WRI INDONESIA

WORKING PAPER

Bridging Science and Law: Aligning Forensic Wood Analysis with Indonesia's Forest Law Enforcement to Tackle Illegal Timber Trade

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CONTENTS

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Highlights

- Wood forensic analysis can be used to verify information that is key to establishing legality; namely, timber species and origin.
- Indonesian law enforcement agencies currently employ wood anatomy analyses for species identification; however, this method cannot be used to verify claims about timber origin.
- The need for forensic analysis for origin verification is clear, as Indonesian laws require evidence to prove the timber was harvested illegally from designated forest zones *(kawasan hutan)* to establish a crime.
- Wood identification methods that can be applied for origin verification, such as DNA analysis and stable isotope analysis, can help law enforcement verify claims on origin. However, this would require Indonesia to accelerate the development of timber reference databases and lab accreditation processes.
- Most sampling efforts to build reference databases for wood identification methods have been driven by Indonesia's universities, researchers, and non-profit organizations. Greater involvement from government agencies is necessary to effectively scale up the use and application of these methods.
- Timber consumer countries are likely to continue mandating more robust traceability requirements, which will require companies and timber producers in Indonesia to adjust their tracking systems and technical capacity. The availability of reliable and rapid methods that can support law enforcement in verifying claims of timber species or origin is, therefore, crucial.

Executive Summary

Context

The illegal timber trade has an estimated global value of US$51 billion–$152 billion. In Indonesia, the Corruption Eradication Commission (Komisi Eradikasi Korupsi; KPK) estimates that the costs of the illegal timber trade amounted to $6.5 billion–$9 billion between 2003 and 2014. Despite ongoing efforts and policies, such as a moratorium on the utilization of primary forests and peatlands, as well as the adoption of a more integrated, cross-sectoral "multi-door approach" to prosecute environmental crimes (UNDP Indonesia 2020), challenges remain in tackling illegal logging and associated trade in Indonesia. These challenges are largely due to limited resources for effective law enforcement and monitoring.

Confirming claims about the geographical origin and species of timber is often necessary to establish the legal nature of the timber trade. Our previous working paper, "How Wood Identification Technologies Help Ensure Timber Legality in Indonesia," outlines how timber species and origin are frequently falsified to avoid paying the legal obligations associated with trading endangered or high-value timber species, as well as to avoid paying royalties. Our analysis of the rosewood (Dalbergia latifolia) supply chain found that documents are commonly forged to avoid complications related to obtaining additional harvesting permits and paying timber royalties, as the species is currently listed under Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). As these levies are calculated based on the commercial value of a timber species and the region from which it was harvested, illegal traders would often attempt to pass rosewood off as a non-CITES species. They might also claim that the timber had been harvested from private forests, because under Indonesian law, levies are only imposed on timber harvested from state forests.

Effective law enforcement in Indonesia requires reliable and accurate tools to verify claims about seized timber products, particularly concerning geographic origin. Multiple wood identification methods—ranging from chemical to genetic analysis—are available to support the verification of geographic origin. However, existing reference databases have limited data on timber species located across Indonesia, and there is currently no recognized national-level database run by an Indonesian institution.

In comparison, the Forest Research Institute Malaysia (FRIM) has developed DNA databases for several commercial timber species in Malaysia and has actively supported enforcement agencies in using genetic analysis to verify origin claims for domestic illegal logging cases. Beyond enforcement applications, the availability of genetic, anatomical, and chemical data from trees and wood samples can also enhance supply chain transparency and promote a more responsible consumption of timber products (World Forest ID 2024).

This working paper identifies the key stakeholders who can benefit from the use of advanced wood identification methods and promotes collaboration to increase their application. It also reviews existing supporting legislation and examines the barriers that currently hinder the wider administration of these methods.

Key findings

- Verifying claims on the species and origin of timber products using wood identification methods can support improved enforcement and compliance with policies aimed at curbing illegal timber trade.
- Wood anatomy is currently the main identification method used in Indonesia (for the identification of species). However, other identification methods, such as stable isotope analysis and DNA analysis, have the potential to provide alternative verification tools for law enforcement purposes, particularly by enabling the identification of timber origin. In 2024, IPB University acquired a direct analysis in real time (time of flight) mass spectrometry (DART-TOF-MS) machine that can be used to provide the rapid identification of species.
- The application of wood identification methods relies heavily on the interest, willingness, and capacity of enforcement agencies and other key stakeholders to be able to use and promote these tools.
- Pursuing lab accreditation is an important step toward integrating these methods into law enforcement processes in Indonesia and ensuring compliance with the procedures needed to collect evidence under Indonesian law. One widely used accreditation standard for laboratories is ISO 17025. The Center of Sustainable Forest Development (Pusat Pengembangan Hutan Berkelanjutan; P2HB), under the umbrella of the Ministry of Forestry (MoF), manages a well-established ISO 17025 accredited lab for anatomy analysis, which is highly referred to by enforcement agencies and the private sector. In addition, the Forest Genetics Lab at IPB University is currently preparing for accreditation as part of an existing ISO certification of its laboratories.

- Standardized protocols for the sampling, collection, and analysis of DNA, stable isotope, and DART-TOF-MS methods in Indonesia remain limited. In light of this, WRI Indonesia and IPB University produced a guideline for DNA forensic sampling, collection, and analysis that can be used as a reference for enforcement agencies and scientists. Other relevant protocols developed by foreign labs and institutions could be adopted by labs in Indonesia, such as those used by the United Nations Office on Drugs and Crime's (UNODC) Wildlife and Forest Crime Analytic Toolkit.

Recommendations

Prosecutors, investigators from the Ministry of Forestry and the National Police are the primary beneficiaries of wood identification technologies, as they are responsible for examining and collecting evidence. As mandated by Law No. 18/2013 on the Prevention and Eradication of Forest Destruction, they are required to provide evidence that timber was harvested without a permit from a forest zone to establish that illegal logging had taken place. Therefore, these institutions should strengthen their collaboration with researchers and scientists who specialize in wood identification methods and experiment with newly developed techniques, such as DNA and stable isotope analysis for origin verification, to verify species and origin in cases of suspected illegal logging.

In terms of infrastructure, the development of wood reference data for each wood identification method is essential. Indonesia currently has a robust collection of reference samples only for wood anatomical analysis. The majority of the sampling effort to build reference data for other methods has been led by non-state actors, such as universities, researchers, and nonprofit organizations. These efforts are often limited in terms of time, funding, and capacity. Indonesia is home to around 4,000 timber species, but only 186 of these are considered commercial (Damayanti et al. 2019; Djarwanto et al. 2017).

The Indonesian government should actively support the collection of wood reference datasets for DNA, stable isotope, and DART-TOF-MS analysis. This could include prioritizing the collection of data for key commercial timber species and deploying personnel from the National Research and Innovation Agency (Badan Riset dan Inovasi National; BRIN) and forest authorities at the subnational level to collect wood samples from forests. Forest auditors employed by certification bodies under the national Timber Legality Assurance System (Sistem Verifikasi Legalitas Kayu; SVLK) could also assist the development of such databases. The breadth of these reference databases can be further enhanced by enabling data-sharing efforts with foreign authorities and among research institutions that conduct chemical and DNA analysis. With more comprehensive reference databases (i.e., containing more data on timber species and geographic chemical signatures), the government could also harness these technologies to support ongoing monitoring efforts, such as verifying timber levies at harvest or conducting checks on the timber legality assurance system.

Wood sampling and species prioritization efforts would be more efficient if carried out jointly with relevant authorities, including Indonesia's provincial Sustainable Forest Management Offices (Balai Pengelolaan Hutan Lestari; BPHL), more than 500 Forest Management Units (Kesatuan Pengelolaan Hutan; KPH), and local Forestry Offices, all of which oversee timber traceability and forest monitoring. With additional resources and coordination, including sample submissions from forest concession holders, these agencies can collect wood samples nationwide and accelerate the adoption and expansion of wood identification methods.

BRIN can play a more central role in providing identification services for genetic and chemical analysis, particularly by employing full-time research staff dedicated to wood identification. While universities can manage the labs and the equipment, most experts are also full-time lecturers at the universities. As such, having dedicated staff within BRIN that can provide wood identification services is key to ensuring these methods are effectively used.

Both BRIN and P2HB—supported by the extensive Xylarium Bogoriense and Xylarium Indonesia collection—can play a central role in managing Indonesia's wood reference data and providing anatomy analysis. Recent tools like the Automatic Wood Identification Tool (Alat Identifikasi Kayu Otomatis; AIKO) app and the Xylotron hand-held identifier apply machine learning for rapid wood identification. However, they rely on fully digitized anatomical datasets, including species characteristics and macro- and microscopic images (Hidayat 2025).

BRIN has the authority to collect primary research data from individual researchers, funders, and educational institutions and grant third-party access (BRIN 2023), providing a strong basis for centralized management of Indonesia's wood reference datasets. However, dataset management remains fragmented, as individual researchers still control their own samples and digital data and decide how they are shared.

Lastly, it is essential to support the accreditation of wood identification labs—especially those outside Java—to address illegal logging hotspots in Indonesia, where law enforcement needs fast, reliable identification methods. WRI Indonesia and IPB University are already training local universities in Aceh, South Sulawesi, and West Papua provinces on DNA and anatomy analysis. Supporting these labs in gaining accreditation would strengthen provincial investigations of timber moving through these areas.

