Development of Integrated Timber Data for Enhancing Legal Timber Trade in the Asia-Pacific Region

RESEARCH PAPER

APEC Experts Group on Illegal Logging and Associated Trade (EGILAT)

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PREFACE

"But when you have bad governance, of course, these resources are destroyed: The forests are deforested, there is illegal logging, there is soil erosion. I got pulled deeper and deeper and saw how these issues become linked to governance, to corruption, to dictatorship." — Wangari Maathai, the 2004 Nobel Prize for Peace.

Illegal logging and illicit wood trafficking are complex transnational forestry crimes that are persisting and evolving with distinct modus operandi. The Asia-Pacific Economic Cooperation (APEC) Experts Group on Illegal Logging and Associated Trade (EGILAT), has served as a valuable information-sharing and capacity-building platform to address these complex issues. The authors are delighted that this research paper entitled "Integrated Timber Data Development for Enhancing Legal Timber Trade in the Asia-Pacific Region" is published on the APEC Secretariat Publications site and can be openly-accessed by all stakeholders from APEC member economies and other interested parties.

This paper is one output under EGILAT Project, "Developing Integrated Timber Data to Enhance Legal Timber Trade of the APEC through Xylaria Networking." This paper intends to provide a comprehensive overview of the current use of wood identification technologies in APEC member economies, the demand and importance of wood identification technologies for wood forensic, recommendation of regional standard for wood identification, and the status and use of Material Transfer Agreements for xylaria networking. The authors offer recommendations to support the potential development of an integrated timber system for enhancing illegal wood trade in APEC member economies, including a wood identification database and potential integration of that database into APEC member economy timber legality frameworks.

The authors strive to showcase detailed explanations for developing and using integrated wood identification technologies to address illegal logging and associated trade along the supply chain based on information shared by stakeholders from APEC member economies and associated project research. In addition, a priority list of wood traded in APEC member economies is highlighted as a reference for understanding wood species that are internationally traded among the member economies.

The authors hope this paper provides novel insights and information for the readers on harnessing wood identification technologies and their integrated database for disrupting forestry crimes. With that expectation, the recommendations outlined in this paper may be used to inform discussions about regional actions and policies on wood identification. We welcome constructive feedback from readers in order to continue to advance this work.

Bogor, 19 February 2024

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EXECUTIVE SUMMARY

Identifying data in logging and trading permits from illegal logging and illicit wood trade in Asia and the Pacific Region is still challenging. Falsified logging documents aggravated with siloed data throughout the wood supply chain are still present, leading to difficulties securing scientific evidence to prosecute the forestry crime actors. Wood identification is a powerful instrument that provides scientific evidence to address illicit timber trade along the timber supply chain. However, there are many hampering factors in harnessing wood identification. This paper intends to address these concerns by providing a comprehensive overview of the current use of wood identification technologies in APEC member economies, the demand and importance of wood identification technologies for forensic wood, and the status and use of Material Transfer Agreements and Regional Standards for Wood Identification. The authors offer recommendations to support the potential integration of wood identification systems in the APEC region to enhance legal timber trade. The authors recommend the development of an integrated system that includes a wood identification database which could be incorporated into APEC member economy's timber legality frameworks.

In this study, the investigation was performed using different scientific methods, including systematic evidence evaluation, mini-survey, and workshops. Systematic evidence evaluation harnessed a Population, Exposure, Counterfactual and Outcome (PECO) framework to search the relevant published literature on wood identification. A mini-survey was conducted two times before the workshop to acquire the most represented data on forensic wood identification in APEC member economies. The data obtained from these methods were subsequently triangulated to enhance the reliability, credibility, and depth of the findings. In addition, by harnessing the triangulation method, a comprehensive understanding of the thematic wood identification issues studied can be produced, with a reduction of bias and limitations.

A comprehensive evaluation of the literature revealed there has been an increasing trend in the number of published wood identification studies in APEC member economies, with varied technologies used for identifying wood. Many published studies devoted to forensic wood have been identified, using digital technologies-based applications (computer vision, machine learning, deep learning technology), wood anatomy, carbon-dating, near-infrared spectroscopy (NIR) or chemometrics in spectroscopy, dendrochronology or tree-ring dating, and DNA analysis. Results from a mini-survey of workshop participants conducted for this project indicated the primary wood technologies utilized in APEC member economies include wood anatomy and DNA barcoding. However, other various tools employed in the economies include machine vision (AIKO, Xylotron, MyWoodID, Xylorix, iWood), mass spectrometry (e.g. AccuTOF-DART), dendrochronology, stable isotope, near-infrared spectroscopy, radiocarbon, population genetics/phylogeography, DNA barcoding, DNA fingerprinting, fibers analysis in medium-density fiberboard, and paper & pulp, mineral or trace elements analysis, wood capacitance, chemotaxonomy, and laser-induced breakdown spectroscopy (LIBS).

Workshop participants recognized there is no one-size-fits-all wood identification strategy, as each tool has different purposes, capabilities, and demands in profiling risks. However, they recommended using affordable and combined field deployable and laboratory modalities for forensic analysis, mainly wood anatomy-based machine vision and wood DNA-based solutions. Various demands were observed for wood identification for forensic wood, with the ultimate goal of investigating the legality of wood harvested and traded at the different profiling risks of wood genus, species, geographic provenance, individual origin, and age. CITES-listed tree species and high-commercial wood, logged and internationally traded among APEC member economies and across other economies, are also mainly demanded as wood legality-studied objects for forensic wood analysis.

According to the findings of this study, the majority of APEC member economies have developed and adopted domestic standards for wood identification. The findings also suggest

the need for harmonizing the domestic wood identification standards at the regional level with different topics of harmonized standards, such as the type of wood identification technologies, shipping and logistics matters, identification of CITES-listed wood, wood sampling, and digitalization of wood identification database. The harmonized standards are anticipated to provide consistent guidance for wood identification to support the normalization of forensic wood application. Stakeholders of the APEC member economies also expressed the need for improved mechanisms to conduct wood identification as well as capacity building for wood identifiers and the development of Xylaria Networking for an excellent center providing best practices, research, support, or capacity building for wood identification.

APEC member economies' readiness level for the implementation of forensic wood is still predominantly at the research stage. The Discussion Groups attended by many stakeholders from APEC member economies strongly recommended the development of Regional Standards on wood identification, specifying proposed thematic issues. The practical implementation of the Standards will expedite and normalize the actualization of forensic wood in the region. APEC member economies have primarily integrated wood identification techniques into a particular phase of the wood supply chain and Timber Legality Assurance System (TLAS). In the stage of export and import, wood identification has been primarily used in the supply chain, and it can be anticipated that APEC member economies will enhance the integration mechanism of forensic wood identification at that level.

Key words: illegal logging and illicit wood trade, wood identification, material transfer agreement, regional standards, Xylaria Networking, Timber Legality Assurance System

1. OVERVIEW

In 1989, the idea of the Asia-Pacific Economic Cooperation (APEC) forum establishment was broached. Since 1998, twenty-one (21) economies have become members, including Australia; Brunei Darussalam; Canada; Chile; People's Republic of China; Hong Kong, China; Indonesia; Japan; Republic of Korea; Malaysia; Mexico; New Zealand; Papua New Guinea; Peru; the Republic of the Philippines; the Russian Federation; Singapore; Chinese Taipei; Thailand; the United States; and Viet Nam. Within its governance mechanism, senior officials, ministerial-level dialogue, and Leaders' meetings are regularly undertaken each year. Under its primary structure, the Senior Officials Meeting (SOM) Steering Committee (SCE) on Economic and Technical Cooperation (ECOTECH) coordinates and manages the APEC members' working groups and task forces besides policy partnership. The Experts Group on Illegal Logging and Associated Trade (EGILAT) is a part of the SOM SCE on ECOTECH's working group.

At the 2011 APEC Leaders' meeting in Hawaii, the Leaders committed to implementing appropriate measures to prohibit trade in illegally harvested forest products and to do more to combat illegal logging and associated trade. Subsequently, the First APEC Meeting of Ministers Responsible for Forestry called on member economies to establish the APEC Experts Group on Illegal Logging and Associated Trade (EGILAT), to take concrete steps and responsibilities to combat illegal logging and associated trade, promote trade in legally harvested forest products, and support capacity-building activities in member economies. Member economies endorsed the EGILAT's Multi-Year Strategic Plan 2018–2022 in 2018 (Asia-Pacific Economic Cooperation 2018) and the EGILAT's Multi-Year Strategic Plan 2023-2027 in 2023 (Asia-Pacific Economic Cooperation 2023a), which supports the APEC Putrajaya Vision 2040 and the Aotearoa Plan of Action. These guiding documents call for an open, dynamic, resilient and peaceful Asia-Pacific community. Furthermore, they support Plan promotes APEC's primary goal of achieving sustainable economic growth and prosperity in the Asia-Pacific region.

To advance the EGILAT Multi-Year Strategic Plan 2018–2022 and EGILAT Multi-Year Strategic Plan 2023–2027, the Government of Indonesia co-partnered with the National Research and Innovation Agency (BRIN) and the Ministry of Environment and Forestry for the EGILAT project "Developing Integrated Timber Data to Enhance Legal Timber Trade of the APEC through Xylaria Networking" (Asia-Pacific Economic Cooperation 2023b). The Project aligns with the Multi-year Strategic Plan and supports multiple agendas, including the APEC Leaders' Declaration on Bio-Circular-Green (BCG) Economy, Putrajaya Vision, Aotearoa Action Plan, and La Serena Road Map for Women and Inclusive Growth. The goals of the Project are to expand knowledge of wood identification technology among industries, research scientists, and the public sector, to consider options for the development of Xylaria Networking (an integrated system of wood identification resembling a Xylarium network) in the APEC region, and to discuss the potential of wood identification integration into the wood legality assurance systems and other relevant mechanisms to supporting international legal wood trade.

2. INTRODUCTION

According to the World Integrated Trade Solution of the World Bank (2023a), about USD86.93 thousand million was rendered from worldwide wood exports, and wood exports contributed to South Asia and East Asia & Pacific as much as USD47.68 and USD3.15 thousand million, respectively. However, Liu et al. (2023) reported that Interpol estimated about 15-30 percent of all wood traded globally was from illegal logging and illicit wood trade. Furthermore, Interpol also noted that the trading of illegally logged wood accounts for between USD51-152 billion annually, representing a significant loss in tax revenues (Interpol 2023). According to Global Financial Integrity (2017), the top three rankings for the illicit markets in the world are counterfeiting, drug trafficking, and illegal logging. Regarding illegal logging, primary wood products contributed an estimated annual value of USD52 billion to USD157 billion, resulting in it being the world's third-largest transnational crime.

In Asia and the Pacific region, it is reported that APEC member economies account for over 54.5% of the world's forests and over 43% of the world's forest products (Food and Agriculture Organization of the United Nations 2020). In addition, the UNFAO Stat in 2019 (Asia-Pacific Economic Cooperation 2023b) recorded that APEC member economies contributed 41% of the global forest products trade in 2019, with a value of over USD344 billion. However, the condition is challenged by the continuous occurrence of illegal logging and illicit wood trade in the Region, leading to high economic loss. The Environmental Investigation Agency (2012) reported that illicit wood trade within and from Asia and the Pacific region is estimated to be worth USD11 billion annually, equivalent to 30 percent of the total trading in wood products. Besides economic value, Reboredo (2013) also considered other socio-environmental and governance impacts of illegal logging and its associated wood trade, such as degradation of the most valuable forest stands, loss of biodiversity, increased soil erosion and landslides, human rights abuses, corruption, crime, coercion, and money laundering, reduction of royalties, taxes, and other charges, and depreciation of legal activities.

An international monitoring and evaluation mechanism on the transnational wood trade, enacted by the Convention on International Trade in Endangered Species (CITES), is also limited, especially for endangered wood species. Many forestry crime actors in several economies still report fake or falsified permits to export CITES-listed wood for the following reasons: lack of tree particular population and geographical distribution data and unskilled forestry officers with technical and theoretical knowledge and capacity building. That condition is also exacerbated by the inconsistencies and loopholes in policies issued at local, domestic, and regional levels in the Asia-Pacific economies, leading to the continuation of illicit trade (Schloenhardt 2008). For instance, a study by Reeve et al. (2015) confirmed that there are some economies with significant natural forests and or potentially engaging in CITES-listed wood trade whose legislation does not comply with CITES. Wyatt et al. (2021) also stated that even though CITES has been adopted by 182 economies and the European Union, implementation of CITES legislation remains inconsistent, compliance at times lacking, and listed species still face extinction.

Besides policy matters, difficulties in integrative monitoring and evaluating the wood value chain for ceasing the clandestine nature of illegal logging and trading are also admitted. Similar to the wildlife trade, efforts to regulate and monitor the wood trade cannot take a “one-size-fits-all” approach, but it should match current and potential traceability mechanisms to wood products to which they may be most suited to increase efficacy and efficiency (Roberts et al. 2020). Even many modus operandi have been dismantled by Interpol (2023), and over thirty different methods of carrying out illegal logging and wood laundering operations have been identified. The most common mode of these forestry crimes is falsifying logging permits or document fraud and mis-declarations to conceal illicit activity and tax evasion. As a result, enhancement of the accuracy of data or information declared in the documents is demanded, and it can benefit from the use of wood identification technologies.

Wood identification technologies comprehend a forensic value in which the technologies can provide a detailed investigation to detect and document the legality of logged or traded wood, presumably infringing the rules of domestic and international laws. The technologies have the nature of "not everyone fits the mold," meaning that each technology has different levels of capacity to prove wood genus, species, geographic provenance, individual origin, and age. Some well-known technologies are digitalized apps, wood anatomy, dendrochronology, mass spectrometry, near-infrared spectroscopy, stable isotope, radiocarbon, DNA barcoding, population genetics, and DNA fingerprinting (Dormott et al. 2015). A study by Boeschoten et al. (2023) discovered a novel method, namely Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and element concentrations, for identifying chemically grouped similar sites (clustering) and assessing the accuracy of tracing samples to their origins.

Forensic wood will not work if it relies only on technological support; many enabling factors must be considered, such as Xylaria or wood collection center, laboratories and instruments completeness, wood identification experts and demands, policies and enforcement, financial mechanism, continuous learning capacity-building, and education. For instance, there are about 180 Xylaria with 1.5 million wood specimens worldwide (Jiao et al. 2018). However, more than 87 wood collection centers across the APEC region play pivotal roles in forensic wood (Global Timber Tracking Network 2023, International Association of Wood Anatomists 2023), having many challenges in financing mechanisms, the availability of advanced technologies, and the need for more human resources.

The above explanations show that wood identification technologies are pivotal to supporting forensic wood in Asia and the Pacific economies, especially APEC member economies. Siloed forensic wood centers and Xylaria networks, lack of database on trans-boundary illegal logging and trade of wood species, and un-standardized wood identification procedures in APEC member economies can be addressed by developing integrated Xylaria Networking, harmonizing names of traded wood species, exchanging wood identification materials, and developing standardized regional wood identification procedures.

3. RESEARCH METHODS

3.1 Date and Places

This study was conducted from 1 September 2023 to 31 January 2024. Data for this study were collected from different sources, including virtual and physical methods. This study extracted data from a literature review and two online workshops conducted in Bogor, West Java, Indonesia by the virtual approach.

