical Timber Organization (ITTO) for US$70,000 to conduct a study on standing stock assessment of *Dalbergia* species in protected and production areas. They tried to use satellite images (LandSat imagery) to assess standing stocks of rosewood and field verification of species by visiting populations while flowering/fruiting. Only US$40,000 was used for study, given that security issues in the field prevented field verification studies.
- WWF-funded project was to assess health/use status of 15 spp. of *Dalbergia* in 2010 in three studies areas, including Mt Francais and the NE corridor.
    - 2013 MBG did another study in one specific area (perhaps SE area?)
    - Uni and MBG will do an inventory on area-specific location
    - SE funded by ETC and Martin; NW funded by GIZ (identified location, not yet studied
- CITES-ITTO project (US$200,000) for one year to examine population status and distribution to support the elaboration of DNA barcoding tools;
- Rosewood Executive Committee doing stock inventory (Prime Minister's cabinet) including US$4 mil USD from World Bank
- Fondation Franklinia grant to the Missouri Botanical Garden for a Global Ebony Assessment, including conservation assessments of selected species of *Diospyros* in Madagascar: USD 375,000
- Darwin Initiative grant to Madagascar Fauna and Flora Group (including Missouri Botanical Garden) to conduct botanical inventory work around the Betampona Reserve and bring threatened species into ex-situ cultivation (including species of Dalbergia and Diospyros): £235,894

10. APPENDIX 4: List of equipment that the Wood lab of ESSA-Forêts needs to complete the handheld NIRS tool

by Tahiana Ramananantoandro – May 2016

Short term

Equipment	**Producer name**	**Price (US$US)**
Computer	-	900
Spectrocolorimeter	Lovibond Tintometer	16 000
FT-IR spectrometer	Bruker	22 000
NIR accessories for liquid and powder	VIAVI	800

Mid term

Equipment	**Producer name**	**Price (EUR)**
Precision balance (0 .001 g)	Ohaus	1 000
Cooler Minichiler	Hubert	3 000
Grinder RETSCH SM 100	Retsch	8 000
Grinder RETSCH ZM 200	Retsch	8 000
Autoclave	HMC	8 000
Vacuum pump	KNF	2 500
Hotplate	Stuart	900

Muffle furnace	Carbolite	2 500
Near Infrared Spectroscopy	Bruker	80 000
UV spectrometer	Perkin Elmer	27 000
Laboratory hood	Erlab	4 000
Fridge	-	600
Chemical equipment	-	5 000
Extinguisher	-	60

11. APPENDIX 5: List of equipment that the Plant lab of Plant Biology and Ecology (DBEV) needs

By Harisoa Ravaomanalina – May 2016

Short term

Equipment	Producer name	Price (USD)
02 Computers	Magasin CONCEPT Madagascar	900
01 Distillator	Maexi Madagascar	1 700
05 students microscope	VWR	3 000
01 Owen 150°	Medical international Madagascar	3 000
01 Precision balance (0 .01 g)	VWR	1000
01 Lab microtom	WSL Switzerland	6 500
01 microtom GSL	WSL Switzerland	3 000
02 Inverter (onduleur)	Magasin CONCEPT Madagascar	200
02 microscale microscope	-	-
01 Microsoft analysis	-	1200

Mid term

Equipment	Producer name	Price (EUR)
Machine tool	Delta Madagascar	2 700
01 Lab microtom	WSL Switzerland	6 500
01 microtom GSL	WSL Switzerland	3 000
Chemical equipment	VWR	8 000
Chemical products	VWR, Fisher	8 000