About this working paper

In 2021, World Resources Institute (WRI) published a working paper on the implementation of wood identification technologies in Indonesia, titled "How Wood Identification Technologies Help Ensure Timber Legality in Indonesia" (Cetera et al. 2021). This working paper provides an update on the research, in light of WRI's continuing engagement with enforcement agencies, forest authorities, and wood scientists on the topic. The analysis below aims to describe how these agencies work and identify ways to strengthen collaboration between law enforcement agencies and key stakeholders to support the implementation of forensic wood analysis in Indonesia and address the illegal timber trade. This present working paper also outlines updates on policies and legal instruments that support the implementation of wood identification technologies in Indonesia, key stakeholders who will benefit from their application, the legal formalities required to harness these technologies, and the need for expanding reference datasets.

Although this study refers extensively to international literature and foreign lab works, the main analysis emphasizes the application of wood identification technologies in Indonesia. Citations on how foreign labs provide identification services, build reference databases, and approach lab accreditation are included for comparison to give stakeholders a broader view of common practices for identification services. Accordingly, the scope of this study is limited to discussions on capacity, legal frameworks, and enabling factors for the implementation of wood identification efforts. Other important subtopics, such as estimations of the total funding required to develop wood identification infrastructure in the country and the feasibility of Indonesian institutions to manage wood reference datasets, are not yet covered and shall be addressed in further research.

Introduction

The global illegal timber trade is estimated to be worth $51 billion–$152 billion, making it the third-largest transnational crime in the world, behind counterfeiting and drug trafficking (INTERPOL 2019). In response, various legal instruments have been developed over the last few decades aimed at tackling the trade of illegal timber. Consumer countries, for instance, have developed laws to prevent the import of illegal timber products, requiring the verification of legality and sustainability in supply chains. The European Union (EU), under its Regulation EU 2023/1115, adopted the EU Deforestation Regulation (EUDR) in 2023, which is set to replace the EU Timber Regulation (EUTR). The EUDR covers a wide range of products linked to deforestation, such as soy, cocoa, coffee, cattle, palm oil, and rubber, and includes more stringent requirements than the EUTR, such as providing geolocation information of the product's origin as part of the due diligence process (European Commission 2025).

Australia also amended its Illegal Logging Prohibition Act, which was first issued in 2012, in 2024. The amendment introduced new due diligence requirements for importers to give notice before importing or processing regulated timber products (Parliament of Australia 2025). Other consumer countries, such as Japan, Korea, and the United States, have also established national measures to prevent illegal timber products from entering their markets (World Resources Institute 2024). To maintain its position as a producer of legal and sustainable timber, Indonesia will need to continue investing in wood identification technologies to respond to these emerging due diligence requirements from major consumer countries.

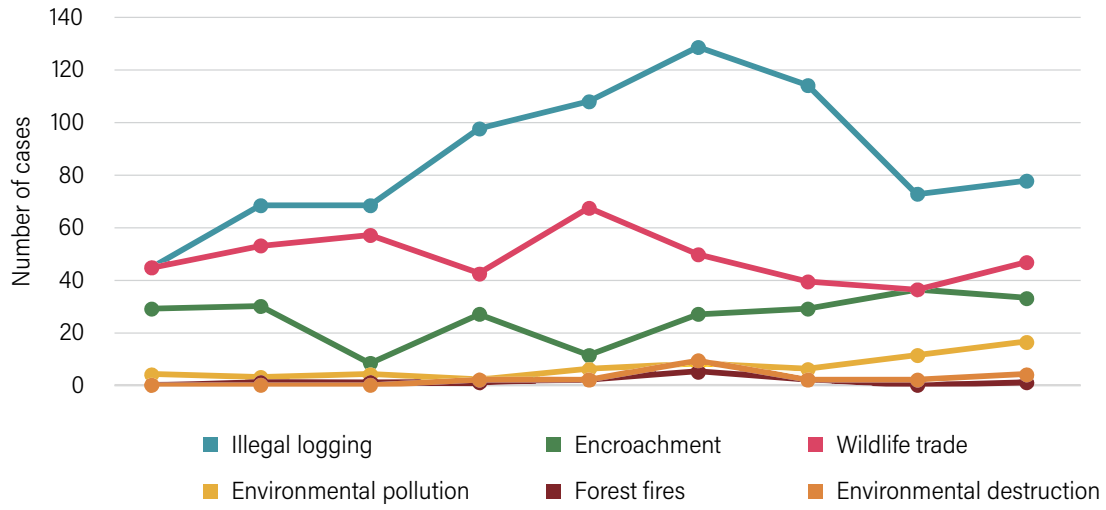
Illegal logging has led to significant forest and biodiversity loss across Indonesia, impacting the national economy and hurting local communities and their livelihoods (FERN 2025). An analysis by the KPK found that between 2003 and 2014, only 19–23 percent of the country's total log production was recorded by the government (KPK 2015). This suggests that 77–81 percent of total timber production was unreported, with unclear origins, and had not been harvested in accordance with the applicable legal provisions related to the payment of timber levies. The resulting loss to the Indonesian government is estimated at $6.5 billion–$9 billion.[1]

As part of efforts to combat illegal logging, Indonesia and the EU ratified a Voluntary Partnership Agreement (VPA) in 2014 to promote trade in legal timber products and improve forest governance. As part of this agreement, Indonesia became the first country to issue Forest Law Enforcement, Governance, and Trade (FLEGT) licenses and was the only country to have done so until Ghana launched its licensing system in August 2025. Indonesian timber products carrying these FLEGT licenses are considered to be compliant with

the requirements of the EUTR and, as a result, are exempt from additional due diligence requirements when placed on the EU market (Chitra and Cetera 2018). The VPA also reformed Indonesia's national traceability system, called the Timber Legality Assurance System (Sistem Verifikasi Legalitas Kayu; SVLK), and supported civil society organizations in conducting Independent Forest Monitoring (IFM).

While Indonesia has strengthened forest protections and enforcement since then, with the latest data from Global Forest Watch showing an 11 percent decrease in primary forest loss between 2023 and 2024 (Goldman et al. 2025), demand for agricultural products and logging still drives deforestation across the country. As shown by the latest data from the Directorate General on Law Enforcement for Environment and Forestry (Direktorat Jenderal Penegakan Hukum Kehutanan; Gakkum), illegal logging remains pervasive. Cases that relate to illegal logging are still the most commonly investigated, compared to all other types of cases associated with nature crimes and environmental damage (wildlife crimes, forest fires, pollution, etc.). Figure 1 provides a detailed view of the number and types of cases investigated by Gakkum between 2015 and 2023.

Figure 1 | **Number of cases investigated by Gakkum by type**



Source: Gakkum 2025.

Generally, timber trade legality is established through the identification of species and geographic origin. This information is frequently falsified by criminals (Dormontt et al. 2015). Government Regulation No. 36/2024 determines the amount of royalties owed based on the species and the region in which the timber was harvested. The royalties for merbau (*Intsia bijuga*), for example, are higher than those for teak (*Tectona grandis*), and the royalties for timber harvested in Kalimantan are higher than for timber harvested in Java. Furthermore, most criminal articles under Law No. 18/2013 on the Prevention and Eradication of Forest Destruction require information on origin and evidence that logs or timber were harvested illegally from a designated forest zone, or *kawasan hutan*.

Indonesia has already developed a national online timber traceability system to capture supply chain information on the harvest, planning, production, and payment of royalties for timber sourced from designated areas within forest zones. Companies self-report this information into the system. This is where wood identification methods can be used: to verify compliance and detect any potential violations that are related to the payment of royalties or harvesting outside permitted areas.

Despite having a national traceability system, Indonesia continues to face challenges in tackling illegal logging and associated trading, mainly due to a lack of resources to support effective law enforcement and weak monitoring (Tacconi et al. 2019). Between December 2018 and January 2019, for example, Gakkum seized 384 shipping containers with around 6,000 cubic meters (m^3) of sawn merbau (*Intsia bijuga*) from Papua. The shipments had documentation, but some of the information had been falsified, namely on the origin of the timber (EIA and Kaoem Telapak 2021). Allegedly, the falsified documents were meant to mislead field officers and facilitate the departure of timber from Papua to other port cities (EIA and Kaoem Telapak 2021). This is a prime

example of timber laundering: converting illegally harvested logs to legally certified timber by exploiting legal loopholes, such as those relating to the transport of timber (Transparency International 2010).

This case illustrates how it remains possible for illegal timber to make its way out of Papua without being detected by local enforcement agencies. Furthermore, if and when an investigation is opened, law enforcement personnel are then faced with the challenge of completing it within 90 days, as stipulated by Article 39 of Law No. 18/ 2013. In high-profile illegal logging cases involving falsified documents, investigators must verify claims related to species and origin and correctly identify the wood-based products—including those that have been processed—while operating under a tight deadline. As such, Indonesian enforcement agencies need access to identification tools that can rapidly and accurately verify information written in key documents, such as customs declarations and transport documents, to help establish the legal (or illegal) nature of the timber being traded.

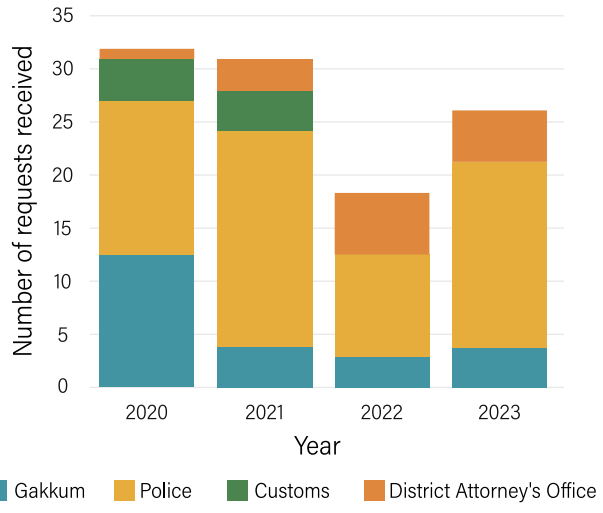
As a science-based method, wood identification can serve not only as a verification tool for law enforcement to identify errors or false claims made about wood samples, but the results can also be used as evidence presented in court. In Indonesia, according to various stakeholders interviewed between 2024 and 2025, the cases that go to court usually require experts to identify the species and harvested volume to estimate the value of the seized timber. The results can also be used for the broader identification of origin and to prove that timber had been illegally harvested from a forest zone. This can be done through DNA analysis or stable isotope analysis of samples from seized logs and comparing them with wood samples that are available in a reference database.