3.2 Method and Procedures

This study used four indispensable methods: systematic evidence evaluation or systematic review, mini-survey, workshop validation, and triangulation. All obtained data from these various methods were then approached using triangulation to develop a comprehensive understanding of phenomena or answer the defined questions.

3.2.1 Systematic evidence evaluation

This method refers to Arksey et al. (2005) to acquire more reliable and robust evidence from various sources and disciplines to inform debates and decisions on specific issues. A proposed question for the study was:

"What are the most suitable forensic wood technologies and data that can be used to develop an integrated Xylaria Networking in APEC member economies?"

Through this question, a PECO (Population, Exposure, Counterfactual and Outcome) research framework was developed, as seen in Table 1, and the framework was utilized further to quest Scopus-published literature using "keywords and Boolean logic operators" within a timespan of "all years" and an English language.

Table 1. PECO framework and its Boolean logic operators for searching literature

	Population (P)	Exposure (E)	Counterfactual (C)	Outcome (O)
Question: ***"What are the most suitable forensic wood technologies and data that can be used to develop an integrated Xylaria Networking in APEC member economies?"***				
PECO	APEC member economies	Wood identification technologies, forensic wood technologies, wood identification, forensic wood	Non-forensic wood technologies, non-scientific methods	Integrated Xylaria networking, integrated wood collection center
Key words	- Australia; - Brunei Darussalam; - Canada; - Chile; - People's Republic of China; - Hong Kong, China; - Indonesia; - Japan; - Republic of Korea; - Malaysia; - Mexico; - New Zealand; - Papua New Guinea; - Peru;	- Digitalized apps, - machine vision, - wood anatomy, - dendrochronology, - mass spectrometry, - near-infrared spectroscopy, - stable isotope, - radiocarbon, - DNA barcoding, - population genetics, and - DNA fingerprinting	Non-forensic wood technologies, non-scientific methods	- Integrated wood identification database, - Integrated Xylria Networking, and - integrated wood collection center.

	- the Republic of the Philippines; - the Russian Federation; - Singapore; - Chinese Taipei; - Thailand; - the United States; - Viet Nam
Search string	Example: *Wood Identification:* *(TITLE-ABS-KEY-AUTH (australia OR "brunei darussalam" OR canada OR chile OR people’s republic of china. OR hong kong, china OR indonesia OR japan OR korea OR malaysia OR mexico OR "new zealand" OR "papua new guinea" OR peru OR philippines OR russia OR singapore OR chinese taipei OR thailand OR america OR vietnam OR usa) AND TITLE-ABS-KEY-AUTH ("wood identification" OR "forensic wood" OR "wood forensics" OR "wood forensics") OR TITLE-ABS-KEY-AUTH ("digitalized apps" OR "machine vision" OR "machine learning" OR "wood anatomy" OR dendrochronology OR "mass spectrometry" OR "near-infrared spectroscopy" OR "stable isotope" OR radiocarbon OR "DNA barcoding" OR "population genetics" OR "DNA fingerprinting") AND TITLE-ABS-KEY (wood OR wood OR "wood products" OR "wood products"))* *Forensic Wood:* *(TITLE-ABS-KEY-AUTH (australia OR "brunei darussalam" OR canada OR chile OR people’s republic of China OR hong kong, china OR indonesia OR japan OR korea OR malaysia OR mexico OR "new zealand" OR "papua new guinea" OR peru OR philippines OR russia OR singapore OR chinese taipei OR thailand OR america OR vietnam OR usa) AND TITLE-ABS-KEY-AUTH ("wood identification" OR "forensic wood" OR "wood forensics" OR "wood forensics") AND TITLE-ABS-KEY (wood OR wood OR "wood products")* *Note:* *ABS = abstract* *KEY = key words* *AUTH = authors* *OR = or* *AND = and*

Resultant data were continued to scope to obtain more general information, which was then processed to produce bibliographic graphics.

3.2.2 Mini-survey

A two-time mini-survey using purposive sampling was conducted on wood identification experts and scientists from APEC member economies participating in project workshops. Open-ended and closed-ended questions on wood identification matters. All submitted questions were integrated into each representative's PowerPoint presentation material, which was used for two events (details are in Sub-Chapter 3.2.3). Survey questions covered:

a. techniques/methods of wood identification that have been developed/used in APEC member economies for forensic wood,
b. list of traded wood of each APEC member economy,
c. views on the potential of developing Xylaria collaboration and operationalization mechanism in the Asia-Pacific region;
d. demands on wood identification and standardized wood identification procedures,
e. advantages or disadvantages of different systems of wood identifications,
f. readiness level of forensic wood implementation in the economy’s wood value chain,
g. potential integration of standardized wood identification procedures into the APEC member economies' TLAS,
h. field observatories and capacity-building on wood identification development for forensic wood in APEC member economies,
i. stakeholder mapping for the implementation of forensic wood system.

For the first mini-survey, representatives from seventeen of twenty-one APEC member economies participated, including Canada; Chile; People's Republic of China; Indonesia; Japan; Republic of Korea; Malaysia; New Zealand; Papua New Guinea; Peru; the Republic of the Philippines; Singapore; Chinese Taipei; Thailand; the United States; and Viet Nam. For the second mini-survey, fifteen of twenty-one APEC member economies participated such as Australia; Brunei Darussalam; Canada; Chile; People's Republic of China; Indonesia; Japan; Republic of Korea; Malaysia; New Zealand; Papua New Guinea; the Republic of the Philippines; Chinese Taipei; Thailand; and the United States.

3.2.3 Workshops validation

Resultant data were obtained from APEC member economies through two workshops conducted virtually in Bogor, West Java, Indonesia, via the Zoom platform. The details of these workshops are as follows:

- First workshop:

Event name	:	Joint Research Discussion on Developing Integrated Timber Data for Xylaria Networking
Date	:	6-7 November 2023
Participants	:	80 participants, covering: 1 APEC member economies representatives, 2 wood identification experts, 3 representatives from non-governmental organizations and certification bodies
Participating Economies	:	17 economies, namely: Canada; Chile; People's Republic of China; Indonesia; Japan; Republic of Korea; Malaysia; New Zealand; Papua New Guinea; Peru; the Republic of the Philippines; Singapore; Chinese Taipei; Thailand; the United States; and Viet Nam
Data covered	:	a techniques/methods of wood identification that have been developed/used in APEC member economies for forensic wood, b list of traded wood of each APEC member economy, c views on the potential of developing Xylaria Networking and its operationalization mechanisms in Asia and the Pacific region, d demands on wood identification and standardized wood identification procedures, e advantages or disadvantages of different systems of wood identifications.

- Second workshop:

Event name	:	Focus Group Discussion on Developing Integrated Timber Data for Xylaria Networking
Date	:	16 January 2024
Participants	:	85 participants, covering 1 APEC member economy representatives, 2 policy makers 3 wood identification experts.
Participating Economies	:	17 economies, namely: Australia; Brunei Darussalam; Canada; Chile; People's Republic of China; Indonesia; Japan; Republic of Korea; Malaysia; New Zealand; Papua New Guinea; Peru; the Republic of the Philippines; Chinese Taipei; Thailand; and the United States.
Data covered	:	a best practices sharing on forensic wood identification, b techniques/methods of wood identification that have been developed/used in APEC member economies for forensic wood, c list of traded wood of each APEC member economy, d advantages or disadvantages of different systems of wood identifications, e readiness level of forensic wood implementation in APEC member economies,

f potential integration of standardized wood identification procedures into the APEC member economies' TLAS,
g stakeholders mapping of forensic timber application in APEC member economies.

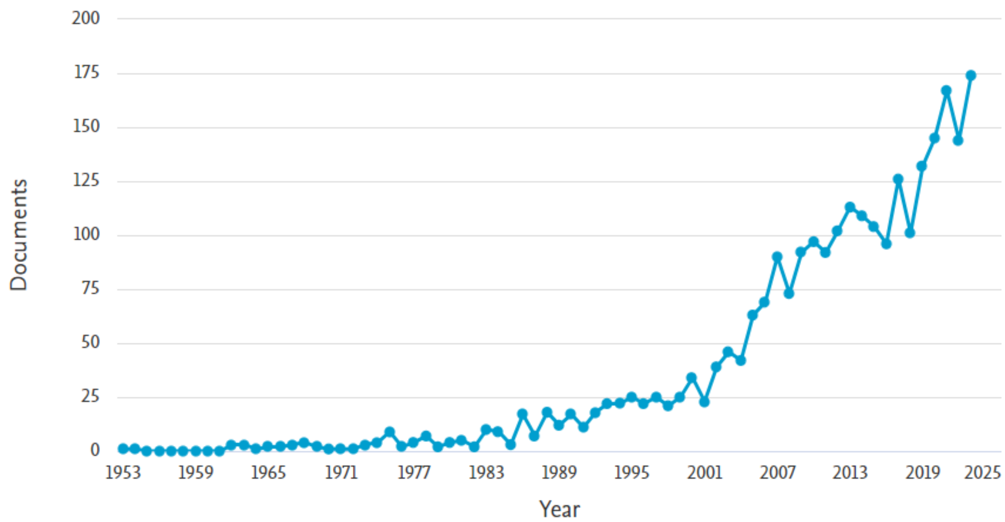
3.2.4 Triangulation and data analysis

This study used three types of triangulation, namely: data, investigators, and method (Noble et al. 2019). It indicated that periods, space, people, several researchers, and several data collection methods were used to triangulate the resultant data in the previously explained ways. Data from systematic evidence evaluation were interpreted using bibliometric analysis. Data from surveys of each APEC member economy were used to draw deductive interference. Tables and figures were also prepared to depict the interference.

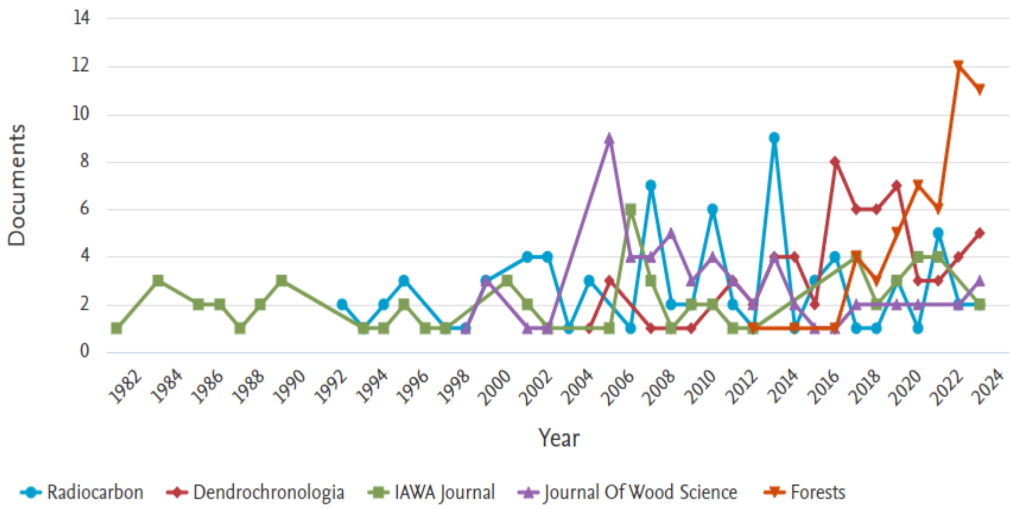
4. RESULTS AND DISCUSSION

4.1 Recent Studies of Wood Identification in Asia and the Pacific
4.1.1 Research and publications

From a scoping review study (Scopus 2024), as of 31 May 2024, about 2,624 published documents recorded on wood identification studies in APEC member economies. Figure 1 shows studies and published documents concerning wood identification in APEC member economies by year, per year by source, type, and subject area. It shows that, to date, the published studies have continuously varied, novel, and or updated wood identification issues since 1953. In addition, the studies have published scientific documents with an increasing trend in the number of publications as tracked in the Scopus-based academic search engine from 1953 to 2023 (Figure 1a). It indicates that scientists are interested in researching wood identification and issuing several knowledge products.



a



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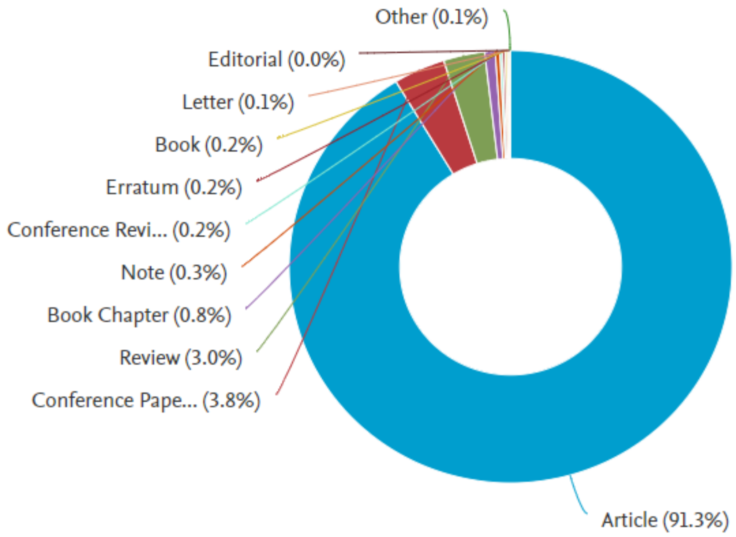

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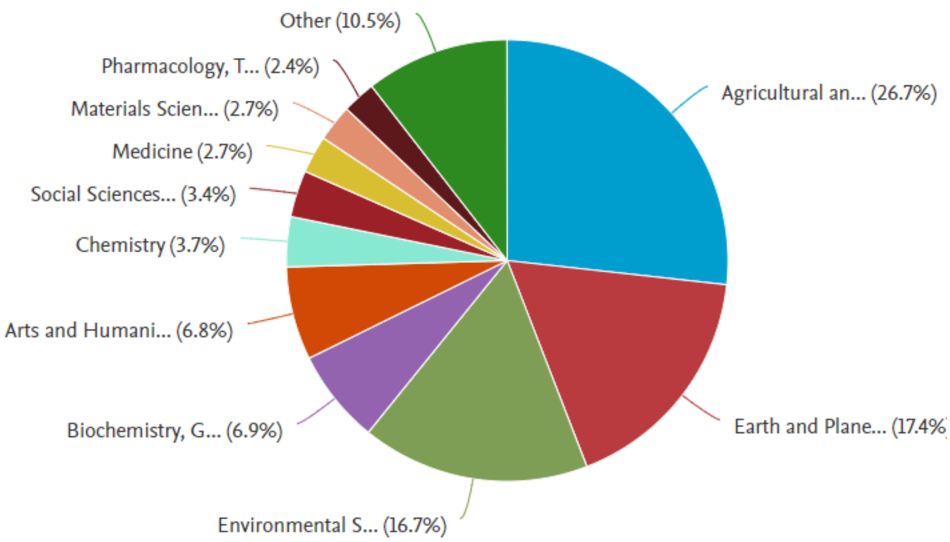