Wood identification methods have been used in illegal logging cases in Europe and the United States, primarily to verify origin, and have supported both enforcement actions and convictions. In 2016, a timber mill owner in Washington State was sentenced to six months in jail, six months of home detention, and three years of supervised release for violating the U.S. Lacey Act by trafficking bigleaf maple illegally cut on national forest land (Gaworecki 2016). The owner was also ordered to pay nearly $160,000 in restitution. Prosecutors used a DNA reference database for bigleaf maple, which was built by the U.S. Forest Service, in partnership with Double Helix Tracking Technologies, the University of Adelaide, and the World Resources Institute, to prove the timber originated from within the Gifford Pinchot National Forest (Mason and Parker-Forney 2018). The database included the analyzed samples of 400 bigleaf maple trees, as they had been identified as a high-priority species for illegal logging. The DNA profiles from the database were matched to the seized stumps (Gaworecki 2016).

Most recently, non-profit organization World Forest ID and research laboratory Agroisolab GmbH have combined wood identification methods with artificial intelligence to cross-reference timber samples to authenticate their origin. In collaboration with Belgium's federal health-and-food safety agency, they identified 261 tons of Russian timber entering Belgium, despite a ban on the import of Russian timber that had been in place since July 2022 (World Forest ID 2023).

In Indonesia, macroscopic wood anatomy is already being used by law enforcement agencies to screen and verify timber species, but the use of wood identification methods to verify claims on origin, for example, through DNA analysis, remains limited. Figure 2 presents the number of wood anatomy analysis requests BRIN and the Ministry of Forestry's BPHL received from Jambi and South Sulawesi between 2020 and 2023. To conduct these analyses and identify collected samples, Gakkum, police, customs, and other enforcement agencies rely heavily on third parties.At the national level, the MoF's P2HB operates the Xylarium Bogoriense, which has collected more than 200,000 wood samples and developed the Automatic Wood Identification Tool (AIKO) to identify the commercial name of a sample. While AIKO is a useful screening tool, it is limited in its scope of application and cannot provide information on the chemical and genetic properties of timber samples to verify their origin. It is, therefore, necessary to strengthen AIKO's functionality and reliability, including by expanding the reference data that the app draws from with more timber samples. The database currently contains reference data from 1,700 timber samples (Damayanti et al. 2025).

Figure 2 | **Number of wood anatomy identification requests received by BPHL Jambi, BPHL South Sulawesi, and BRIN in 2020-2023**



Source: WRI authors, from BPHL Jambi, BPHL South Sulawesi, and BRIN.

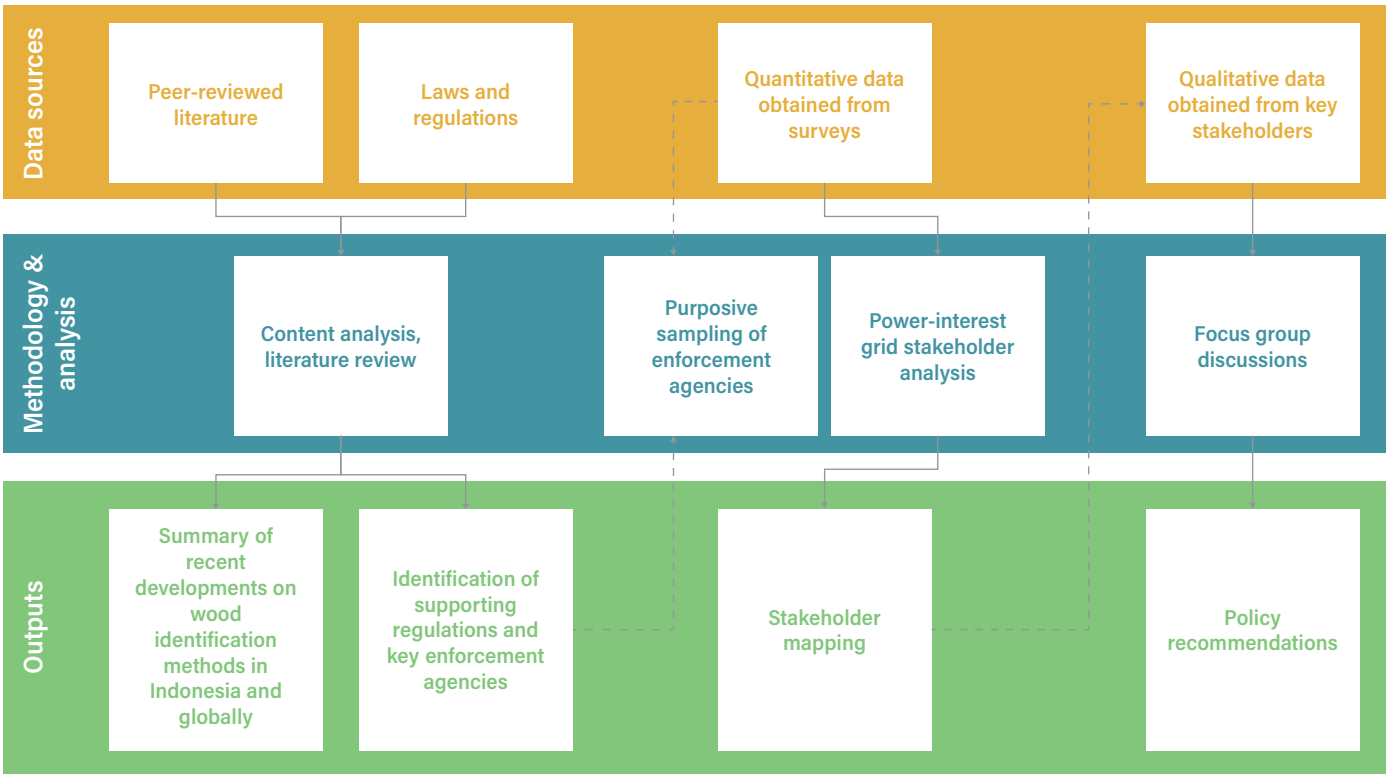
There is also a need for more rapid and efficient species identification, as wood anatomy alone cannot meet all existing identification needs for enforcement purposes, particularly related to origin. Although laboratory capacity for the genetic and chemical analysis of wood already exists or is being built, obstacles remain for the wider application of these methods in Indonesia. Such wider application includes expanding sampling efforts with more geographic locations in reference databases, obtaining legal recognition of wood identification methods in forensic investigations, and obtaining accreditation for the labs conducting the analyses. It is important to scale up these methods to improve actions to combat forest crimes and illegal logging across Indonesia.

Methodology

The information and data presented in this report were collected through a literature review, surveys with potential users, and interviews with experts. The authors reviewed relevant laws and regulations, as well as various peer-reviewed journal articles and reports, to detail the strengths of wood identification methods and the current state of global wood reference databases for each method.

Based on the surveys and interviews, the authors proceeded to map stakeholders based on their interests and power using a power-interest grid approach. Each stakeholder's level of power and interest was assessed using 1–4 scale, where a score of 1 represents the lowest and 4 represents the highest degree of power or interest. The surveys provided insight into which institutions have an interest in conducting wood identification analyses and which authorities have the power to execute and/or influence the implementation of the different wood identification methods. Stakeholders were then further engaged through a series of workshops and focus group discussions designed to foster a shared understanding among law enforcement agencies and other relevant stakeholders in advancing wood identification methods, identify potential risks and clarify the role and objective of each stakeholder, and prioritize the needs of stakeholders to guide resource allocation and the development of strategic interventions. The list of respondents and discussions can be found in Appendix A. Figure 3 provides a summary of the methodology applied.

Figure 3 | **Methodology**



Source: WRI authors.

Development of wood identification methods and the need for comprehensive wood reference data

Several methods of wood identification technologies are currently available, and selecting the most appropriate one depends largely on the specific question being asked. As noted in the Introduction, if the aim is to identify the country of harvest, such as in the World Forest ID and Agroisolab case involving Russian timber entering Belgium, the specific question is whether the timber originated from Russia, due to the trade ban. In contrast, in the bigleaf maple cases in Washington State, the question was whether a specific sample of confiscated wood came from a particular stump. This question required a very different methodology and far greater granular sampling of reference samples.

Box 1 summarizes the common types of wood identification methods and the information they can provide. Further details on these methods and comparisons of the type of data they provide can be found in WRI's previous working paper (Cetera et al. 2021).

In a previous WRI working paper, Cetera et al. (2021) provided an overview of the wood identification methods available in Indonesia and discussed their potential to support timber traceability and the building blocks needed for future implementation. The working paper found existing capacity to conduct wood anatomy analysis. However, to achieve a wider uptake of a broader set of analytical methods, including chemical analysis to verify claims on both species and origin, some enabling conditions were not yet in place. Two prerequisites are key to enabling wood identification methods to verify origin and species: first, access to the necessary technological equipment and trained staff to operate them; second,

Box 1 | **What information can different wood identification methods provide?**

Wood anatomy

Wood anatomy relies on the analysis of the composition of wood cell structures. The anatomical properties of wood are affected by taxa (***family, genus, species***) and, to some degree, by the environment in which the tree grows. Using reference data, wood anatomy can differentiate samples based on taxa. In most cases, identification can only be achieved up to genus (Dormontt et al. 2015).

DNA analysis

When applied to timber, DNA analysis can identify a single tree and differentiate between multiple species of wood (Schröder and Blanc-Jolivet 2022). Identifying species through this type of analysis is referred to as DNA barcoding. As the genomes of plants and animals are constantly changing, there can also be differences in DNA within a single species, depending on the geographic origin of individuals (Schröder and Blanc-Jolivet 2022). As such, DNA analysis can also be applied to identify the origin of timber, using the genetic patterns of wood species (Jiao et al. 2020). This is referred to as population genetics.

Stable isotope analysis

Stable isotope analysis, which can be used to trace origin, analyzes the chemical properties of samples by compiling information about the distinct ratio of isotope elements, commonly carbon, hydrogen and oxygen. Climate conditions and other anthropogenic factors impact the ratio of stable isotopes of certain elements within the tissue of the wood sample (Deklerck 2023).

The results of stable isotope analysis can be very granular. A study conducted by Lee et al. (2015), for example, was able to identify different hydrogen and oxygen compositions between Korean red pine timber growing inland versus in coastal areas. The stable isotope ratio of a wood sample can therefore be compared to another sample to verify claims about its origin. This analysis relies on reference data containing isotope ratios from around the globe.

Direct analysis in real time (time of flight) mass spectrometry (DART-TOF-MS)

DART-TOF-MS or DART is another type of chemical analysis that can be used for wood identification. Unlike stable isotope analysis, DART can be used to verify claims about species as it relies on metabolites/toxins produced by related strains and/or species. Using those results and probability scoring, DART can identify entries that have a chemotype profile that is most similar, producing a list of potential matches and their associated probability score (Price et al. 2022).

Source: WRI authors.

a sufficient number of analyzed reference samples to allow comparisons (Gasson et al. 2021).

The availability of reference data varies greatly based on the type of identification needed—that is species versus origin—and the method used. At the global level, it has been estimated that, for species identification, 100 percent of reference data exists for global priority timber taxa[2] using wood anatomy. By contrast, only an estimated 41 percent of reference data exist for DART-TOF-MS (Low et al. 2022). For origin identification, Low et al. (2022) estimate the availability of reference material to be even lower at less than a quarter.

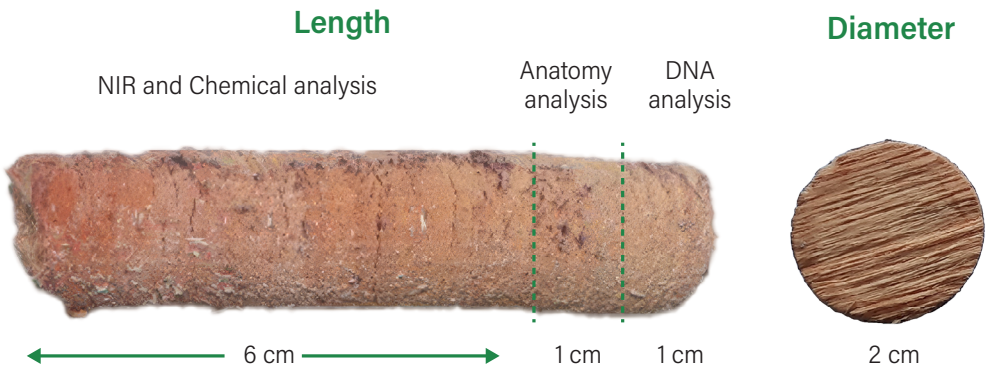
As such, although the technologies discussed above already exist, the reference data needed to use them effectively are often incomplete. In Indonesia, for example, the Xylarium Bogoriense has the largest collection of wood samples in the world, housing 200,000 samples as of November 2022. However, only a limited number of stable isotope reference samples have been collected and analyzed to date.[3] As the identification methods mentioned in this paper collect and analyze different types of data—but also store and format data differently—there are important differences between their results.

Box 2 | **How much wood does each identification method require to conduct an analysis?**

As part of WRI-IPB's collaborative activities, IPB University has been collecting samples from core, bark, leaf, and soil of select species to build reference datasets (Dwiyanti and Siregar 2024b). Collecting wood core is particularly important, as one sample can be extracted and analyzed using various identification methods. This approach can save time and resources for developing reference datasets, as there is no need to conduct different sampling missions for each identification method. Figure B2.1 illustrates how IPB University's research team divides wood core samples for each identification technique.

Source: Reproduced from Tim Riset Wood ID (2025).

Figure B2.1 | **The size of core wood samples for each identification technique**



Source: WRI authors, from IPB University (2025).

DNA analysis

Reference data for DNA barcoding for the identification of species are available via the National Center for Biotechnology Information (NCBI) platform.[4] Data for popular commercial timber species are already available because researchers all over the world are required to upload their DNA sequences as a prerequisite to publishing their work.

NCBI does not include reference data for population genetics for the identification of origin, nor is the information—to the knowledge of the authors—publicly available in any other databases. In Indonesia, datasets are individually managed and stored by universities and research institutions, among other organizations. Scientists collaborate by individually sharing data for research in the absence of "a single database." WRI and IPB University have collected samples of three commercial timber species as part of their collaboration: eboni (*Diospyros celebica*), meranti merah (*Shorea leprosula*), and bengkirai (*Shorea laevis*). Additional reference data for population genetics have been collected for ulin (*Eusideroxylon zwageri*), palahlar (*Dipterocarpus hasseltii*), kapur (*Dryobalanops camphora*), raru (*Cotylelobium melanoxylon*), and sonokeling (*Dalbergia latifolia*) (Dwiyanti and Siregar 2024b).

Stable isotope analysis

There is currently a need to expand the available reference data analyzed for stable isotope ratios to improve the applicability of the method, both geographically and across timber species (Watkinson et al. 2022; Boeschoten et al. 2023). Some renowned stable isotope analysis laboratories, such as those at AgroIsoLab and the University of Adelaide, manage reference data for identification purposes and share those data through bilateral treaties with partner institutions. In 2024, IPB University and BRIN scientists received stable isotope analysis training from World Forest ID and University of Adelaide experts. Through World Forest ID, laboratories can test against existing stable isotope ratio data via their evaluation platform; however, this is currently active for only a select number of species and regions.

In Indonesia, researchers at IPB University have conducted extensive studies using DNA analysis, while the application of chemical identification—that is stable isotopes and DART—is still relatively new. For chemical identification, IPB University has so far collected only three commercial species,[5] with the addition of ramin (*Gonystylus bancanus*), for which sampling expeditions began in 2025.

DART-TOF-MS

With regard to reference data, DART allows for transfers of spectra data—that is the unique pattern of electromagnetic radiation emitted or absorbed by a substance typically shown as a graph of intensity versus wavelength or frequency—from one machine to another. The main database used for DART analyses for wood identification is called the Forensic Spectra of Trees (ForeST©) and is managed by the U.S. Fish and Wildlife Forensic Laboratory, which contains heartwood reference spectra for species identification (Deklerck 2023).

As explained above, every technology to identify species and/or origin requires different types of data and datasets. Some datasets are centralized in a single storage or platform, as is the case with ForeST© for DART-TOF-MS and the NCBI platform for DNA barcoding. In practice, most datasets are managed and stored locally by universities and research centers, and are not accessible to the public. In principle, data outputs such as statistical spectra analysis, chemical composition, and genetic information of timber species are transferable and can be shared. However, several intellectual property and legal considerations should be met, depending on the institutional policies and national regulations in place.

Beyond the availability of databases, there is also a need for these systems to exchange data and information across institutions and borders. As Kaulen et al. (2023) highlight: "The biggest challenges are not to be found in the availability of forestry technology but in the interoperability of the resulting data and in the economic incentives to (further) develop digital technology."

Because illegal timber trading is considered a transnational crime, tackling this issue requires coordinated cross-border collaboration and the exchange of information. Ideally countries need access to relevant reference databases for effective law enforcement of illegal logging cases, particularly through the use of wood identification (Damayanti et al. 2024). For example, if German port authorities receive a suspected illegal shipment of merbau timber (*Intsia bijuga*) from Papua and need to verify its origin, they would have to contact a lab in Indonesia, such as at IPB University or BRIN, for support, if their own labs lack the necessary reference data. However, under the current international legal framework—namely, the Nagoya Protocol under the Convention on Biological Diversity—German labs, IPB University, and BRIN would need to enter a formal agreement before any datasets can be transferred—an extremely time-consuming administrative process.

In practice, state and private research institutions have turned to establishing bilateral and multilateral transfer agreements (MTAs) with foreign partners to enable this process. However, setting up these MTAs can take time, which is problematic, as enforcement agencies are typically faced with tight investigation timelines.

The Asia-Pacific Economic Cooperation (APEC) Experts Group on Illegal Logging and Associated Trade (EGILAT) highlighted the importance of sharing wood reference data in a recent publication (Damayanti et al. 2024). The report noted

that Indonesia's readiness for forensic wood is particularly low, especially "in terms of the availability of experts, regulations, capacity building and education, database, and finance." It further outlined potential solutions for more efficient data-sharing, including the use of queries that could access data in its original location through an algorithm and without requiring institutions to share their data directly.

The report's findings should be further explored by relevant Indonesian institutions, such as BRIN, to learn ways to promote wood reference data-sharing from the international scientific community. Such an approach can help prepare research institutions and the Indonesian government for deeper cooperation with APEC members and advocate for similar policies in other countries to bolster efforts to combat transnational illegal timber trading.