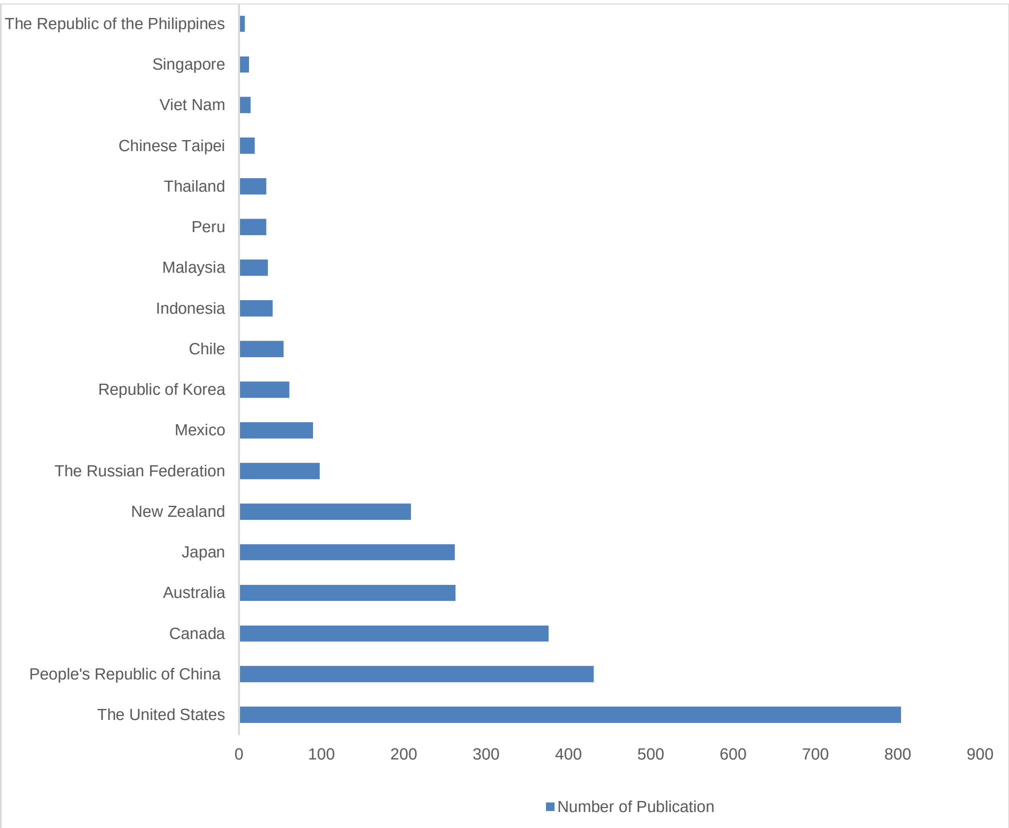
d

Figure 1. Number of published documents by year (a), per year by source (b), by type (c), and by subject area (d) related to wood identification in APEC member economies

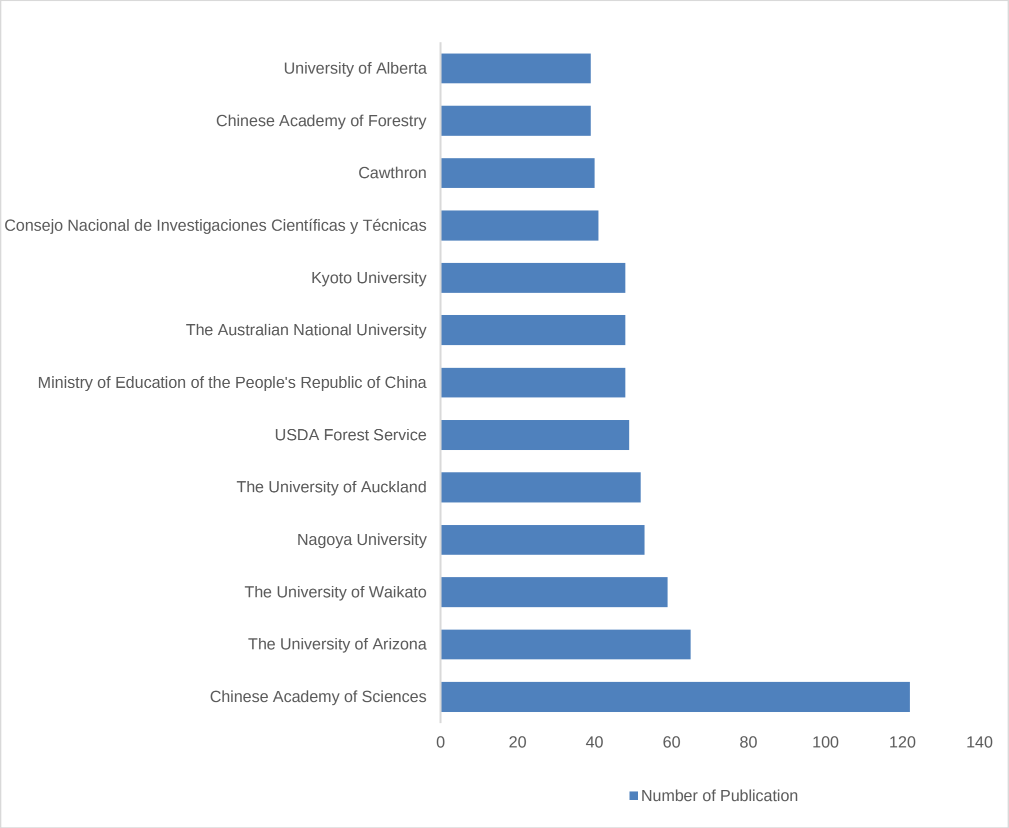
The published studies have been primarily concerned with laboratory-based and enough applicative industry uses. In terms of application, studies on explorations of different wood identification technologies, database collection, and wood forensics applications to identify wood legality and combat wood trafficking have become one of the wood researchers' attentions. From questing relevant literature in the Scopus academic search engine, the increasing trend of the studies' attention denotes that wood identification technologies for forensic wood are considered appealing and have the value of providing forensic evidence for addressing illegal logging and its associated trade. It is also regarded that forensic wood sciences have been used for identifying tree species through different technologies since 1983, such as computer-assisted wood identification systems, wood anatomy, synchrotron X-ray microtomography, DNA analysis, tree-ring dating, and others.

Wood identification researchers in APEC member economies have preferred to publish their studies results in Radiocarbon, Dendrochronologia, IAWA, Journal of Wood Science, and Forests, becoming the top five publishing journals with a high total number of wood identification issues since 1953. However, in the last three years (2020-2023), Forests (36 documents) and Dendrochronologia (15 documents) have become their favourite journals for publication. The published documents are mainly in the form of articles (91.30%), conference papers (3.80%), and others (4.90%), including reviews, book chapters, notes, conference reviews, etc.) indexed by Scopus. Their publications are predominantly categorized into several indispensable subjects, such as agricultural and biological science (1,194 documents), earth and planetary sciences (776 documents), environmental science (745 documents), biochemistry, genetics, and molecular biology (308 documents), and arts and humanities (305 documents).

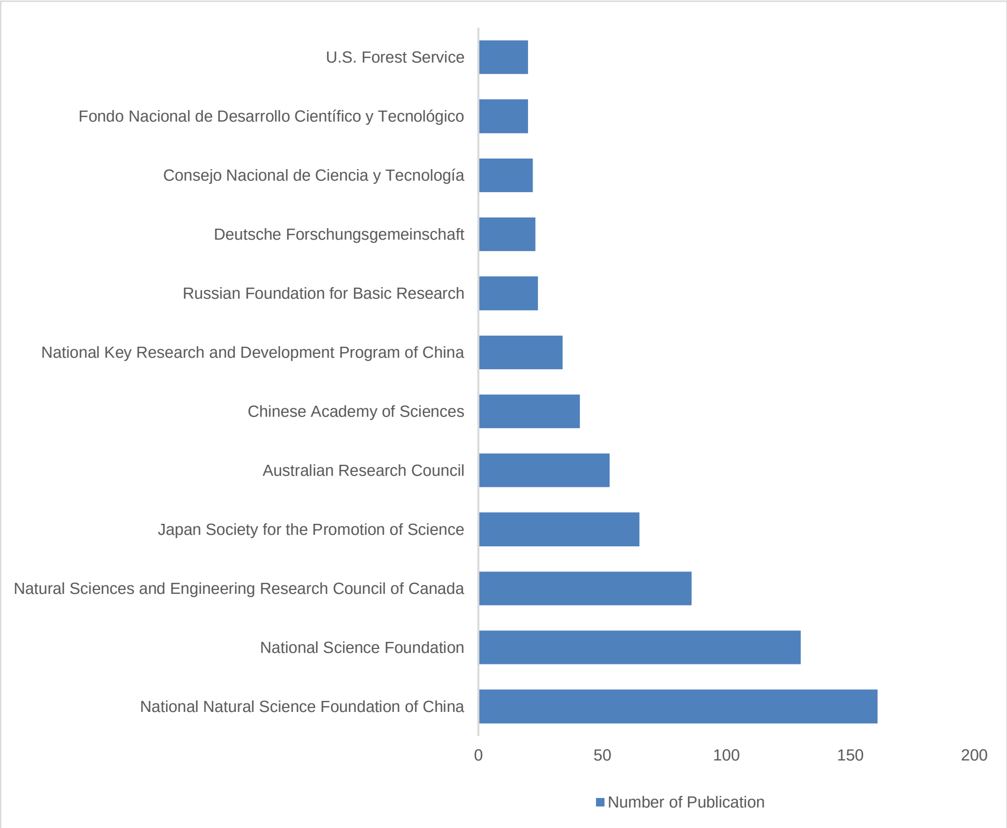
Figure 2 shows the different statuses of published studies in the Scopus-indexed academic search engine. APEC member economies, such as the United States (804 documents); People's Republic of China (431 documents); Canada (376 documents); Australia (263 documents); Japan (262 documents); New Zealand (209 documents); the Russian Federation (98 documents); and Mexico (90 documents) have the intense contributions to publish studies relevant to wood identification. Regarding the published documents by affiliation, the Chinese Academy of Science, University of Arizona, University of Waikato, Nagoya University, University of Auckland, USDA Forest Service, Australian National University, Ministry of Education of the People's Republic of China, Kyoto University, and Consejo Nacional de Investigaciones Científicas y Técnicas are the forefront studies centres, actively



a



b



c

Figure 2. Published documents per economy (a), affiliations (b), and funding sources (c)

conducting studies on wood identification. Furthermore, in terms of funding sponsors enabling the execution of wood identification studies, the National Natural Science Foundation of China, the National Science Foundation, the Natural Sciences and Engineering Research Council of Canada, the Japan Society for the Promotion of Science, the Australian Research Council, the Chinese Academy of Sciences, and the National Key Research and Development Program China are the most active funders for sponsoring wood identification studies in their respective APEC member economies.

4.1.2 Studies of wood identification application for forensic wood

As highlighted in 4.1.1, it is known that published documents on both wood identification and forensic wood in the APEC region have a mounting trend. The published papers on forensic wood have increased since 1983, and many conventional, advanced, and disruptive technologies have been used for forensic wood studies. Table 2 shows the chronicles of different wood identification technologies and their uses for forensic sciences in APEC based on the Scopus-searched literature. It is observed that wood identification studies have been carried out since the 1950s to date, in which different technologies have been used in the form of individual technologies and or multiple technologies. Some of the identified technologies are, for instance, radiocarbon dating, wood anatomy, computer-assisted wood anatomy and machine learning, tree-ring analysis or dendrochronology, stable isotope, solid-state 13C nuclear magnetic resonance (NMR), DNA barcoding, DNA fingerprinting, population genetics, pyrolysis-gas chromatography-mass spectrometry (GC-MS), liquid chromatography-mass spectrometry (LC-MS), time-of-flight secondary ion mass spectrometry (TOF-SIMS), direct analysis in real-time ionization coupled with time-of-flight mass spectrometry (DART-TOFMS), inductively coupled plasma mass spectrometry (ICP-MS), laser ablation direct analysis in real-time imaging–mass spectrometry (LADI-MS), gas chromatography with high-resolution quadrupole Time of Flight mass spectrometry (GC/QTOF, GCxGC-TOFMS), thermal desorption-gas chromatography-mass spectrometry (TD-GC-MS), near-infrared spectroscopy (NIR), UV-Vis fluorescence, and synchrotron X-ray microtomography. In the 1950s, radiocarbon, stable isotope, and dendrochronology were utilized to identify paleoclimate records, archeology, driftwood age and origin, and human history.

Table 2. Studies on wood identification and their use for forensic wood in APEC member economies

Wood identification tools	Purposes of wood identification technologies	Year of publication	References
Individual technologies			
Radiocarbon dating	To determine the latest dates for the Eskimo period	1953	Henry (1953)
	To clarify the correlation between events marking the closing phases of the last glacial period, using radiocarbon ages of wood	1963	Wallace et al. (1963)
	To determine the year of death of logs and snags of Thuja plicata	1997	Daniels et al. (1997)
	To undertake Δ14C analysis of ~140 decadal floating New Zealand wood samples	2013	Hogg et al. (2013)
	To identify archaeological wood samples	2017	Dong et al. (2017)
Wood anatomy	To examine the secondary wood of available species of the genus New Guinea Nothofagus	1954	Dadswell et al. (1954)
	To identify the native or commonly cultivated genera of Oleaceae	1986	Pieter et al. (1986)
	To identify dicotyledons indigenous of myrtaceae from New Zealand	1995	Patel et al. (1995)
	To identify different wood species from the rainforest in Quintana Roo, Mexico	1998	Rebollar (1998)
	To identify wood anatomy of five dipterocarp species endemic to the Republic of the Philippines	2009	Rana et al. (2009)
	To find anatomical characters that distinguish the wood of *Dalbergia nigra* from other commercially important species of Dalbergia	2010	Gasson et al. (2010)
	To study on origin and authentication of medicinal materials of *Dalbergiae Lignum*	2015	Liu et al. (2015)