The implementation of certain wood identification methods faces additional challenges, including higher costs and longer processing times. Enforcement agencies engaged with this research have often raised concerns about these constraints, as they must operate with a limited budget and a deadline of 90 days to complete their investigations. Verification of origin using DNA and stable isotopes analysis is generally more costly than species identification. For example, the P2HB charges around IDR250,000 (about $15) per sample for genus identification using wood anatomy. In comparison, when IPB University was asked by an enforcement agency in 2014 to track the origin of a suspected illegal merbau shipment from Papua, more than IDR20 million (about $1,184) was needed to analyze four wood samples as some of the necessary materials for analysis had to be procured from overseas.

Processing time also varies. Scientists at IPB University estimate that DNA analysis for species (barcoding) and origin (population genetics) can be completed within two weeks, assuming all of the material is available and reference databases are available. Meanwhile, DNA microsatellite analysis for matching stumps and logs requires more time—typically four to six weeks—as it relies on a visit to the suspected crime scene (Dwiyanti and Siregar 2024b).

These estimates are consistent with those in other Southeast Asian countries. In Malaysia, assuming wood reference databases and required material are available, species and population identification can be conducted in about two weeks, according to interviews conducted under the study. In comparison, wood anatomy analysis in Indonesia can be completed in 7 to 14 days.

As previously highlighted, Indonesia already has the necessary equipment for wood identification purposes. The key component required is a wood reference database. The costs to collect samples can vary greatly, depending on where the sampling needs to be conducted. For example, joint IPB University-WRI Indonesia missions to sample three species *(Shorea leprosula*, *Shorea laevis,* and *Gonystylus bancanus*) in Sumatra and Kalimantan, targeting 500 samples, required about $88,000 just to cover travel and logistics expenses. The figure would have been higher if the expeditions required collecting samples from timber species in eastern Indonesia, like Sulawesi and Papua, which would have incurred higher logistics costs. The cost could be cheaper if local personnel were available to collect the samples. This option, however, could result in additional upfront costs to build their capacity.

Although the total estimation of wood identification investment will require further study, the value is relatively reasonable when compared to the costs of failure to deter illegal timber trade. As highlighted in a KPK study, illegal logging cost Indonesia $6.47 billion–$8.98 billion in state revenue loss from timber royalties between 2003 and 2014. When taking into account the catastrophic environmental harm caused by the damage to forest functions, the total can be much higher.

While having the necessary infrastructure to implement wood identification is key, it needs to come hand-in-hand with policies and regulations that can effectively support its implementation in practice. Indonesia has a civil law system that requires all legal principles to be codified in writing through the issuance of legislation (Noho and Dzikirullah 2020). Consequently, the application of wood identification methods can only be possible if there are laws and regulations in place that allow their use. The next section will discuss existing policy instruments in Indonesia that support the use of wood identification methods.

Existing policy instruments for implementing wood identification methods in Indonesia

Indonesia currently has four legal instruments within its forest law enforcement and judicial ecosystem that support the application of wood identification methods. These instruments are Law No. 18/2013 on the Prevention and Eradication of Forest Destruction, Supreme Court Decree No. 1/2023 on the Guidance for Adjudicating Environment Cases, Government Regulation No. 36/2024 on the Types and Rates of Non-Tax Revenues Applicable to the Ministry of Forestry and Ministry of Forestry Regulation No. 2/2025 on the Base Price for Timber Products and Non-Timber Products for the Calculation of Non-Tax Revenues, and the National Timber Legality Assurance System (TLAS). Together, these laws and policies indicate the need to use wood identification technologies for monitoring and enforcement purposes.

However, we identified a legal formality gap regarding the admissibility of forensic results from DNA, stable isotopes, and DART-TOF-MS analysis as evidence in court. Solutions on how to address this gap will be discussed in a later section.

Law No. 18/2013 on the Prevention and Eradication of Forest Destruction

As Indonesia's main legal instrument for criminalizing illegal timber trade, Law No. 18/2013 places the responsibility on investigators to prove that confiscated timber was harvested illegally from designated forest areas, such as national parks. More than three quarters—21 out of 27—of articles that refer to criminal sanctions require evidence that timber was harvested and sourced from forest areas without a permit.

In many cases, investigators will attempt to trace the timber by manually locating the tree stumps (*lacak balak*), particularly when the suspect claims the logs were harvested from private forests or legal concessions. In these cases, the logs and stumps are assessed and matched based on the size and species of timber, which poses a risk of incorrect matches. More accurate and science-based verification methods, such as DNA and stable isotope analyses, could enhance enforcement by enabling more reliable identification of timber origin. Article 39 of Law No. 18/2013 also limits forest crime investigations to 90 days, comprising a 60-day period after the start of the investigation that can be extended a maximum of 30 days. Such a tight timeline further underscores the need for rapid and accurate tools that can be used as part of the investigation process.

Supreme Court Decree No. 1/2023 on the Guidance for Adjudicating Environmental Cases

Supreme Court Decree No. 1/2023 is not a legally binding regulation, but it is a persuasive tool that judges can refer to. It emphasizes the use of scientific evidence in both civil and criminal cases that relate to the environment and includes examples of scientific evidence that can be used in court, such as laboratory testing, electronic documents, including satellite image analysis, and expert witness testimonies. The decree also discusses the formal legal requirements for presenting scientific evidence in a court of law, such as lab accreditation, qualification of experts, and so on.

Government Regulation No. 36/2024 on the Types and Rates of Non-Tax Revenues Applicable to the Ministry of Forestry and Ministry of Forestry Regulation No. 2/2025 on the Base Price for Timber Products and Non-Timber Products for the Calculation of Non-Tax Revenues

Government Regulation No. 36/2024 imposes tariffs or royalties on timber products against a "base price" (*harga patokan)*, which varies for different species. For example, the tariff for a reforestation fund (*dana reboisasi*) applied to meranti (*Shorea leprosula*) is 8 percent of the base price for small roundwood and 30 percent for big roundwood, while the tariff for merbau (*Intsia bijuga*), a species endemic to the eastern part of Indonesia, is 30 percent.

The base price is further regulated under MoF Regulation No. 2/2025, which bases the figure on seven harvesting locations: Sumatra, Sulawesi, Kalimantan, Java-Madura, Maluku, Bali-Nusa Tenggara, and Papua. As such, the same timber species can have a different base price depending on where it was harvested. Timber levies are calculated through a self-assessment mechanism, where companies calculate their own levies and report the amount to the government. Timber species that are included under CITES Appendices, such as rosewood (*Dalbergia latifolia*) and ramin (*Gonystylus bancanus*), are also subject to additional levies. The obligations under these laws require a declaration of species and origin to ensure the payment amount is correct.

National Timber Legality Assurance System

Indonesia implements a national TLAS that has undergone major improvements since the VPA between Indonesia and the EU was ratified in 2014 (SVLK Indonesia 2024). Under the TLAS, a licensed certification body (CB) is authorized

to conduct due diligence on companies or business units operating across the timber supply chain against established legality standards. Once the assessment is complete, the CB will certify companies that meet all the administrative and on-the-ground verification requirements. For every batch of exported products, certified exporters must request the issuance of a V-legal document from the CB, which is equivalent to a FLEGT license.

The TLAS is governed by a MoEF regulation, and the latest revision allows CBs to use laboratory testing to ensure the traceability of timber products (MoEF 2022). Mainstreaming the use of wood identification methods in the TLAS is important because, in principle, exporters must ensure that all suppliers and the entire chain of custody are certified and verified in order to request a V-legal document. Although violating TLAS provisions is not considered a crime in itself, the assessment and verification processes mandated under the TLAS can help detect crimes that can then be investigated by enforcement authorities.

Despite the relevance of wood identification methods to the laws and policy instruments presented here, the application of such technologies still relies heavily on the interest, willingness, and ability of enforcement agencies and other key stakeholders to use and promote these tools. The following section maps out the agencies and stakeholders in Indonesia that are relevant to the implementation of wood identification methods for law enforcement purposes and identifies the potential roles they can play in advancing these methods.

Mapping stakeholders involved in the implementation of wood identification methods in Indonesia

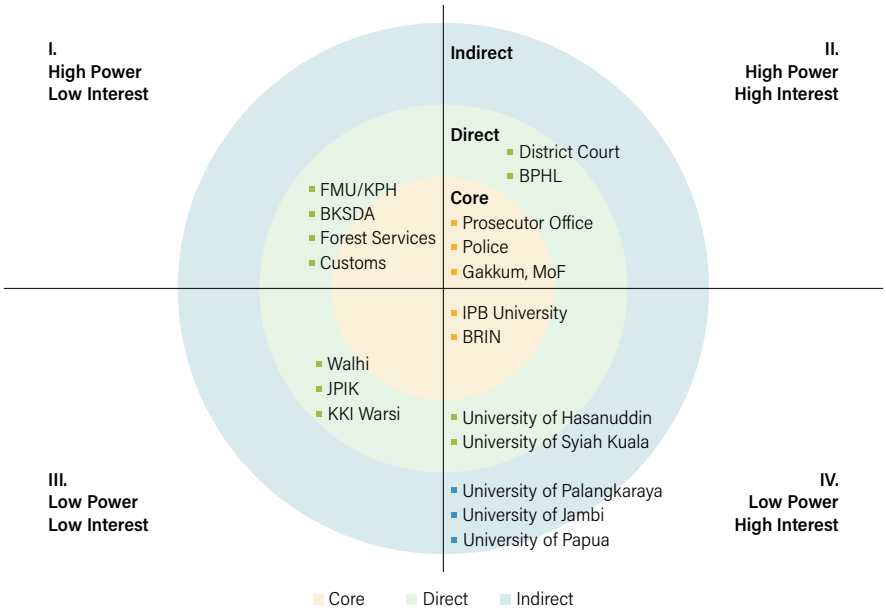
This analysis mapped stakeholders who influence, are affected by, or may have an interest in the implementation of wood identification in Indonesia by plotting two variables: power and interest. *Power* is broadly defined as the ability to influence, and *interest* as the willingness and desire to be engaged with (Mathur et al. 2007). In the context of this research, *power* is defined as the ability to adopt and benefit from wood identification methods and interest as the willingness to understand and engage with these technologies.

Results of the stakeholder mapping (Figure 4) show that most law enforcement agencies have a strong interest in understanding the use of wood identification, with varying degrees of power to influence the adoption of the various methods.

The Customs Office and the Provincial Forestry Service were placed in Quadrant I, as they have strong institutional power but relatively low interest, as their primary mandates focus on trade facilitation and forest management rather than direct law enforcement. While both institutions have oversight and control functions, law enforcement is not their primary focus.

The National Police, Prosecutor's Office, and Gakkum show the highest power and interest, driven by their need for

Figure 4 | **Results of stakeholder mapping**



Source: WRI authors.

credible, scientific evidence to support illegal logging prosecutions, as reflected in Quadrant II. They mostly work with BRIN and BPHL, who have the technical expertise in wood anatomy. As BPHL operates under the Directorate General of Sustainable Forest Management in the Ministry of Forestry and holds authority at the provincial level, its subagencies play a more operational role by relying on wood identification as part of their monitoring activities. As such, they have a higher potential to benefit from the use of other wood identification technologies.

Quadrant III encompasses NGOs and community-based organizations, which, despite having limited power, continue to play an important role in monitoring illegal logging and reporting cases to law enforcement agencies. NGOs can also be potential users, as they frequently utilize technologies to support forest monitoring and independent monitoring activities for TLAS or SVLK (Ichwan, 2025). Their contribution to independent forest monitoring strengthens accountability and complements the work of law enforcement and government agencies.

Lastly, Universities and research institutes were placed in Quadrant IV because they show strong interest but have limited power to influence. They play a vital role in supporting wood identification methods by conducting research and providing laboratory facilities and expert capacity. These institutions are critical to ensuring the long-term use of wood identification methods, particularly as many advanced techniques require well-equipped laboratories and trained personnel. For these actors, stronger collaboration with enforcement agencies is essential to increasing adoption and improving understanding of these technologies, especially in the context of forensic wood identification.

Addressing the legal formalities for implementing wood identification methods in Indonesia

In Indonesia, criminal recourse is the main legal response to deter those involved in the illegal timber trade. In criminal law, there is a generally accepted principle called "beyond a reasonable doubt," meaning that suspects are presumed innocent unless proven otherwise by evidence that establishes their guilt beyond the doubts of a theoretically impartial, rational person (United States Environmental Protection Agency 2025). Consequently, when an illegal logging case is brought before a court of law, the judge must be convinced that the evidence obtained through wood identification methods is accurate and credible and can therefore be used in the conviction process and the delivery of sanctions. The procedures followed to obtain evidence and secure it from the point and time of seizure to its presentation in court—the chain of custody—are also an important factor in determining whether the results of wood identification can be used in a criminal case. The section below discusses the procedures needed to obtain the evidence (wood sample)—also referred to as the legal formalities—that should be in place to deploy these technologies in Indonesia.

Through literature review, the authors have identified an illegal logging case in Indonesia where the court considered scientific evidence as a relevant factor in its sentencing. Box 3 describes the case and how scientific evidence—in this case, expert witness testimonies—was used.

The case presented in Box 3 illustrates how judges in Indonesia were able to incorporate scientific evidence to prosecute an illegal logging case, even though no regulations at the time specifically defined the types of scientific evidence that prosecution could refer to. Today, in cases relating to forestry and illegal logging, the legal definition of scientific evidence is much clearer and more widely accepted in court. As previously mentioned, Article 1 of Supreme Court Decree No. 1/2023 defines scientific evidence as the explanation of the relationship between two or more components or elements in the environment, presented in written form by an expert based on research findings or scientific results, with or without additional explanation provided in court. Article 71 of this decree further recognizes eight types of evidence that can be presented in environmental crime cases: witness statements, expert testimonies, written evidence in the form of letters, electronic evidence, guidance, statement of the defendant, corporate statements, and environmental, forest, and wildlife forensics.

Based on ongoing engagement and discussions with enforcement agencies, the authors believe that evidence from wood identification methods can be brought forward either as expert

testimony or as part of environmental, forest, and wildlife forensics. Investigators and prosecutors generally prefer expert witnesses to explain the accuracy of the technologies and detail how laboratory analyses are conducted, as this is more convincing to judges—particularly because the technologies are still relatively new. In most illegal logging cases, prosecutors will invite forest agencies and anatomy experts to explain the legal dimension of the case; that is whether the timber was harvested inside or outside a forest zone, and to provide an assessment of the resulting losses incurred by the state.

Meanwhile, "environmental, forest, and wildlife forensics" can be interpreted as requiring written forensic results from reputable and credible laboratories. Because experts in more recent wood identification technologies, such as DNA, stable isotope, and DART-TOF-MS analyses, are still limited in Indonesia, relying on written forensic results is often more feasible than summoning experts to testify, unless uncertainties in the results require further clarification. In addition, DNA-based forensic results for animal species identification have already been accepted by the courts in Indonesia as part of wildlife crime enforcement.[6]

Articles 72 (1) and 72 (2) of Supreme Court Decree No. 1/2023 further stipulate that, when examining scientific evidence submitted as part of a trial for environmental cases, judges must consider the following elements: the accuracy of the method, the validity of sample collection, laboratory accreditation, and expert opinions. The latter are examined and assessed based on three credibility criteria: conformity with science and acceptance by the relevant scientific community, the existence of publications that can be used as references, and peer reviews on the theory and scientific methods used.

To demonstrate the accuracy of the methods used, a wide range of examples can be used to convince judges about the effectiveness of the latest techniques, especially from peer-reviewed academic articles on stable isotope, DNA, and DART-TOF-MS analysis. Additionally, international agreements such as CITES also promote the use of wood identification methods to support compliance and species-level verification process,[7] thereby strengthening their broader application. In 2022, the Conference of Parties (COP) of CITES adopted Decisions 19.145 to 19.148 on the "identification of timber and other wood products" (CITES Secretariat 2022), which included the need to "develop a plan

Box 3 | **Harnessing science to generate legal evidence in the court room: PT. Keang Nam Development Case (2010)**

In 2010, the Indonesian Supreme Court imposed a 10-year prison sentence and a fine of IDR1 billion, in lieu of six months in jail, on the director of timber company PT. Keang Nam Development Indonesia, who had been found guilty of cutting down timber outside the designated production area and falsifying timber production reports (The Supreme Court of the Republic of Indonesia 2011). The owner was also ordered to pay restitution for state losses worth around IDR120 billion and nearly $3 million of reforestation fund for illegally harvesting timber outside their concessions. The sentence was relatively high for an illegal logging case and was notable because the prosecutors submitted an indictment that combined crimes relating to forestry and corruption, as the suspect had also bribed forestry officers to falsify production reports and transport documents.

The case was initially heard at the Medan District Court in 2007, where the suspect was found not guilty. Prosecutors relied on Article 50 (2) of Law No. 41/1999 on Forestry, which stipulates that forestry license holders "are prohibited from activities that cause forest destruction." Forest destruction is further defined in the law as "the occurrence of physical conditions, physical properties and biodiversity changes that negatively impact the forest's designated function." Based on this definition, the judges concluded that no destruction had occurred, as some trees were still standing and the degraded forest could be replanted.

The prosecutor later filed an appeal with the Supreme Court, which was granted in 2008. Two expert witnesses were presented to verify the occurrence of "forest destruction" using scientific evidence. The first expert witness, an environmental consulting firm, assessed the company's logging practices against sustainable forest management principles. Based on production, ecological, and social criteria, the assessment found that the company's performance was "poor" in managing the area sustainably, as evidenced by the extinction of several high-value timber species, the lack of clear boundaries between protected and production areas, and land conflict with Indigenous communities.

The second expert witness was a scholar with a background in forestry science who collected samples and tested soil in the concession and its surrounding areas. The tests identified major degradation of the soil's physical, biological, and chemical properties and found that the company had failed to apply "selective cutting and replanting system" methods, thereby making the harvesting unsustainable. The Supreme Court overturned the initial ruling after taking into consideration the scientific assessments presented in court.

Source: WRI authors.

to prioritize the CITES-listed tree species to focus global efforts on developing and sharing identification reference databases and tools" and the establishment of an online repository of wood identification tools and resources (CITES Secretariat, 2022). In 2016, the UNODC also published a Best Practice Guide for Forensic Timber Identification, which guides scientists and enforcement agencies on how to apply wood identification techniques for enforcement. These materials can be useful to demonstrate global support and recognition for wood identification methods.

To assess the validity of the sample collection process, BRIN has developed a standardized protocol for conducting macroscopic wood anatomy analysis, which is recognized under the Indonesian National Standard (SNI).[8] The guideline partly explains why wood anatomy remains the most widely used technique for enforcement purposes, particularly for verifying timber species under Government Regulation No. 36/2024. For other methods, there is a need to develop additional guidelines to support their uptake, especially given that much of the necessary capacity is already available. Several local universities and laboratories operate DNA laboratories, in addition to a stable isotope laboratory at BRIN. Furthermore, IPB University acquired a DART-TOF-MS in January 2025, with support from the Norwegian Agency for Development Cooperation (Norad).

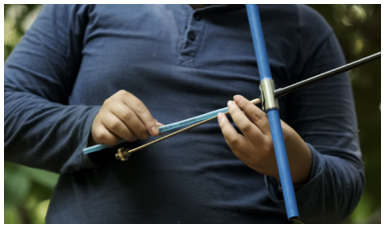
To address the absence of a sample-collection guideline for other methods, WRI Indonesia is in the process of developing one for DNA analysis, which is expected to be finalized in March 2026. This guideline will outline several key requirements that scientific evidence must meet under Indonesian Law (Figure 5) and that need to be considered when conducting wood DNA forensics.