	To develop an automated macroscopic wood identification system	2018	Tang et al. (2018)
	To analyze the anatomical characteristics of various wood plywoods	2021	Lee et al. (2021)
	To describe the macroscopic wood anatomical features of Peruvian Amazon tree species	2023	Ferreira et al. (2023)
Computer-assisted wood anatomy and machine learning	To identify commercial Leguminosae of southeast Asia and Australia.	1983	Quirk (1983)
	To develop mobile-based applications for practical wood identification	2020	Arifin et al. (2020). Hidayat et al. (2020)
	To identify tree species and their structures	2021	Lopes et al. (2021), Ravindran et al. (2021), Tsuya et al. (2021), Zhao et al. (2021)
	To provide wood identification based on anatomical images	2023	Minh Trieu et al. (2023)
	To reveal interspecific differences between closely related tree species.	2024	Zheng et al. (2024)
Tree-ring analysis or dendrochronology	To determine the geographic origin of archaeological wood	1975	Eckstein et al. (1975)
	To determine the past snow avalanche events	1979	Carrara et al. (1979)
	To identify the growth rings in the wood of fast-growing tawa	1981	Ogden et al. (1981)
	To investigate the origin and age of the Frobisher Bay driftwood	1995	Eggertsson et al. (1995)
	To study secondary forest succession in the tropics.	2009	Brienen et al. (2009)
	to establish discrete proxies besides tree-ring width	2023	Thomte et al. (2023)
Stable isotopes	To determine paleoclimate records by comparing marl and wood	1988	Edwards et al. (1988)
	To identify 13C records of annual growth rings of two Japanese cedars	1993	Kitagawa et al. (1993)
	To identify stable oxygen and carbon isotopic composition of tree-ring cellulose in pine and conifer	2007	Roden et al. (2007), Holdaway et al. (2007)
	To identify the geographic origin of pine wood using tree-ring isotopes	2010	Kagawa et al. (2010)
	To compare dendroisotopic series of cellulose from late and whole ring of black spruce trees	2018	Alvarez et al. (2018)
	To retrospectively quantify these responses in three conifers inhabiting drought-prone areas	2020	Pacheco et al. (2020)
	To address the differences in stable isotope ratio profile of bulk, homogenized wood from Gabon	2021	Watkinson et al. (2021)
	To investigate relationships between tree-ring δ13C, tree-ring width index and ecosystem-level GPP in a Korean pine	2023	Diao et al. (2023)
	To identify the geographic origin of Eastern European timber using stable isotopes and trace elements	2024	Mortier et al. (2024)
Solid-state 13C nuclear magnetic resonance (NMR)	To determine angiospermous wood from Australian brown coal	1989	Hatcher et al. (1989)
	to gain information about lignin molecular characteristics of some Austral hardwoods	1999	Martinez et al. (1999)
	To characterize the chemical properties of wood and wood products	2002	Maunu et al. (2002)
	To analyze structural elucidation of archaeological woods	2009	Bardet et al. (2009)
DNA analysis: DNA barcoding or DNA fingerprinting	To identify prospective genetic marker Japanese representatives of Cyclobalanopsis	1999	Ohyama (1999)
	To test DNA barcodes of *Dalbergia odorifera* and *Dalbergia tonkinensis*	2016	Yu et al. (2016)
	To develop DNA databases from *Shorea leprosula, Intsia palembanica,* and *Gonystylus bancanus*	2016, 2022	Ng et al. (2016), Ng et al. (2020), Ng et al. (2022)
	To optimize and modify the common CTAB protocols to extract DNA from Sengon wood	2019	Shabrina et al. (2019)
	To develop and validate a set of genetic markers for individualisation in bigleaf maple	2020	Dormontt et al. (2020)
	To solve the tree species mystery of the imperial wood “Nanmu” in the Forbidden City	2022	Jiao et al. (2022)

	To build genomic prediction models for genomic selection of *Shorea macrophylla*	2023	Akutsu et al. (2023)
Population genetics	To assess metabolomics of Douglas-fir	2007	Robinson et al. (2007)
	To identify potential differences in spatial genetic structure o *Pinus engelmannii* and *P. leiophylla*	2017	Ortiz-Olivas et al. (2017)
	To examine the genetic variation and spatial distribution of *Dryobalanops aromatica*	2018	Ritonga et al. (2018)
	To identify spatial genetic structure and genetic diversity of *Juglans regia* samples	2023	Khan et al. (2023)
Pyrolysis-gas chromatography-mass spectrometry (GC-MS)	To determine angiospermous wood from Australian brown coal	1989	Hatcher et al. (1989)
	To determine the films of *Rhus vernicifera* and *Rhus succedanea* lacquers	1995	Niimura et al. (1995)
	To analyse chemical compositions of lipophilic fractions from Eucalyptus woods	2007	Silvverio et al. (2007)
Time-of-flight secondary ion mass spectrometry (TOF-SIMS)	To examine pulp fiber and paper properties and the distribution of heartwood extractives	2007	Fukushima et al. (2007)
Direct Analysis in Real Time ionization coupled with time-of-flight mass spectrometry (DART-TOFMS)	To provide rapid chemical analysis of Dalbergia wood	2012	Lancaster et al. (2012)
	To determine distinct chemical fingerprints of the wood of *Afzelia pachyloba* and *A. bipindensis*	2021	Kitin et al. (2021)
	To identify distinctive lignin peak between Angiosperms and Gymnosperms woods	2022	Cody et al. (2022)
	To identify distinctive lignin peak between Hardwood Angiosperms and Coniferous Gymnosperms	2023	Cody et al. (2023)
Inductively coupled plasma mass spectrometry (ICP-MS)	To determine major, minor, trace, and ultra-trace elementals of Douglas fir	1990	Hall et al. (1990)
	To trace the origin of commodities	2023	Boeschoten et al. (2023)
Laser ablation direct analysis in real time imaging–mass spectrometry (LADI-MS)	to survey the chemical profile of wood, while also preserving the small-molecule spatial distributions	2022	Deklerck et al. (2022)
Gas chromatography with high resolution quadrupole Time of Flight mass spectrometry (GC/QTOF)	to analyze wood extracts for chemotyping in support of endangered Dalbergia wood species identification	2020	Shang et al. (2020)
	to differentiate plantation-grown Fijian *Swietenia macrophylla* from the same wood species obtained from native forests.	2023	Kim et al. (2023)
Two-dimensional gas chromatography combined with time-of-flight mass spectrometry (GCxGC-TOFMS)	to differentiate five Meliacea (Mahogany) species	2023	Duchesne et al. (2023)
Thermal desorption-gas chromatography-mass spectrometry (TD-GC-MS)	To identify mixed tropical hardwood species in pulp and paper products based on their extractives	2023	Flaig et al. (2023)
Near-infrared spectroscopy (NIR)	To rapidly predict the crystallinity of slash pine	2007	Jiang et al. (2007)
	To identify similar Pinus species used as building materials for traditional architecture	2016	Hwang et al. (2016)
	To discriminate the spectra of some high-value Dalbergia wood species	2018	Snel et al. (2018)
UV-Vis fluorescence	To determine the fluorescence characteristics of Mexican woods	2008	Silva Guzmán et al. (2008)
	To identify the types, number of fluorescent compounds, maximum excitation and emission wavelengths, and effects of solvent and pH of *Pterocapus santalinus*	2021	Du et al. (2021)
Synchrotron X-ray microtomography	To identify an old wooden mask discovered at Yatsushiro city	2010	Mizuno et al. (2010)
	To identify wood taxa selected for archaeological artefact manufacture	2016	Whitau et al. (2016)
	To identify wood fragments from wooden members used in the Manseru pavilion of Bongjeongsa temple in Andong	2020	Hwang et al. (2021)
Combined Technologies			
Wood anatomy and carbon isotope	To measure radial variation of carbon isotope composition and vessel traits in tree species	2009	Ohashi et al. (2009)

Wood anatomy and machine learning	To discriminate CITES-listed species from their look-alikes in international trade	2022	Liu et al. (2022)
Synchrotron X-ray microtomography and optical microscopy techniques	To identify small and important artifacts	2011	Tazuru-Mizuno (2011)
	To identify Japanese Shinto deity statues in Matsunoo-taisha Shrine in Kyoto	2021	Tazuru et al. (2019)
Fourier transform ion cyclotron resonance mass spectrometry (FTICR-MS)	To conduct species-level wood identification of *Pterocarpus santalinus* and *Pterocarpus tinctorius*	2019	Zhang et al. (2019)
DART-TOFMS and chemometrics	to classify archeological wood and recent wood into three groups according to their deterioration states	2020	Guo et al. (2020)
High-resolution QTOF mass spectrometers interfaced with liquid chromatography (LC), GC, and DART, and machine learning	to develop wood species identification procedures suited to legally defensible wood genus and species identification	2021	Brunswick et al. (2021)
DART-TOFMS, wood anatomy, and fluorescence spectroscopy.	To provide more accurate identification of different Pterocarpus species	2021	Price et al. (2021)

In the 1980s, wood anatomy was embarked on to examine different species of wood and their anatomical features. Around that year, computer-based systems were harnessed to integrate macroscopic and microscopic wood feature data into a more digital and computerized database system. In the 20th to 21st century, a significant shift in wood identification studies was tracked in which different advanced, disruptive, and digitalized techniques for identifying wood have been explored for studies. For about a decade and a half, some studies have used multiple wood identification technologies for wood identification. For instance, the combination of wood anatomy and carbon isotope, synchrotron X-ray microtomography and optical microscopy techniques, DART-TOFMS and chemometrics, high-resolution QTOF mass spectrometers interfaced with liquid chromatography (LC), GC, and DART, and machine learning, and DART-TOFMS, wood anatomy, and fluorescence spectroscopy. Multiple techniques are used to increase the accuracy and certainty in profiling genus, species, origin, geographical provenance, age, and individual (Zhang et al. 2019, Del Valle et al. 2020, Price et al. 2021).

The scoping study also suggests that there are vital interventions to nudge the implementation of research findings to practical use, such as forensic wood. Many studies have focused on identifying the legality of traded wood and explicitly providing scientific evidence to solve various crimes. Although in previous studies in the 1950s, wood identification was used for archeological and paleoclimatology purposes, intensive studies on forensic wood have been conducted in the 2015s. Different wood identification tools, both individual instrumentation and multi-instrumentations, are used for forensic wood analysis to determine genus, species, age, provenance (origin), and individual. For example, in 2016, a 20 DNA marker database of West and East Malaysia's *Gonystylus bancanus* at the species, population, and the individual level was developed from a study by Ng et al. (2016), and the study was anticipated to support forensic applications and help safeguard this valuable species into the future. Ng et al. (2022) continued to develop DNA databases from 1410 *Shorea leprosula* samples of 44 populations in Peninsular Malaysia, which can fit the existing reference database for illegal logging investigations and verification of legality in wood supply chains. Forensic wood benefitted from multiple instruments, for instance, the combination of DART/QTOF, GC/QTOF, and LC/QTOF and machine learning processes to readily perform wood identification to the species level of Dalbergia, with the reduced time-consuming process of extracting "identifying" mass spectral ions (Brunswick et al. 2021).

4.1.3 Strengths and limitations of various wood identification technologies

Integrating different methods for wood identification for APEC member economies could provide their overview, advantages, and limitations. APEC member economies could consider the use of these methods to identify sample size, such as tiny pieces (pulp and paper, veneer, char, microfibers, and other lignocellulose components), small to medium size (a few centimeters thick of wood and wood products), or actual size (log, tree, etc. presumably using non-destructive test). In addition, they could consider them based on what will be profiled for their risks as CITES/non-CITES-listed wood or high-commercial wood, with relevant HS code and their permits, and based on the points to prove genus, species, provenance, and age. Other considerations in selecting them are the speed of obtaining the results, cost-efficiency in using the technologies, required equipment, reference materials availability, and others.

Table 3. Strengths and limitations of wood identification technologies

Wood Identification Technologies	Definition	Strengths	Limitations
Machine vision	Automated wood anatomy technique with advanced image-based analysis and AI technologies for intelligent field-level wood identification.	- Easily installed and used on smartphones - Non-destructive wood identification - Fast process to acquire the results of wood identification - Enabling untrained individuals to obtain high identification accuracy - No subject to a range of human failings	- Lack of accuracy for wood having inter- and intra-anatomical variability and high anatomical resemblance - Low frequency intensity variations in the image - Difficulties to identify stained or deformed samples - Limited image databases - Difficult to quantify model overfitting in the absence of extensive field testing and verification - Requiring specific expertise to understand digitalization and develop machine vision
Wood anatomy	Identification of wood's macroscopic and microscopic structure at the genus and species level.	- Common use and the oldest technique for wood tracking - Built on decennia of studies and application experience - Available extensive databases with reference samples - Able to identify fibers, pulp, papers, and its engineered wood products	- Hindering to determine wood species due to high anatomical resemblance - Challenges to identify the origin of wood due to inter- and intra-anatomical variability resulting from environmental condition - Difficulties to identify engineered wood products composed by fibers from different wood species
Dendrochronology	Known as tree ring dating, estimating the age or the period of wood formation from the annual growth increments analysis of trees	- Used for retrospective biomonitoring with reliable and ubiquitous archives for dating past events and for paleoenvironmental reconstruction. - Providing specific information on tree age, individual (origin), and provenance - Considering variations for local conditions in the analysis and the tree ring record	- Difficulties in determining wood species in the tropics, having no sufficiently distinct seasonal patterns - Requiring more preservation treatment to wood, leading to readable rings
Mass spectrometry	Analytical tool, such as DART-TOFMS, GC-MS, LC-MS, ICP-MS, TOF-SIMS, FTICR-MS, and others, for conducting a qualitative and quantitative study of the chemical substances of wood	- Non-destructive method, requiring no sample preparation (a piece of wood is enough) - Fast characterization to acquire the results - Able to differentiate wood genus, species, and provenance	- Limited reference collection - Most phytochemical profiles are species-specific
Near-infrared spectroscopy	Rapid, noninvasive, and cheap chemometric method used for profiling the chemical composition of wood under the near-infrared region from 780 nm to 2500 nm	- Non-destructive and not costly analysis of wood - Rapid and frequent measurements - Suitability for field and laboratory use - Simultaneous determination of different attributes	- Limited reference data - Reliance on reference methods and model development using chemometrics - Varied identification accuracy
Stable isotope	Method used to identify the isotopic compositions of wood in order to verify	- Able to identify provenance - Nontoxic, no radiation hazard, and no decay over time	- Fluctuating stable isotope ratios in nature due to

	its geographical origin, with common bio-elements of $\delta^{18}O$, $\delta^{2}H$, $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ used for wood tracing		climatological, biological, and geological variables - High expense and sophistication of instrumentation - Requiring an intensive labor analysis
Radiocarbon	Method used to measure time and date objects of wood using the decay of a radioactive isotope of carbon (^{14}C)	- Able to identify age of a specimen formed over the past 55,000 years - High accuracy and precision, depending on sample size, preservation state, and features of the calibration curve - Allowing unattended and remotely controlled operations for modern accelerator mass spectrometry	- Destructive and costly - Requiring a certain amount of carbon - Only able to analyze organic materials, not inorganic materials
DNA barcoding	System used to identify wood species by analyzing a DNA barcode and subsequently comparing its sequence to a reference library, which contains many species information	- Invaluable and handy tool for detecting errors in wood genus, species, and occasionally provenance - Not requiring expert taxonomic knowledge in order to identify specific samples as solid reference database was well established - Improve and complement other wood identification technologies - Proving high efficiency and accuracy of wood identification, depending on the species sampling and size	- Dependent on the pure and high-quality DNA isolated - Very difficult to extract high quality DNA from wood due to its degraded nature - Requiring significant amount of sampling and proper homogenization - Limited reference database - Costly and requiring several days for analysis - No standard barcoding marker - Taxonomic resolution variable among groups - Difficult to distinguish wild and. plantation - Long wait time for results - Not suitable as screening tool - Needing physical samples
Population genetics and phylogeography	Methods that examine genetic similarities and differences of individuals and populations within species and determine the link between geography and intraspecific genetic diversity	- Able to identify species occasionally, provenance, and geographic ordination of genotypes - Provide more accurate and better understanding of biological patterns and process of wood	- Requiring complex knowledge on a range of subtle skills - Costly and requiring several days for analysis - Obstacles in the development of genetic markers and reference databases - Taxonomic resolution variable among groups - Difficult to distinguish wild and. plantation - Long wait time for results - Not suitable as screening tool - Needing physical samples
DNA fingerprinting	Known as DNA profiling, a technique employed to identify a specific pattern or DNA profile from wood	- Affordable and reliable technique to identify individuals - Little or no information required on the DNA sequence - Easy and painless to obtain a testing specimen - Small quantity of samples required	- Costly and requiring several days for analysis - Obstacles in the development of genetic markers and reference databases - Requiring trained manpower to interpret the results - Taxonomic resolution variable among groups - Difficult to distinguish wild and. plantation - Long wait time for results - Not suitable as screening tool - Needing physical samples

Wood identification technologies are dynamic, evolving every year to change the wood identification techniques. With the evolved technologies, reference data on wood identification is anticipated to be available for wood verification. Generally, five wood identification tool categories have been explored in studies and used in several forensic wood applications in APEC member economies, including digitalized techniques, wood anatomy, wood molecular biology, wood chemistry, and a combination of these methods. However, there is also a primary attempt to identify wood's electrical, mechanical, and acoustical properties through novel techniques. In this part, as shown in Table 3, various wood identification advantages and disadvantages will be highlighted. By understanding the purposes, strengths, and limitations of wood identification, the APEC member economies could consider the fittest technology that can be used for forensic wood. They can also take the parameters for deciding which technologies to invest in. Investors can also know the risks of technology investment for their finances. Furthermore, by evaluating the technology risks, the APEC member economies also evade societal discrimination and determine whether the technologies will assist in achieving their goals and improving forensic wood operations.