Figure 5 | **Key aspects of scientific evidence required under Indonesian Law**

Source: WRI authors, from Tumpal (2024).

Figure 6 | **Examples of the current tools and techniques used by IPB University's research team to collect wood samples**

Increment borer



Silica-gel-dried wood sample

Hollow steel punch - cambium tissue

Source: WRI authors, from Dwiyanti and Siregar 2024.

The DNA guideline currently in development will share similarities with the UNODC's *Best Practice Guide for Forensic Timber Identification* (2016), but will place more emphasis on DNA analysis and the local context and policies of Indonesia. WRI Indonesia has prioritized the development of the DNA guidelines based on the needs identified during engagements with key experts and stakeholders and the available infrastructure and reference data. Figure 6 highlights some of the tools and techniques currently used by IPB University to collect wood samples, which will be covered in the guideline. WRI has also supported capacity building for IPB University and BRIN scientists by facilitating training and workshops with renowned institutions to adopt their guidelines and sampling preparation protocols for stable isotope and DART-TOF-MS analyses.

As far as demonstrating the credibility of expert opinions, the qualifications of the experts can be assessed through indicators such as their academic background, the number of scientific articles they have published, and the reputation of the journals in which their work appears. Since 2021, as part of WRI's ongoing activities, IPB University has served as the focal point for conducting DNA and DART-TOF-MS analyses, while BRIN has acted as the primary service provider for wood anatomy and stable isotope analysis. Over the past six years, both IPB and BRIN have published various scientific and peer-reviewed papers on wood sample collections, anatomy, chemical, and genetic identification (IPB University 2020).

Another challenge hampering the integration of wood identification methods into law enforcement processes is the need for laboratories to obtain accreditation. One of the most common forms of accreditation is ISO:17025, "General requirements for the competence of testing and calibration laboratories." The Integrated Laboratory at IPB University, which provides DNA and RNA testing for various products, has already obtained this accreditation. For wood identification specifically, the DNA Laboratory within the Faculty of Forestry at IPB University and IPB's Advanced Laboratory, where the DART-TOF-MS is located, are currently exploring potential avenues toward accreditation by leveraging the existing accreditation held by the Integrated Laboratory.

Interviews conducted for this research provided differing perspectives on the importance of accreditation. Discussions with foreign laboratories that have applied wood identification methods for enforcement purposes indicated that accreditation is generally pursued as an exception. Most laboratories do not hold accreditation but instead operate under established protocols and guidelines for sample collection and chain of custody. Only one of the four laboratories interviewed had obtained accreditation. Nevertheless, test results from both accredited and non-accredited laboratories have been accepted as forensic evidence in legal cases in their respective countries.

By contrast, Indonesian enforcement agencies reported that they would have confidence in wood identification results only if they were produced by an accredited laboratory. Their position reflects the requirements stipulated in Supreme Court Decree No. 1/2024 and draws on experience from illegal wildlife trade enforcement, where species identification is carried out by an accredited laboratory. They believe the absence of accreditation could be used by lawyers as a loophole to challenge the admissibility of forensic results in court.

Table 1 | **Current status of compliance with legal formality requirements for wood identification methods in Indonesia**

WOOD IDENTIFICATION METHOD	EQUIPMENT CURRENTLY AVAILABLE IN INDONESIA	DEMONSTRATING THE METHOD'S ACCURACY	DEMONSTRATING THE SAMPLE'S VALIDITY *Standardized protocols*
Wood anatomy	Several anatomy labs that are based in local universities and state laboratories	▪ Peer-reviewed literature on the accuracy of the methods	▪ A standardized protocol has been developed for conducting macroscopic wood anatomy analysis ▪ The Xylarium Bogoriense applies a macroscopic anatomy methodology in accordance with international standards endorsed by the International Association of Wood Anatomists (IAWA).
DNA	Several DNA labs that are based in Local universities and state laboratories	▪ Peer-reviewed literature on the accuracy of the methods	▪ IPB University and WRI Indonesia are currently producing the final draft of a DNA sampling protocol. A standardized protocol is usually developed from scratch as a requirement to obtain lab accreditation, as learned from our visit to FRIM.
Stable isotope	One stable isotope laboratory at BRIN	▪ Peer-reviewed literature on the accuracy of the methods	▪ IPB and BRIN staff have received training from World Forest ID and Adelaide University, which has created an open protocol for stable isotope analysis . The open protocol can be adopted by IPB and BRIN as part of their lab accreditation process in the future.
DART-TOF-MS	One DART-TOF-MS machine was acquired in January 2025 and is now located at Advanced Research Lab, IPB University	▪ Peer-reviewed literature on the accuracy of the methods	▪ The Society for Wildlife Forensic Science (SWFS) has standards and guidelines covering the standardized procedures that relate to chemical analysis for taxonomic identification (Moore et al. 2021). This standard is voluntary and has been adopted by several DART-TOF-MS laboratories, which means IPB can also adopt SWFS guideline for its protocols. The guidelines, however, lack details and do not cover sample preparation for analysis, which is a key step in obtaining results. In addition, the IPB laboratory also received visits from representatives of the UK's Kew Laboratory and the U.S. Fish and Wildlife Service, who shared their protocols as reference.

Source: Series of interviews, lab visits, and Moore et al. (2021).

In light of this, WRI Indonesia has initiated discussions with the National Accreditation Committee (Komite Akreditasi Nasional; KAN), which grants ISO accreditation. Assuming all administrative requirements are met, KAN estimates the accreditation process will take one year. As previously mentioned, the Forest Genetics Laboratory at IPB University plans to begin its accreditation process by leveraging the existing ISO certification of another university laboratory.

Although Indonesia's application of wood identification methods already aligns with most legal formality requirements, laboratory accreditation has become a priority to prevent potential legal challenges in court. However, the costs and timelines associated with laboratory analyses remain a major obstacle for enforcement agencies seeking to apply these technologies in practice. Developing a protocol is an important first step, as it will provide technical guidance on wood sample collection and chain of custody, ensuring that all legal requirements are met. In addition, WRI Indonesia and IPB University have begun coordinating with KAN to prepare access to the Integrated Laboratory's ISO accreditation, with commitments to offer more competitive and affordable DNA analysis services.

Conclusion

Stakeholder analysis conducted under this study highlights the need for stronger collaboration between enforcement agencies and research institutions. Wood identification can only be useful to law enforcement officials working to uncover illegal trading if they connect with the researchers who have the necessary technical expertise. While wood anatomy is widely used in Indonesia, it cannot be applied to verify geographic origin; that is determine whether timber was sourced from a designated forest zone. Therefore, alternative techniques, such as DNA analysis and stable isotope analysis, must be deployed to meet these enforcement needs.

To enable the effective use of wood identification, two enabling factors remain incomplete. First, additional samples are needed to strengthen the availability of reference data. This can be achieved not only through sample collection in forests but also through collaboration with other laboratories and scientists. Second, the remaining legal formalities must be fulfilled. Establishing sample collection procedures and laboratory protocols are important first steps, followed by accreditation. Furthermore, endorsement from relevant government agencies will help boost credibility and confidence in the use of these protocols for enforcement purposes.

While the study results indicate that the pathway toward fulfilling legal formality requirements is largely within reach, collecting additional data to strengthen reference datasets requires stronger commitment and participation from government agencies. To date, most sampling efforts to build reference databases for wood identification technologies in Indonesia have been led by universities, researchers, and non-profit organizations. These efforts are often constrained by time, funding, and capacity. Greater involvement from government agencies within the MoF and BRIN is needed to scale up the development of these databases. P2HB, with its strong foundation and focus on anatomy, can play a pivotal role in expanding the number of wood anatomy datasets and supporting their digitalization to provide rapid assessment tools for the identification of species.

With the EUDR set to replace the EUTR, Indonesia—despite being the first country to obtain FLEGT licenses—should adjust and improve its technical capacity to meet EUDR requirements. The EUDR will require operators and traders to include, among other information, the geolocation of the plots of land where a product or commodity was produced to prove it is deforestation-free and compliant with the legislation of its country of origin. Wood identification technologies can help provide reliable and rapid verification of species and origin. Investment in these technologies would enable operators in Indonesia to meet these requirements and improve access to global markets.

Appendix A – List of respondents and focus groups discussions

Table A-2 provides a summary of the actors who were surveyed and interviewed as part of the research process and outlines their roles and expertise. Surveys were conducted with 48 stakeholders, who included representatives from forest authorities, enforcement agencies, universities, and civil society organizations (CSOs) from the provinces of Kalimantan, Sulawesi, Sumatra, and Papua. Additional interviews and discussions were conducted with seven persons from four foreign labs.

WRI Indonesia has been working with IPB University in organizing workshops, focus group discussions (FGDs), and training for enforcement agencies, civil society organizations (CSOs), and forest authorities on the application of wood identification methods (see Table A-2). They enabled discussions on key topics, such as building technical capacity and the legal formalities required to enable the use of wood identification methods.

Table A-1 | **List of actors surveyed and interviewed**

Typology of actors	Actors	Number of respondents	Roles and expertise
Forestry agencies under the MoF	Sustainable Forest Management Office (Balai Pengelolaan Hutan Lestari; BPHL)	4	Responsible for sustainable forest management, biodiversity conservation, as well as the monitoring and evaluation of forest use. Some have the technical expertise to identify wood species through anatomical analysis.
	Nature Conservation Office (Balai Konservasi Sumber Daya Alam; BKSDA)	3	
	Forest Police/Rangers (Polisi Kehutanan Indonesia; Polhut), Forest Services (Dinas Kehutanan; DisHut)	8	
	Forest Management Unit (Kesatuan Pengelolaan Hutan; KPH)	1	
Law enforcement agencies	Police	5	The law enforcement officers involved primarily serve as investigators, while prosecutors and judges are responsible for prosecution and case adjudication. The respondents generally have experience in handling illegal logging cases.
	District Court (Pengadilan Negeri)	2	
	High Prosecutor Office/Attorney Services	4	
	Forest Protection and Law Enforcement Office (Direktorat Jenderal Penegakan Hukum Kehutanan; Gakkum), Ministry of Forestry	4	
	Restriction and Transnational Crime, Directorate-General Customs	3	
Universities and research institutions	National Research and Innovation Agency (Badan Riset dan Inovasi Nasional; BRIN)	2	Universities and research institutions were selected based on their expertise, research experience, and/or those with laboratories relevant to wood identification. Although some institutions do not have laboratories, most possess expertise in wood identification, particularly in anatomy and genetics.
	University of Syiah Kuala (Aceh Province)	1	
	University of Hasanuddin (South Sulawesi Province)	2	
	University of Muhammadiyah Palangkaraya (Central Kalimantan Province)	1	
	University of Palangkaraya (Central Kalimantan Province)	1	
	University of Papua (West Papua Province)	1	
	University of Jambi (Jambi Province)	1	
Civil society Organizations (CSOs)	Members of the Independent Forest Monitoring Network (Jaringan Pemantau Independen Kehutanan; JPIK)	3	Expertise in forest monitoring, community-based forest management, and law enforcement.
	Indonesian Forum for Environment (Wahana Lingkungan Hidup Indonesia; WALHI)	1	
	Indonesian Conservation Community Warsi (Komunitas Konservasi Indonesia; KKI WARSI)	1	

Table A-1 | **List of actors surveyed and interviewed (cont.)**

Typology of actors	Actors	Number of respondents	Roles and expertise
Foreign laboratories	Forest Research Institute Malaysia (FRIM) (Malaysia)	Discussion and lab visit (three persons).	Expertise in providing DNA and wood anatomy identification services.
	Barcoding Facility for Organisms and Tissues of Policy Concern (BopCo), Institute of Natural Sciences (Belgium)	Interview via Zoom (two persons).	
	Belgian Center of Expertise for Forensic Wood Research (ENFORCE), Royal Museum for Central Africa (RMCA) (Belgium)	Interview via Zoom (one person).	
	Thünen Center of Competence on the Origin of Timber, Thünen Institute (Germany)	E-mail discussion (one person)	

Source: WRI authors.

Table A-2 | **Number of activities (training, workshops, etc.) organized by WRI Indonesia and IPB University on the application of wood identification methods in Indonesia since 2021**

Type of activity	Location	Year	Participants	Description of activities undertaken by participants
Workshops on wood identification tools	Makassar (Sulawesi Province) Palangkaraya (Kalimantan Province) Jambi (Sumatra Province) Manokwari (West Papua Province)	2022–2024	Prosecutors, police, judges, local forest authorities, scientists from local universities, Gakkum, local CSOs, and customs officials.	WRI, IPB University, and BRIN presented various genetic, chemical, and anatomy wood identification techniques. Participants also received training on wood anatomy to support their work in screening illegal timber.
Trainings on wood sample collection for DNA analysis	Makassar (Sulawesi Province)	2022 & 2024	Prosecutors, police, lab technicians from the National Police, Gakkum, and customs officials.	WRI, IPB University, and Hasanuddin University collaborated to organize field training for Gakkum Sulawesi on collecting wood samples for DNA analysis. IPB University also provided lab training to local scientists from the university to conduct DNA analysis of the wood samples.
	Bogor (West Java Province)	2024	Prosecutors, police, lab technicians from the National Police, Gakkum, and customs officials.	It then organized field training in collecting wood samples for DNA analysis at IPB's University Forest. Participants also visited IPB's Advanced Research Lab, where they were able to watch wood DNA analysis being conducted.
FGDs to collect input on the development of guidelines for forensic DNA wood identification	Bogor (West Java Province) Surabaya (East Java Province) Makassar (Sulawesi Province)	2024 2024 2024	Prosecutors, police, judges, local forest authorities, Gakkum, and customs officials.	WRI hosted a forum to discuss chain-of-custody protocol and the legal formalities required to enable the implementation of forensic timber DNA identification.
Trainings on the enforcement of illegal timber trade	Medan (North Sumatra Province) Bogor (West Java)	2024 2025	Prosecutors, police, Gakkum, and judges	In Medan, WRI, IPB University, and the Attorney General's Office of Education and Training (Badiklat Kejagung) conducted training for enforcement agencies working across the Indonesian criminal justice system on DNA forensics, timber traceability, as well as corporate and white-collar crimes in the forest sector In Bogor, WRI, IPB University, and P2HB organized training for representatives from the Directorate of Sustainable Forestry Management and Gakkum to potentially integrate anatomy and DNA for their verification and investigation work.

Source: WRI authors.

Abbreviations

AI	Artificial Intelligence
AIKO	Alat Identifikasi Kayu Otomatis (Automatic Wood Identification Tool)
APEC	Asia-Pacific Economic Cooperation
BRIN	Badan Riset dan Inovasi National (National Research and Innovation Agency)
BPHL	Balai Pengelolaan Hutan Lestari (Sustainable Forest Management Offices)
CB	Certification body
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CSOs	Civil society organizations
DART-TOF-MS	Direct analysis in real time (time of flight) mass spectrometry
EU	European Union
EUDR	European Union Deforestation Regulation
EUTR	European Union Timber Regulation
EGILAT	Experts Group on Illegal Logging and Associated Trade
FDGs	focus group discussions
FLEGT	Forest Law Enforcement, Governance, and Trade
FRIM	Forest Research Institute Malaysia
Gakkum	Direktorat Jenderal Penegakan Hukum Kehutanan (Directorate General on Law Enforcement for Forestry)
IAWA	International Association of Wood Anatomists
IP	Intellectual property
IPB	Institut Pertanian Bogor (Bogor Agricultural University)
IRMS	Isotope ratio mass spectrometry
KAN	Komite Akreditasi Nasional (National Accreditation Committee)
KPH	Kesatuan Pengelolaan Hutan (Forest Management Units)
KPK	Komisi Pemberantasan Korupsi (Corruption Eradication Commission)
MTAs	Material transfer agreements
MoEF	Ministry of Environment and Forestry
MoF	Ministry of Forestry
NCBI	National Center for Biotechnology Information
Norad	Norwegian Agency for Development Cooperation
P2HB	Pusat Pengembangan Hutan Berkelanjutan (Center of Sustainable Forest Development)
SIPUHH	Sistem Informasi Penatausahaan Hasil Hutan (Forest Products Management Information System)
SNI	Standar Nasional Indonesia (Indonesian National Standard)
SVLK	Sistem Verifikasi Legalitas Kayu (Timber Legality Assurance System)
SWFS	Society for Wildlife Forensic Science
TLAS	Timber Legality Assurance System
VPA	Voluntary Partnership Agreement
WRI	World Resources Institute

Endnotes

1. The number was obtained by comparing official statistics from the MoEF and KPK, which used a spatial approach (concession area and productivity assumptions in m^3/ha). Based on the difference between official statistics and KPK calculations, KPK estimated that the state lost $6.47 billion–$8.98 billion in revenue from the Forest Resources Provision (PSDH) and Reforestation Fund (DR).
2. The authors reviewed 322 taxa (36 genera and 286 species) listed in the 2019 Global Timber Tracking Network (GTTN) Trees Species Priority List, taxa which have been identified as susceptible or already impacted by illegal logging and associated trade.
3. WRI, through an initiative funded by the Norwegian Agency for Development Cooperation (Norad) and in partnership with IPB University, has been supporting the implementation of wood identification technologies to strengthen Indonesia's ability to enforce its forest laws. As part this project, scientists from IPB University and BRIN participated in training led by World Forest ID and the University of Adelaide in mid-2024 on how to set up BRIN's newly installed isotope ratio mass spectrometry (IRMS) laboratory. This included training on sample preparation and non-proprietary stable isotope ratio measurement protocols and should enable BRIN to conduct analyses in the near future.
4. Can be accessed through https://blast.ncbi.nlm.nih.gov/Blast.cgi. The users should insert the genotype, and the platform will then search for matching species.
5. The three species collected are eboni (*Diospyros celebica*), meranti merah (*Shorea leprosula*) and bengkirai (*Shorea laevis*). This sample collection has been conducted through an initiative funded by NORAD and in partnership between WRI and IPB University..
6. One of the referred laboratories for wildlife DNA forensics in Indonesia is the Animal System Laboratory in the Biology Department at Gadjah Mada University. An article covering the expert Dr. Dwi Sendi Priyono can be found here: https://ugm.ac.id/id/berita/kisah-dosen-ugm-jadi-anggota-ahli-forensik-satwa-liar-internasional-swfs/. WRI Indonesia team met with Dr. Sendi in his laboratory to discuss the legal formalities that are often questioned by enforcement agencies and judges in wildlife crime cases.
7. Indonesia ratified the CITES Convention in 1978 and two of its commonly traded timber species, namely ramin (*Gonystylus bancanus*) and rosewood/sonokeling *(Dalbergia latifolia*), are included in the CITES Appendix II.
8. SNI 8491: 2018.
9. See more about the work of World Forest ID on stable isotope through https://worldforestid.org/work

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About WRI Indonesia

World Resource Institute (WRI) Indonesia is an independent research organization dedicated to contributing to the socioeconomic development of Indonesia in an inclusive and sustainable way. Our work is focused on six main areas: forests, climate, energy, cities and transportation, governance, as well as oceans. We turn big ideas into action at the nexus of environment, economic opportunity, and human well-being