It is well-noted that the " one-size-fits-all " approach cannot apply to forensic wood. In addressing diagnostics analysis by profiling risks at the genus, species, provenance, individuals, and age, not all forensic wood can address it. The scientists can make use of the combined technologies. However, as the diagnostic analysis is only for the wood age, wood scientists can use dendrochronology or radiocarbon for forensic wood techniques. Besides these parameters, many diagnostic wood identifications can be referenced for APEC member economies for forensic wood identification methodologies (Table 4). Besides diagnostic methods for forensic wood, initial screening methods can also be applied for suspected wood and its products using various wood identification, such as fluorescent analyzer, macroscopic wood anatomy, microscopic wood anatomy, machine vision, near-infrared spectroscopy, and detector dogs. These methods are considered rapid-field identification tests of suspect wood to prove a possible occurrence of a criminal violation. The test can be undertaken by front-line officers or wood scientists working directly in the field.

Table 4. Diagnostic approaches for forensic wood identification

Parameter analyses	**Forensic wood technologies**									
	Machine vision	**Wood anatomy**	**Dendrochronology**	**Mass spectrometry**	**Near-infrared spectroscopy**	**Stable isotope**	**Radiocarbon**	**DNA barcoding**	**Population genetics and phylogeography**	**DNA fingerprinting**
Points to prove - Genus - Species - Geographic provenance - Individual origin - Age	 Yes Occasionally Unknown No No	 Yes Occasionally Occasionally No No	 No No Occasionally Yes Yes (requiring the presence of growth ring)	 Yes Yes Yes No No	 Yes Yes Yes No No	 No No Yes No No	 No No No No Yes	 Yes Yes Occasionally No No	 No Occasionally Yes No No	 No No No Yes No
Approximate cost per sample and expertise	< USD1	< USD100	< USD100	< USD1 –100 (depending on the mass spectrometry method used)	< USD100	USD100-400	USD300-400	USD100-300	USD100-300	USD100-300
Speed of process	Seconds-minutes	Minutes-days	Hours-days	Minutes-days (depending on the mass spectrometry method used)	Seconds-minutes	Several days	Several days	Several days	Several days	Several days
Prior information requirements	None but Suspected region of origin	None but Suspected region of origin	Species	Suspected genus	Broad region of origin	Species	None	None - but suspected taxa can be helpful	Genus for species identification, species for regional identification	Species
Major equipments for testing	Machine vision, deep learning, and apps-based smart phone equipped with database	Microscope and other observation tools	Microscope and its tree-ring measuring apps	Mass spectrometer and equipment for isolating extractives	Near infrared spectroscopy machinery and database link	Isotope ratio mass spectrometry, stable isotope tracer, and elemental analyser	Radiocarbon accelerator mass spectrometry and liquid scintillation counting	Polymerase chain reaction, DNA sequencer, genomic DNA analysis, and molecular biology	Polymerase chain reaction, DNA sequencer, genomic DNA analysis, and molecular biology	Polymerase chain reaction, DNA sequencer, genomic DNA analysis, and molecular biology
Wood basic properties analysed	Morphological properties, with possibilities to know all properties of wood depending on database	Morphological properties	Growth rings	Chemical propertes	Chemical properties	Chemical and isotope properties	Chemical properties, especially age and chronologies	Biomolecular properties	Biomolecular properties	Biomolecular properties
Reference materials required	Central database of scientific reference images processed for automated classification	Access to microscopic wood anatomy examples through microscope	Tree ring series data derived from reference tree cross-sections from specific areas	Heartwood samples from multiple individuals of the desired taxa and potential lookalikes	Regional specific database loading of reference spectra obtained from wood	Wood samples from the desired species with various tree rings	None	Leaf, cambium or wood samples from the desired taxa and potential lookalikes	Leaf, cambium or wood samples from multiple individuals from across the range of the species	Leaf, cambium or wood samples from multiple individuals from across the range of the species

		slides and electronic databases			specimens					
Current use	Used predominantly in a research context and in pilot implementation Projects	The most commonly and extensively used method for genus identification	Used occasionally to match wood coming from same tree or to determine antique verses modern origin of wood	Used extensively for identification of some taxa (e.g. Dalbergia)	Used extensively for assessment of wood properties and currently used in pilot studies for identification	Used extensively for origin check in agricultural products and used in proofs of concept studies and pilot tests for wood	Used extensively for age determination in a wide range of materials, limited application to wood at present	Used extensively for species identification in a wide range of taxa, limited application to wood at present	Used predominantly in a research context and in pilot implementation projects	Used extensively for individual identification in humans and other taxa, limited application to wood at present
Obstacles to implementation	Incorporation of reference material into database, classification models robust for global context vs. regional models	Training of sufficient numbers of wood anatomists, maintenance of reference collections	Collection of tree ring series data for important taxa in areas of interest	Development of reference databases for additional taxa of interest	Development of reference databases for additional taxa of interest	Development of reference databases for additional taxa/areas of interest	No significant obstacles to implementation	Development of discriminating barcodes that work on DNA extracted from wood	Development of genetic markers and reference databases that discriminate areas and taxa of interest	Development of genetic markers and reference databases that discriminate individuals in taxa of interest
Research needs	Development of global scientific image reference collection, uncertainty quantification and probabilistic model development	Discrimination between closely related taxa, forensic validation of methods	Accuracy of dating, provenancing and individual identification, forensic validation of methods	Forensic validation of methods for additional taxa	Development of reference databases, forensic validation of methods	Development of reference databases, forensic validation of methods	No specific research needs with regards to wood	Development and forensic validation of DNA barcoding methods	Development and forensic validation of discriminating genetic markers and reference databases	Development and forensic validation of discriminating genetic markers and reference databases

Source: Dormontt et al. (2015) and United Nations Office on Drugs and Crime (2016)

4.2 Readiness Level of Wood Identification for Forensic Wood Application

The readiness level of wood identification technologies for forensic wood application serves as a consistent reference for APEC member economies and their relevant stakeholders to understand the current maturity of forensic wood identification implementation. In addition, it helps the management make decisions on how to normalize, progress, and optimize forensic wood identification in addressing the illicit wood trade. The actions can be followed up through relevant forensic wood research, development, exchange of best practices, networking and collaborations, financing mechanisms, and capacity-building. For readiness level analysis, several parameters are developed, considering their demand, priorities, and current situation. Some variables analyzed include the availability of wood identification laboratories, infrastructure, and technology; the availability of wood identification experts, scientists, or researchers; the relevant regulations or policies; the domestic wood identification standards or guidelines; wood identification capacity-building, education, and skills enhancement; the integrated wood identification system (databases/tools); sustainable financing or investment mechanism; and integrated standardized wood identification tools, methods, and processes.

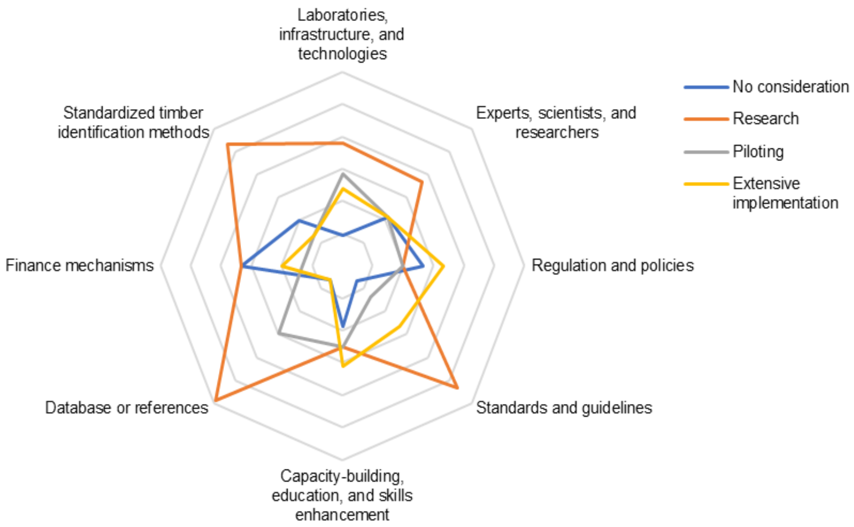


Figure 3. Readiness level of forensic wood in APEC member economies

Figure 3 shows that the readiness level of APEC member economies' forensic wood is, on average, at the research stage. It indicates that they have used and explored different types of wood identification technologies for laboratory or field studies. The results of the studies are intended for publication, policy-decision-making, piloting projects, and other studies reference. Besides that, some APEC member economies have already applied extensively wood identification for forensic wood analysis, meaning that forensic wood identification has been normalised into their wood legality assurance operations, which are presumably strengthened with the relevant policies or legislation. It is also known that each member economy has a different readiness level to implement forensic wood identification on the ground. For instance, the United States has a readiness level at extensive implementation in terms of the availability of laboratories, technologies, scientists, policies, guidelines, sustainable financing, databases, capacity-building and education. Another example is Indonesia; although wood species identification has been regulated in the Regulation of the Government of Indonesia Number 23/2021 and Regulation of Minister of Forestry Number 8/2021, this APEC member economy has mostly no consideration readiness level for forensic wood operation, especially in terms of the availability of experts, regulations, capacity-building and education, database, and finance. In addition, Indonesia also has not yet considered the integration of wood species identification into TLAS.

4.3 Forensic Wood Practices in APEC Member Economies

4.3.1 Australia

It is reported that the Australian Bureau of Agricultural and Resource Economics and Science manages wood and its wood product data, where most Australian wood is supplied from domestic forestry and imported wood. About 77% of eucalypt forests, 8% of acacia forest, 5% of melaleuca, and 3% of rainforest are sources of domestic wood, and at least 150 taxa of wood species are recorded for trading. With this richness of wood species, illicit trade may happen if not monitored and reported integratively. One of Australia's best practices for forensic wood implementation is the world-leading scientific provenance and forensic science services offered by Source Certain, supporting transparent, traceable, and trusted wood supply chains. Working over 40 years, this company, composed of forensic scientists, analytical chemists, and geochemistry specialists, has harnessed machine vision, wood anatomy, mass spectrometry, near-infrared spectroscopy, stable isotope, DNA barcoding and fingerprinting, population genetics, and phylogeography for forensic wood and screening. In addition, fiber analysis in wood-derived products, such as composite-based materials, pulp, and paper, was performed.

Although origin verification is less expensive and more achievable in wood traceability, forensic wood identification technologies are demanded, especially for origin verification, to meet the requirements of the regulations on the conclusive and verifiable origin information on wood commodities, to know the origin and legally harvested wood, to avoid significant fines in demand-side Economies, to avert fraudulent over-supply resulting in price suppression, to prove that illegal wood will provide unfair advantages. A case study conducted by Source Certain (Watkinson 2023) in partnership with the World Forest ID and Kolombangara Forest Products Ltd. showcased the use of TSW Trace® Technology, equipped with trace elements analyses and stable isotopes, to assess the elemental composition of the wood and to establish discrete geographical origin determination of the wood samples. About 60 elementals were analyzed in each of the 108 teak samples from the study. They also scaled provenance verification of wood species across the Solomon Islands, in which the samples were taken from different sites, such as New Georgia, Choiseul, Santa Isabel, Malaita, Guadalcanal, San Cristobal, and other proximate islands.

4.3.2 Canada

Principal tree species that dominate forest regions in Canada include white spruce, black spruce, balsam fir, alpine fir, jack pine, lodgepole pine, Douglas-fir, western red cedar, white birch, yellow birch, sugar maple and trembling aspen. Canada also exports and imports forest-derived products with a value of CAD49.26 billion and CAD21.95 billion in 2022, respectively. Most of the imported products, in the form of paper and paperboard (42%), wood products (24%), wooden furniture (16%), books (13%), wood pulp (3%), and musical instruments (2%), are from the United States; People's Republic of China; Brazil; Germany; Mexico; Indonesia, and other economies. With Canada's imports being almost half of its exports in economic value, the risk of fraud in timber trading is still observed. As a result, the Canadian Forest Service (CFS) of Natural Resource Canada (NRCan), Environment Climate Change Canada (ECCC), and Canada Border Service Agency developed the Canadian Wood Identification Project in 2018, aiming to develop tools for enforcement officers to prevent illegal wood imports and create traceability tools for forest certification. The Project includes 1) the development of reference database of tree species, 2) standardization of wood identification protocols, 3) training and outreach, 4) data collection on retail products and imports, and 5) networking of Canadian wood identification experts.

Under the Project, complementary forensic wood identification methods, such as machine vision (Xylotron), wood anatomy, mass spectrometry (AccuTOF-DART), have been tested to identify illegal timber imports in Canada (Duchesne 2023). Traceability tools based on population genetics and genomic signature are also being tested to determine the geographic origin of North American tree species. NRCan's CFS has a reference wood collection (xylarium) of about 2,000 species of 800 genera, which supports forensic wood anatomical identification using light and confocal microscopy and the Inside Wood

Identification tool. NRCan-CFS is registered as a scientific institution for CITES to facilitate exchanges of CITES-regulated woods across borders. The Project Team also developed an Identification Guide of Exotic Wood found on the Canadian Forest Products Market for enforcement officers. Regarding chemical signature analysis, AccuTOF-DART, GC/QTOF-MS and GCxGC-TOF-MS, are used to identify wood at the genus and species levels. Since 2018, ECCC's forensic laboratory has handled 55 legal cases of wood identification that included CITES-regulated species and other high-value timbers.

It is important to use complementary methods for accurate wood identification, as every method has limitations. It is demanded to increase the traceability of tropical timber (for forensic timber investigation), especially using genomic signatures (similar to current research on North American tree species). However, the challenge is the limited access to reference samples for tropical tree species. The Project Team has also endeavored to continue collecting the reference samples for the tropical and North American tree species, optimizing and standardizing scientific protocols for wood identification, and validating wood identification techniques at the species and geographic origin levels.

4.3.3 Chile

From 2013 to 2023, the wood exported from Chile was 97.9% from exotic tree species and 2.1% from native species, as per the data on products traded in tons. In terms of products traded in cubic meters, wood from exotic species constituted 99.7%, whereas native species made up 0.3%. In detail, within the species group, the main ones traded in tons correspond to Pinus radiata with 96.3%, and other species with lesser participation such as Populus (0.3%), Quercus (0.05%), and Eucalyptus (0.8%), all exotics. Only the native species Quillaja saponaria is within this group with a minor share of 0.15%. In the group of species traded in cubic meters, the main one also corresponds to Pinus radiata with 99.2% of the volumes exported. The remaining fraction comprises some native species of the Nothofagus genus, such as Nothofagus pumilio (0.25%), Nothofagus obliqua (0.05%), among others. The differentiation in groups is due to the type of product traded. All this information is available on the official website of Forest Statistics of INFOR. The demand for forensic wood identification is observed with the high number of woods traded. Triple-bottom problems that include the limited supportive tools for forest inspection, no wood identification systems in ports, and the demand on wood identification technologies specialists have triggered the economy to harness forensic wood technologies to address illegal commercial and CITES-listed wood trade. However, the challenges are still finite access to wood anatomy libraries, similar wood anatomy features among species, time-consuming sample preparation and analysis, unportable wood identification technologies, and different properties of wood species depending on the age and sample condition.

To address the illegal trading of wood, the Instituto Forestal (INFOR) utilized two common wood identification technologies: wood anatomy and spectroscopy (Campos 2023). In terms of wood anatomy, INFOR took a strategic measure to establish a macroscopic and microscopic wood identification library as a project deliverable of the SIMEF Project. The wood anatomy database was developed by characterizing tree species using varied microscopes, such as electronic microscopes, laser microscopes, electron microscopes, and confocal microscopes. Different spectroscopy tools, such as VIS-NIR, FT-NIR, NIR, and FTIR, were used for phylogeographic origin identification of *Araucaria araucana*.

4.3.4 People's Republic of China

According to Yin et al. (2020), the Macroscopic Identification Atlas of Endangered Woods in Common in Trade reports that twenty-six CITES-listed tree species are internationally traded in China. The report also provides information on taxonomy, geographic distribution, morphological characteristics of trees, wood description, identification characteristics of wood, type of wood products, and conservation. In the global trade of wood and its products, there is an extremely high demand to identify individuals, species, and geographic origin. Yin et al. (2023) reported the current use of wood identification tools for forensic wood, including machine vision, wood anatomy, mass spectrometry, near-infrared spectroscopy, stable isotope, DNA barcoding, population genetics and phylogeography, and mineral elementals analysis. In detailed practices, for example, the Chinese Academy of Forestry developed the iWood System application for wood identification with more than a 99% identification success rate in the field. Another tool was DART-FTICR-MAS used for chemical fingerprinting studies and forensic wood of different species of Pterocarpus.

Under the Research Institute of Wood Industry, Chinese Academy of Forestry, machine vision, genetic tools, and chemical techniques are present, complemented by the world's largest wood science team. China has applied forensic wood identification for several forestry crimes. For instance, DNA barcoding was harnessed in 2017 to support the Tianjin customs in inspecting imported wood of *Pterocarpus erinaceus* (CITES II). Through this case, the first DNA identification report of the wood sample was released in 2017. The same technique was also used by the customs in 2019 to prove the non-endangered wood species of *Guibourtia ehie* imported. However, the results showed that the DNA barcoding tested wood was *Guilbourtia demeusei* (CITES II). Another new forensic wood identification used was artificial intelligence-based computer vision, harnessed by Chinese customs in 2022 to test the CITES-listed wood legality of *Pterocarpus erinaceus*, *Dalbergia oliveri*, and *Dalbergia cochinchinensis*.

4.3.5 Indonesia

The Ministry of Environment and Forestry (2024) of the Government of Indonesia has listed 173 tree species with nine categories of source, of which about 52.10% and 38.90% of wood species are from the group of plantation forest and mixed species, respectively. The wood and its derived products have been internationally traded, with dominant species of acacia, eucalyptus, red shorea, Dipterocarps, *Shorea* spp., teak, mixed species, pine, Instia bijuga, yellow shorea, etc. However, with the high consumption of tropical wood in Indonesia, a plea for forensic science has increased from forestry institutions and wood industries, and the utilization of the technologies has been perceived, such as wood anatomy, mass-spectroscopy, near-infrared spectroscopy, DNA barcoding, and population genetics. Although machine vision (AIKO) and stable isotopes are available in Indonesia, these advanced technologies have yet to be used intensively for forensic.

Presided by Bogor Agricultural University, several pilot projects on forensic wood were performed entirely, such as the WoodID-Ebony, DNA Barcoding of Vascular Plants, Forensic Tracing of Tropical Wood, and Indonesian-based Wood Identification Program. Under the WoodID-Ebony Project, by using genetics, anatomy, near-infrared spectroscopy, and mass spectrometry, ebony wood from 16 sites with 320 total samples was investigated in its baseline database for addressing illegal logging in Indonesia (Siregar et al. 2023). Not only based on the collaborative studies, the Bogor Agriculture University team also translated the studies into more actions under the Forensic Tracing of Tropical Timber Project and Indonesian-based Wood Identification Program by disseminating the research products to the relevant stakeholders and providing capacity-building for law enforcement agencies. From these projects, a takeaway can be taken into account; for example, there is a high demand for wood identification from law enforcement agencies, customs, quarantine centers, and conservation centers. The demand is also intensified with the high economic value of traded wood and transnational illegal logging.

4.3.6 Japan

In Japan, there are about 300-400 genera of traded wood, 200 of which are from Southeast Asia. Hosted by the Forestry and Forest Products Research Institute (FFPRI), 30,000 wood samples representing 8,000 tree species are preserved in its Xylarium through vouchers and microscopic slides, gathering comprehensive information, such as species, geographic origin, sampling data, and others (Kagawa et al. 2023). Besides archiving anatomical features of the species, the FFPRI provides services in forensic wood identification upon external requests. The Institute has also attempted to develop non-invasive methods to determine wood species using NIR technology and discovered an innovative method to pinpoint the geographic origin of wood by analyzing tree-ring isotopes.

With many genera traded internationally and the presence of Xylaria, the potential of wood identification technologies' importance to acquire database information for forensic wood is a necessity in Japan. This growing demand is also strengthened by international regulation of CITES, the revised Clean Wood Act Japan by 2025, and the importance of accurate Japanese customs declaration. In Japan, for example, the FPRI mainly uses wood anatomy for wood identification and forensic purposes. However, other identification tools used are dendrochronology, near-infrared spectroscopy, stable isotope, DNA barcoding, population genetics, and chemotaxonomy. A case study on the novel method of identifying the geographic origin of wood using tree-ring oxygen isotope ratio or dendroprovenancing was conducted by Kagawa et al. (2010). The study revealed that the tested trees showed the strongest correlation with reference trees from sites close to the actual origins of the test trees, and tropical wood without clear visible ring boundaries has invisible isotope rings.

4.3.7 Republic of Korea

The Republic of Korea recorded almost 55 wood species used for foreign trading in 2022. The flows of international wood trade from and to the Republic of Korea have the potential to be infiltrated with illicit wood and its products along the wood supply chain. Different wood identification techniques are employed to verify wood and its products according to the information on the legality documentation, to promote clean trade by assuring the exact product information for all subjects on the market, and to identify the spot illegal logging and production of related items happened off the supply chain. The techniques used in the Republic of Korea are machine vision, wood anatomy, near-infrared spectroscopy, DNA barcoding, and DNA fingerprinting (Jiyoung et al. 2023). In Korea, three indispensable institutions contribute to the development of wood identification for forensic wood, namely the National Institute of Forest Science (NIFoS), the Korea Forestry Promotion Institute (KoFPI), and the National Instrumentation Center of Environment Management (NICEM), having varied wood identification techniques.

The NIFoS has harnessed DNA analysis technologies for two primary research: 1) optimal conditions for DNA extraction of wood and 2) development of DNA marker and DNA barcoding database. The KoFPI benefits from microscopic images, machine vision, wood Xylaria, and a wood analysis and inspection database. With digital technology, the NICM executed a project of artificial intelligence-based wood identification techniques. The Project utilizes artificial intelligence complemented with macro- and microscopic anatomical features for species identification of wood according to the IAWA codes. However, the Project confronted various challenges, including a need for more capacity-building in collecting image databases of wood species and limited time in sample preparation and anatomical wood feature analysis. However, the Project learned lessons on seizing more opportunities to obtain inter-regional and more systematic data for cross-validating the wood species, more accurate wood identification, and more explainable wood identification results.

4.3.8 Malaysia

Malaysia has one hundred twenty-eight local tree species traded internationally, and the dominant tree species traded include dark red meranti, red meranti/seraya, rubberwood, keruing, kempas/impas, kapur, balau, mersawa, merbau and yellow meranti. To address issues of illegal logging and associated trade, Leong et al. (2023) reported that Malaysia has applied several wood identification techniques for wood forensics, such as wood anatomy, DNA barcoding, population genetics and phylogeography, DNA fingerprinting, and a still-prototyped machine vision (MyWoodID). These technologies prove different risks in illegal wood trade cases, such as wood anatomy and DNA barcoding for species level, phylogeography for geographic origin, and DNA profiling for the original stump.

Malaysia has two excellent wildlife forensic laboratories located at the National Wildlife Forensic Laboratory and Forest Research Institute Malaysia. As the best practices for forensic wood, the Xylarium Kepong (KEPw) of the Forest Research Institute Malaysia (FRIM) has become laboratory reference for macroscopic and microscopic wood anatomy, collecting 10,036 wood samples from 108 families, 426 genera, and 1,587 species from Malaysia. In the terms of DNA barcoding, Malaysia becomes DNA barcoding database repository for 699 species from 154 wood trade names, whereas DNA profiling and phylogeography database was successfully developed for 13 important wood species, i.e. *Dryobalanops aromatica*, *Dryobalanops oblongifolia*, *Dipterocarpus cornutus*, *Rhizophora apiculata*, *Rhizophora mucronata,* etc., using 398 population and 12,656 samples. Malaysia also successfully developed the DNA Database Management System of Forest Resources, consisting of four main modules, MyDNA, MyMARKER, MyBARCODE, and MyTRACK. This economy also published Standard Operating Procedure (SOP) of Forensic DNA Testing on Plant Species Identification and Wood Training, with four elements of SOP, including sample collection, DNA isolation and purification, DNA sequencing, and short tandem repeat genotyping.

4.3.9 New Zealand

The wood sources traded in New Zealand are from domestic and other economies. Regarding domestic wood, New Zealand species include kahikatea, radiata pine, tawa, kauri, rimu, totara, macrocarpa, saligna, matai, and silver beach. The imported woods are primarily durable hardwood from Australia, Asia, the Pacific, and South American, with the dominant traded species of radiata pine. To date, wood anatomy is the sole device applied for forensic wood in New Zealand, while mass spectrometry, near-infrared spectroscopy, DNA barcoding, and DNA fingerprinting have yet to be employed. As an example of forensic wood in New Zealand, Scion has provided a fee for forensic wood identification services to various clients, including consultants, universities, police, commercial companies, and private individuals. The offers include identifying historic building wood, product contaminants, forensic investigation of Cannabis, differentiation between two common softwood species in New Zealand (rimu and totara), and reliable identification between New Zealand kauri from Australia or Fiji (Donaldson 2023).

There are several practical applications of forensic wood for Polynesian canoes, buried forests, Antarctica driftwood, food products, Muriwai shipwrecks, and musical instruments. Ancient canoes were used to investigate the Polynesian settlers coming from, and the results of the forensic investigation showed that there were two canoes, namely the Huahine canoe made from terminalia wood originating from Tahiti and the Anaweka canoe made from matai wood of New Zealand. Forensic wood identification was used to identify different species in pre-historic New Zealand's buried forests. For instance, in the northland, the buried logs are exclusively kauri; in the Waikato, most of the logs are matai; and the Pureora buried forest contains many different species of Podocarps and hardwoods. Wood identification was also used to identify the driftwood in Antarctica, and the forensic study showcased that the wood was nothofagus from South America. Contaminated food products with wood materials were successfully identified forensically, and generally, small fragments of softwood species (pine) from pallets and eucalypt from warehouse flooring are the major contaminants. Muriwai shipwreck was successfully identified through forensic wood identification, and kauri and rata were the confirmed wood thought to be the wreck of the Daring, possibly 153 years old. Scion Research also examined the cell structure of the uncovered log and compared it to their database on a microscopic level. The log was tanekaha (*Phyllocladus trichomanoides*), the most elastic woods in the world, subsequently used for making a guitar.

4.3.10 Papua New Guinea

Papua New Guinea is reported to have the third-largest tropical rainforest in the world, with high biodiversity. This APEC member economy exports primarily hardwood species, such as *Alstonia scholaris*, *Pterocymbiwn beccarii*, *Nothofagus* spp., *Callophyllum* spp., *Paquiun* spp., *Intsia bijuga, Anthocephalus cadamba, Terminalia* spp., and so forth, which are processed into sawn wood in specified sizes. Papua New Guinea has a domestic herbarium, housing more than 200,000 reference collections of plant specimens from New Guinea and abroad. However, widespread government corruption has enabled the illegal wood trade to continue uncontrolled (Marai et al. 2023). Under the Papua New Guinea Forest Research Institute (PNG-FRI), wood anatomy is the most used and dominant technology for wood identification. However, the wood anatomy laboratory was ceased in the early 2000s due to lack of funding. In addition, advanced instruments for wood identification are still unavailable, along with other challenges hampering the utilization of wood identification, such as lack of funding, capacity-building, training, and infrastructure.

As a result, botanical specimens, primarily leaves, are requested by senior botanists from the clients for wood identification. This APEC member economy also still demands advanced technologies for wood identification because of the third-largest tropical forest owner in the world, the anticipated transformation of wood identification research ecosystem intervening policy-making, and the obligation to reduce illegal logging and its associated wood by discovering more efficient and cost-effective techniques and technologies. Furthermore, building collaboration on wood identification research and capacity building for forestry stakeholders among Xylaria across the Asia-Pacific region is vital to address the PNG-FRI challenges in applying forensic wood identification.

4.3.11 Peru

In Peru, it is reported that about 470 wood species traded in the form of sawn wood, charcoal, flooring, round wood, veneers, and ties. Some of the wood species listed in CITES, such as *Dipteryx odorata*, *Cedrela* spp., and *Swietenia macrophylla*, are also traded in small volumes. Identifying the wood's legality is paramount with the high number of traded wood species. According to Olivia et al. (2023), several wood identification techniques adopted for forensic wood in Peru are machine vision, wood anatomy, and mass spectroscopy. However, forensic science has yet to employ other technologies like dendrochronology, near-infrared spectroscopy, stable isotopes, radiocarbon, DNA barcoding, population genetics, and DNA fingerprinting. As a case study, CITEmadera Lima is the Peruvian forestry research institute, which has commonly harnessed wood identification techniques, including wood anatomy, Xylotron, and DART-TOFMS, for forensic evidence obtainment. These technologies are used and channeled with the National Forest Service, supervisory agencies of forest resources, customs, regional governments, specialized environmental prosecutors, wood companies, and universities or research-based institutes.

In terms of wood anatomy, around 5,000 wood samples of 400 different species are identified using macroscopic and microscopic wood analysis, and around 120 species are botanically identified. Xylotron and DART-TOFMS are also widely applied, using artificial intelligence and chemical analysis, respectively, to identify genera and species of traded wood. However, the scope of uses is distinct; Xylotron is employed for field deployable testing with fast results, whereas DART-TOFMS is carried out in the laboratory to verify the screening test results with high reliability. A series of training on the Xylotron implementation was introduced to the National Forest Service of Peru, customs, regional governments, and justice operators. In contrast, DART-TOFMS was donated and installed in the CITEmadera, and different following activities were also carried out, such as training and method validation, sample reference analysis and maintenance, database development, wood proficiency testing, dissemination to forestry institutions, compliance with the Society for Wildlife Forensic Sciences guidelines, and services for stakeholders.

4.3.12 The Reoublic of the Philippines

The Republic of the Philippines lists several species of wood traded internationally, with classifications of imported wood (family of Cannabaceae, Dipterocarpaceae and Fabaceae, Fagaceae, Juglandaceae, Oleaceae, and Sapindaceae), exotic wood (family of Fabaceae, Euphorbiaceae, Lamiaceae, Meliaceae, and Myrtaceae), and naturally growing wood (family of Dipterocarpaceae and Fabaceae). All the listed woods are documented in the Revised Lexicon of Philippine Trees (Rojo 1999), Department of Environment and Natural Resources (DENR) Administrative Order 2000-63 (Department of Environment and Natural Resources 2020), and Equivalent Timber Names in ASEAN (Ong et al. 2019). To date, the Republic of the Philippines has harnessed wood anatomy technology for forensic wood. At the same time, machine vision, dendrochronology, mass spectroscopy, near-infrared spectroscopy, stable isotope, radiocarbon, DNA barcoding and fingerprinting, and population genetics have yet to be used.

Under the leadership of the Department of Science and Technology, the Forests Products Research and Development Institute (DOST-FPRDI), several initiatives have been taken for the improvement of wood identification faculties, including database development and digitalization of Institute's Herbarium and Xylarium's Philippine Tree Species, mobile application development for the Republic of the Philippines' indigenous and plantation tree species, and DNA barcoding of the selected mahogany species (Estudillo 2023). The DOST-FPRDI has become the center of information, knowledge, and excellence for wood identification in the Republic of the Philippines due to having the most extensive xylarium collection of the Philippine tree species. However, this APEC member economy still needs to improve forensic wood headway due to insufficient financial support, laboratories, and training activities. For instance, DNA fingerprinting and DNA barcoding equipped with complete instrumentations of an established molecular biology laboratory in the DOST-FPRDI are anticipated to be developed because the technologies are more objective and accurate in proving wood species, origin, and geographical provenance. In addition, the technologies will significantly improve species identification capacity, enhancing the Republic of the Philippines' capability to combat illegal wood activities.

4.3.13 Singapore

Singapore mostly consumes wooden products like plywood, wood-based flooring, and furniture, but very limited solid woods are imported from Europe; China; Indonesia; and Myanmar. Wood identification technologies are required to identify the suspected illegal composite-based products and logs. Referring to the virtue of the technologies, Singapore is familiar with wood anatomy, stable isotopes, DNA barcoding, and DNA fingerprinting. One of the industries using forensic wood tests as full service for due diligence, wood verification, and accredited certification solutions is DoubleHelix, which was established in 2008. DoubleHelix was certified with ISO and is physically located in Singapore; Indonesia; the USA; and Myanmar, with proximity to producer economies. This industry has partnered widely with different forensic wood laboratories in the world. Most clients are importers and exporters from the United States; the European Union; and Australia (Tang 2023). DoubleHelix integrates supply chain auditing, document checks, and scientific testing to verify wood legality physically and independently using DNA analysis, wood anatomy, and stable isotope. Some of the case studies of DoubleHelix documented a mixed species or origin of oak flooring, Indonesian meranti plywood and other species-based plywood, and teak stumps, tested using stable isotope, wood anatomy, and DNA barcoding, and DNA fingerprinting, respectively.

Three case studies of forensic wood applications conducted by DoubleHelix are highlighted. DoubleHelix conducted an onsite risk assessment, including the risk of mixing Western European oak from different suppliers and the potential for mixing in the warehouse despite being a Programme for the Endorsement of Forest Certification's chain of custody (PEFC CoC) holder. There is also potential to collect proof of the origin of oak by using stable isotopes. Different verification systems were undertaken, including 1) document verification of all raw material purchases to verify origin and certification claims, 2) auditing of production records, and 3) low-frequency isotope testing of oak samples. One of the examples is their multiple tests using onsite assessment, wood anatomy, and DNA fingerprinting to identify Indonesian meranti-based plywood purchased by the United States from SLVK-certified Indonesian wood industries. The test was explicitly performed to better control species use, which impacts product quality, and to provide more accurate species listings on their Lacey Act Plant and Plant Products Declaration (PPQ) submissions. The results showed that plywood marketed was meranti with much broader species. DoubleHelix worked with the manufacturers to offer better species lists for PPQ submissions and thus avoid any potential risk of misdeclaration.

4.3.14 Chinese Taipei

Chinese Taipei has imported logs and lumber from Papua New Guinea; Japan; Europe; and Canada, with around 6 million m^3 of wood-related products imported yearly. However, only some wood-related products are exported. Different wood species identified as being traded are *Pinus* spp, *Pseudotsuga* spp, *Tsuga* spp, *Picea* spp, *Abies* spp, etc. With the vast amount of wood traded with diverse species, wood identification is essential to identify the legality of wood marketed. This APEC member economy has utilized varied types of wood identification technologies for forensic wood. These technologies include machine vision, wood anatomy, mass spectrometry, DNA barcoding, population genetics, and DNA fingerprinting (Wu 2023). These wood identification technologies are in demand in Chinese Taipei, in which the excellent nature of the technologies is counted, such as faster, more accurate, and more efficient. However, the biggest challenges in implementing forensic wood are the unfocused motives of researchers on wood identification and difficulties in sample exchanges and data access.

The Taiwan Forestry Research Institute has developed wood identification instruments that are more applicable and accessible to the public. For instance, an IoS and Android-based wood identification APP was digitally developed and available in Chinese in the research stage. The APP benefits from using deep learning algorithms in AI technology and image processing technology and has a recognition accuracy of 94.5%, 352 wood images, and 49 species in the database. The Institute provides wood and bamboo identification services and has collected 770 genera and 2393 species from domestic and foreign sources. The Institute also has carried out many instrumentations for wood properties using mass spectrometry and DNA analysis. Different mass spectrometry tools are used, such as TOF-SIMS and SPME/GC-MS. Case studies using DNA-based characterizations (DNA barcoding, DNA fingerprinting, and population genetics) have been conducted in the last two decades and have intensely progressed with the development of DNA markers for wood identification from the past two decades and the announcement of export control of precious wood products in 2022, primarily for four species of *Cinnamomum kanehirae*, *Calocrdrus formosana*, *Chamaecyparis formosensis*, and *Chamaecyparis obtusa*. A forensic wood case of the illegal cutting in *C. obtusa* wood was undertaken to identify individuals using SSR markers that are highly polymorphism, co-dominant and used widely in human criminal cases.

4.3.15 Thailand

As reported on the Single Window of the Royal Forestry Department, the Thai Forestry Department has launched a system for certification of wood, wood products, and charcoal. The Department has also developed a permission and verification system to trade wood and its wood products to and from Thailand. In this APEC member economy, there are common commercial woods requesting wood verification to acquire a certificate for export and import processes, such as teak, eucalyptus, rubberwood, Marwan, keruing, balau, acacia, ironwood, kempas, karanji, Ofelia, Merbau, panga, and Misawa. With the presence of wood identification techniques, the traded wood species can be studied for their structural features and properties. The traded wood also can be verified for its legality, types, and quality intended for certificate issuance.

In Thailand, the most commonly used wood identification technology is wood anatomy. The technique is the sole technology used for forensic wood identification, intended to characterize the non-anatomical (colour, odour, and weight) and anatomical properties of wood, subsequently verifying wood types and quality in issuing certificates. In contrast, dendrochronology, mass spectrometry, DNA barcoding and fingerprinting are envisaged to have yet to be used for forensic wood. The demand for wood identification technologies is evident due to the following reasons: 1) the accomplishment of the mission of the Royal Forestry Department, especially acquiring wood certification for exporting; 2) to prove specific points of wood, including genus, species, origin, age, and provenance; and 3) to share and exchange academic knowledge on wood identification (Chadthasing 2023).

4.3.16 The United States

The United States trades North American softwoods and hardwoods. As reported by Alden (1995) and Alden (1997), the woods consist of 53 taxa of hardwoods and 52 taxa of softwoods, and not every species in these publications is currently traded, and the relative volumes change over time, depending on the market demand and forest management plan.

Wood identification has played a significant role in addressing illicit wood trade, especially in the import/export stage of the wood supply chain. Many techniques have been employed for wood identification, such as machine vision, traditional wood anatomical identification, dendrochronology, mass spectrometry, near-infrared spectroscopy, DNA barcoding/hybridization probes, population genetics/phylogeography, DNA fingerprinting, and laser-induced breakdown spectroscopy. These technologies can be classified into two uses, namely field-deployable with near real-time results (field wood identification manuals, machine vision, and NIR spectroscopy) and laboratory techniques with a processing time of days to weeks (traditional wood anatomical identification, DNA-based approaches, and spectroscopic approaches, i.e. DART-TOFMS and LIBS). These technologies must work complementarily in forensic wood identification, meaning that field deployable screening technology must scale with laboratory forensic capacity, and laboratory forensic capacity must support and scale with field screening.

Wiedenhoeft et al. (2023) reported that botanical identification technologies are commonly well-developed. It should be applied similarly to the technologies that are used for the identification of wood origin because of its demanding and emerging priority for APEC member economies. Rapid and reliable species-level identification using botanical technologies and geographic origin technologies is critically needed. As a case study, the US Forest Service International Programs Wood Identification and Screening Center (WISC) has harnessed DART-TOFMS for forensic analyses of wood to both verify supply chains and identify wood legality. The tool, using a spectral database of known wood reference samples, can be used for species identification and is a well-researched method accepted by the US courts of law. However, the biggest challenge for the DART-TOFMS methodology is the reliability of reference samples, which requires a larger sample quantity for statistical analyses. The Center is also continuously studying geographic origin verification through chemical analysis methods in order to provide information relevant to the enforcement of the US Lacey Act and other laws.

4.3.17 Viet Nam

Viet Nam issued a Decision 3808/QD-BNN-KL dated September 11, 2023, on imported wood species to support the Government Decree No. 102/2020/ND-CP dated September 1, 2020, regulating the Vietnamese TLAS (Ministry of Agriculture and Rural Development 2023). The Decision includes 837 wood species, covering the list of previous wood species stipulated in Decision No. 2752/QD-BNN-TCLN dated June 30, 2022, issued by the Minister of Agriculture and Rural Development. In supporting the Vietnamese TLAS, wood identification technologies are expected to contribute to species-level identification. In addition, these technologies are used to strengthen the wood chain of custody and wood identification capacities owned by customs, forestry departments, universities, and research institutes and to halt illegal logging and its associated trade.

Viet Nam has benefited from various types of wood identification tools for forensic analysis, including machine vision, wood anatomy, dendrochronology, mass spectrometry, near-infrared spectroscopy, stable isotope, radiocarbon, and DNA barcoding. Under the auspice of the Vietnam National University of Forestry, wood identification has progressed to certain extents for forensic wood implementation, such as Xylotron image database and DART-TOFMS database collection, wood identification-based smartphone application for species identification traded in Hanoi, DNA barcoding databank development for high-value wood species, samples collection by World Forest ID, and development of forest specimens museum with 15,000 plant specimens (Phuong 2023). However, some challenges to these technologies' use for forensic wood are identified, including limited microscopic reference samples and the demand to develop a comprehensive wood identification database. As a result, international cooperation is anticipated to be established.

4.4 Current and Recommended Wood Identification Tools

Every APEC member economy has different priorities for selecting and making use of wood identification technologies. The priorities can depend on the points to prove, reliability, accuracy, required sample number, speed to acquire results, cost-effectiveness, and other strengths and limitations (Dormontt et al. 2015, Schmitz et al. 2020). Figure 4 shows the percentage of APEC members who use wood identification technologies. It shows that all listed techniques are used in APEC member economies for wood identification, and it is recorded that new technologies are utilized, such as fiber analysis for pulp and paper and engineered wood products, chemotaxonomy, capacitance, and mineral or trace elements analysis. Wood anatomy, both macroscopic and microscopic examination, is still prevalently utilized in APEC member economies, with a use percentage of 21.51%. Besides wood anatomy, DNA barcoding (12.65%), mass-spectroscopy (10.13%), machine vision (10.13%), population genetics (10.13%), spectroscopy (8.86%), and DNA fingerprinting (7.59%) are surveyed to be also harnessed for providing forensic analysis for wood. This mini-survey also shows that APEC member economies rarely utilize radiocarbon, fiber analysis, trace elements analysis, capacitance, and chemotaxonomy for forensic wood identification. That is likely due to the novel technologies that request to be deeply researched and the consumers' need to test wood and its products.

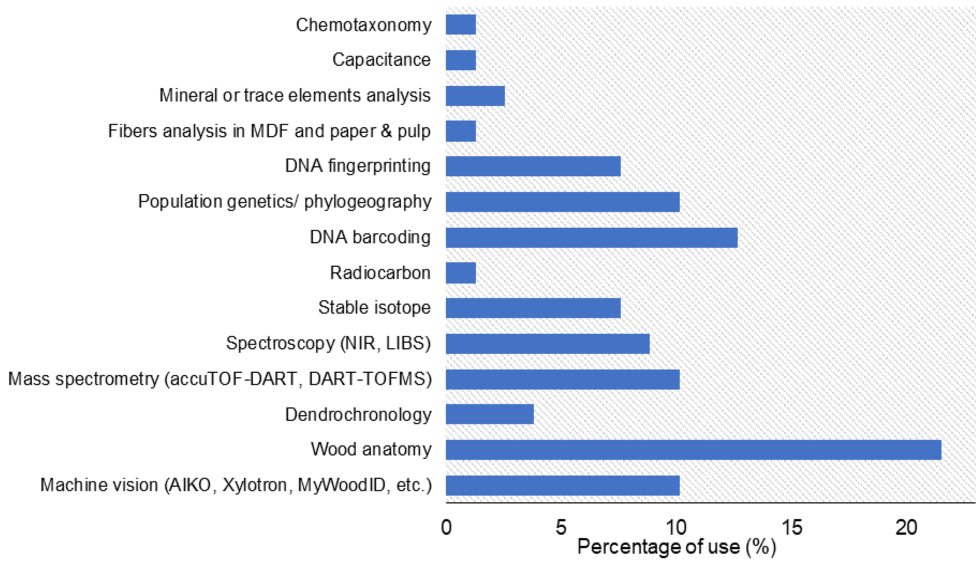


Figure 4. Wood identification technologies use in APEC member economies

With the presence of wood identification technologies, valuable analysis can be acquired, holding forensic value for forensic scientists for tackling illegal logging and solving a variety of crimes. For instance, the United States has applied species identification of wood using DART-TOFMS to provide legal evidence supporting US law enforcement agencies. Origin or provenance verification of wood using DNA analysis, trace elements, and stable isotopes, with conclusive and verifiable information, is also favored for wood identification in Chinese Taipei; Australia; and Japan, respectively. DNA markers are also developed in Chinese Taipei to fulfill the legal requirements of the government in controlling wood product exports and obtaining an export permit for wood products. In Indonesia and Viet Nam, reference databases of CITES-listed wood and high commercial value wood from machine vision (XyloTron and AIKO), DNA analysis, DART-TOFMS, LC-MS, and NIR are intended to be developed to address illicit wood trade. New Zealand and Papua New Guinea are also concerned with the use of wood anatomy for historical building analysis and policymakers' recommendations in addressing illegal logging.

The functions of these wood identification techniques align with the purposes of many documented wood identification studies, amplified in Sub-Chapter 4.1. For example, Espinoza et al. (2015) used DART-TOFMS to make unequivocal species determinations of American *Dalbergia* listed under CITES. Jiao et al. (2020) recommended the combination of DNA barcoding and other supplementary techniques (wood anatomy) to offer a practical approach and a new perspective to promote legal logging for wood trade custody and global biodiversity conservation. A brief research report by Bukhya (2023) stated that by harnessing the technology identification of wood, wood can be a primary source for identifying the source of a tool used in a forestry crime, determining the time of the crime, or tracking the movement of transnational forestry crime. In addition, wood can be used to track a crime scene's location, reconstruct a crime scene, or identify the cause of a fire. As a result, wood identification and analysis are pivotal instruments for forensic experts to solve a variety of forestry and other crimes. In general, APEC member economies wood identification researchers recommended the use of wood anatomy - as a screening and forensic diagnostic tool as it is the most practical and affordable technique for wood identification. The reference database (wood properties and macro- and microscopic images) and its technique can be transformed into a digital application in the form of machine and computer vision for field-level wood identification. The digitized wood anatomy technique is deployable and can be applied to acquire near-fast evidence for further criminal investigations and prosecutions.

However, the recommended technique (wood anatomy) is advised to be paired with other laboratory techniques with higher forensic specificity, such as NIR, DART-TOFMS, and DNA approaches. This is required to enhance verification strategies for establishing reliability and validity in diagnostic tests of forensic wood identification and to complement the screening and diagnostic methods for specific-level wood identification. Some notes from the APEC member economies wood identification scientists, which can be taken into account for forensic wood application, are:

1) Wood identification technologies must fit for purpose as the best indicator for research and implementation of forensic wood and can be used for due diligence/care for small to big wood industries.
2) There are new, innovative, and accessible technological tools that can complement the current control system for wood forest products, and reconciling various methods of wood identification for screening and diagnostic tests is advised.
3) Xylaria and other related wood identification resources (microscopic images and databases) are suggested to be available online and digitalized. The automatized resources can assist in tackling the discordance between products and documents.
4) There is a solid demand for wood identification at different steps of the wood supply chain, especially for auditors and government officials to verify the information declared by wood industries.
5) The wood identification tools are bargained to identify basically the exact wood species, but more choices and concentrations for geographic provenance, individual origin, and age are needed for cost.
6) Wood identification tools should respond to identify CITES-listed wood, high commercial value of wood, customs clearance for engineered or modified products, and economy-specific legislations.

4.5 Wood Identification Demands

Generally, many studies have confirmed the pivot of wood identification as a demanded instruments for commercial, forensic, archaeological, and paleontological purposes. Forensic and other due diligence-related tests, for example, were generated to gain substantial scientific evidence of botanical and wooden products from illegal activities, such as fraud and misrepresentation (Gasson 2011, Lowe et al. 2010, Lowe et al. 2011, Wiedenhoeft et al. 2019, Ravindran et al. 2020). The demands are apparent, and according to Brusselen et al. (2023), the drivers of demand for wood identification technologies and associated services are a) compliance with policy/legislation, b) certification compliance, c) customer awareness, d) procurement requirements, and e) reputation management.

Table 5. Needs on wood identification technologies by APEC member economies

APEC member economies	Demands/Needs
Australia	☐ to investigate of the legality of traded wood, ☐ to avoid the misrepresentation of origin of wood resulting in significant fines in demand-side Economies, ☐ to avert fraudulent over-supply resulting in price suppression (dumping effects on the market), ☐ to offer unfair advantages for business, using illegal/grey market wood, ☐ to offer less expensive and more achievable process than implementing traceability from harvest to retail.
Chile	☐ to safeguard and manage the Chile's forestry sector sustainably, ☐ to provide alternatives on the reliance on the conventional wood identification, such as microscopy and macroscopy, ☐ to address the issue on the limited supportive tools for forest inspection, ☐ to provide wood identification systems in port, ☐ to nudge wood identification specialists for developing wood identification tools.
Indonesia	☐ to analyse high commercial value of wood traded, ☐ to address large-scale illegal logging, ☐ to offer solutions on the proper wood identification.
Japan	☐ to identify CITES-listed wood species that has been increasingly demanded, ☐ to conduct archaeological studies through determining the growth years and geographic origin of wood, especially when certain harvest years and regions are deemed illegal, ☐ to support the upcoming enforcement of the revised Clean Wood Act in Japan by 2025, ☐ to provide accurate customs declaration of wood species, because the import tax rate depends on the species.
Republic of Korea	☐ to provide and enhance transparency system by verifying wood and its products according to the information on the legality documentation, promoting clean trade by assuring the exact product information for all subjects on the market, and identifying the spots of illegal logging and production of related items happened in the supply chain, ☐ to undertake forensic analysis of the wood species of mixed products, ☐ to identify the wood species of a damaged domestic treasure.
Malaysia	☐ to address illegal logging, ☐ to comply with the CITES regulation, ☐ to provide the request of plantation industries and wood industries (wood trade, quality control in building construction, trade disputes, restoration and conservation of historical building).
New Zealand	☐ to document the woods used or in some cases to facilitate repairs, ☐ to identify the potential origin of wood contamination in products such as milk powder in relation to customer complaints, ☐ to confirm the identity of plant stems suspected to be Cannabis as part of police investigations.
Papua New Guinea	☐ to control illegal wood trade, ☐ to shift the research roadmap within the economy to ensure impactful scientific contributions, that yield effective and informed decisions on forest policy in Papua New Guinea, ☐ to employ efficient & cost-effective techniques and technology through a standardized protocol for wood identification that is critical to help improve accuracy of wood identifications and aid in our economy's overall efforts towards reducing illegal logging in the member economies.
Peru	☐ to provide training and capacity-building for law enforcement and non-law enforcement agencies on wood identification and forensic wood
The Philippines	☐ to play an essential role as the most extensive Xylaria collection of Philippines tree Species with the purpose of serving as the Institute's reference in identifying confiscated wood from the agencies above, ☐ to investigate unauthentic samples at the different levels, such as genera and species, ☐ to be able to extract DNA material from its current collection that will serve as a database of DNA material that could be used for a more accurate wood identification up to species level.
Singapore	☐ to verify the origin or species of harvested woods, ☐ to confirm forests of origin (plywood is high volume, so factories source from multiple concessions and traders).
Chinese Taipei	☐ to provide faster, more accurate, and more efficient methods for identification, ☐ to provide several types of wood identification technologies with several options of advantages, ☐ to track the traceability of wood origin.
Thailand	☐ to support the missions of the Royal Forest Department in issuing wood export certificates and providing training and education for operating staff, ☐ to serve people who want to know the species of wood in order to use them.

	☐ to provide academic knowledge to interested citizens regarding the structure of wood and the identification of wood types.
The United States	☐ to offer techniques that rapidly and reliably provide species-level botanical identification and similarly reliable verification/determination of geographic origin, ☐ to provide information relevant to the enforcement of the US Lacey Act and other laws, ☐ to offer the need of forensic wood identification, which is inherently modality-agnostic, however: 1) field deployable screening technology *must* scale with laboratory forensic capacity, and; 2) laboratory forensic capacity *must* support and scale with field screening
Viet Nam	☐ to investigate wood legality, ☐ to strengthen CoC, ☐ to combat illegal logging because Vietnam is the leading exporter of wood, ☐ to strengthen wood identification capacity for customs, forest protection department, university, research institute.

Table 5 shows the demand for APEC member economies to utilize wood identification for forensic wood. It shows that every APEC member economy has different demands in prioritizing wood identification for forensic propositions. The ultimate goal of utilizing wood identification technologies is to address illegal logging and associated trade. For particular purposes, the technologies are demanded to investigate and profile risks of wood at certain levels, such as genus, species, provenance, individuals, and age. Each wood identification technology cannot be like the "one-size-fits-all" approach, and the technology has strengths and limitations in determining the extent of risk proof for investigated wood. The technologies can also complement each other to provide scientific evidence for law enforcement and non-enforcement agencies. For instance, in the field, near and fast real-time data from field deployable wood identification instruments are needed to attest to the legality of wood. However, it requires laboratory testing, i.e., DNA analysis, stable isotope, radiocarbon, or DART-TMFS, to provide more reliable evidence to verify the results of the field screening tests.

4.6 List of Traded Commercial Wood

Forest products trade in the Asia-Pacific region is closely related to the movement of wood and its derived products at domestic, regional, and international markets. According to the World Bank (2023b), the world's export and import values for wood products were estimated at USD105,190,832.65 thousand and USD119,389,720.76 thousand in 2021, respectively. East Asia and the Pacific region contributed 52.38% and 48.74% to the export and import value of global wood products (Figure 5). With the high economic value contribution of wood trade, illegal logging and associated trade are the persisting common issues. Apeti et al. (2023) reported that the enforcement of wood trade regulations from the United States; Australia; Republic of Korea; and members of the European Union (EU) is an essential measure in international trade as it aims to promote the legal trade of wood and wood products. Besides that, wood identification has been widely integrated and mainstreamed in these regulations addressing illegal logging and illicit wood trade.

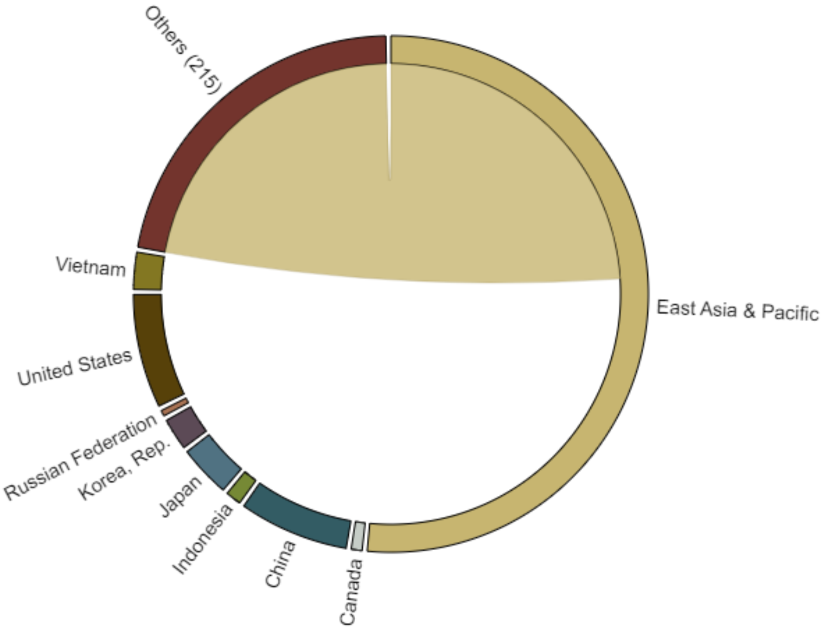


Figure 4. Wood products export and import value by regions in APEC Members
Source: World Bank (2023b)

For instance, the Japanese Clean Wood Act issued in 2017 was used to check legally harvested wood and wood products (Government of Japan 2016), and wood identification technologies can play roles in examining the compliance standards of the Act, such as wood species and origin (Momii et al. 2020).

Table 6 shows the list of traded wood species by scientific name in APEC member economies by integrating different wood species from seventeen of twenty-one APEC member economies. The wood species comprises hardwood and softwood from various sources, including plantation/production forests, community forests, and others. The list can be used as a reference and database by APEC member economies wood scientists, forensic wood researchers, or law enforcement agencies on the traded wood species, in the form of export and import, at the international market. The list also helps equip the existing wood identification database for developing APEC member economies' Xylaria networking.

Table 6. APEC priority list of timber species common in trade

APEC member economies	Wood species	
Australia	*Abies alba* *Abies balsamea* *Abies grandis* *Abies lasiocarpa* *Abies nordmanniana* *Abies spp* *Acacia mangium* *Acacia sp.* *Acer campestre L* *Acer platanoides* *Acer pseudoplatanus* *Acer rubrum* *Acer saccharum L* *Alnus glutinosa* *Alnus incana (L.) Moench* *Aquilaria sp.* *Aucoumea klaineana* *Betula alleghaniensis* *Betula papyrifera* *Betula pendula*	*Eucalyptus smithii* *Eucalyptus spp* *Eucalyptus tereticornis* *Eucalyptus urograndis* *Eucalyptus urophylla* *Eucalyptus urophylla x E. grandis hybrid* *Eucalyptus viminalis* *Fagus grandifolia* *Fagus sp.* *Fagus sylvatica L.* *Fraxinus spp.* *Handroanthus sp.* *Hevea brasiliensis* *Hevea sp.* *Intsia bijuga* *Juglans nigra* *Juglans spp.* *Larix cajanderi* *Larix decidua*

	Betula pubescens *Betula sp.* *Callitris sp.* *Carpinus betulus L.* *Carya spp.* *Castanea sativa Mill.* *Castanea spp.* *Casuarina spp.* *Cedrela* *Cedrus atlantica (Endl.) Manetti ex Carr.* *Corymbia calophylla* *Corymbia maculata* *Corymbia sp.* *Couratari stellata* *Cunninghamia lanceolata* *Dalbergia latifolia* *Dalbergia sp* *Dendrocalamus strictus* *Dipteryx odorata* *Eucalyptus andrewsii Maiden* *Eucalyptus benthamii* *Eucalyptus camaldulensis* *Eucalyptus camaldulensis* *Eucalyptus delegatensis R.Baker* *Eucalyptus diversicolor* *Eucalyptus dunnii* *Eucalyptus globulus* *Eucalyptus globulus Labill.* *Eucalyptus globulus ssp bicostata* *Eucalyptus grandis* *Eucalyptus maidenii* *Eucalyptus marginata* *Eucalyptus nitens* *Eucalyptus obliqua* *Eucalyptus patens* *Eucalyptus pellita* *Eucalyptus pilularis* *Eucalyptus regnans* *Eucalyptus saligna* *Eucalyptus sieberi.*	*Larix decidua* *Larix eurolepis A.Henry* *Larix gmelinii* *Larix kaempferi* *Larix kaempferi* *Larix laricina* *Larix sibirica* *Larix spp.* *Larix sukaczewii* *Leucaena leucocephala* *Liriodendron sp.* *Mangifera indica* *Neosinocalamus affinis (Rendle) Keng* *Ochroma sp.* *Paulownia sp.* *Picea abies* *Picea abies (L.) H. Karst.* *Picea engelmannii* *Picea glauca* *Picea mariana* *Picea sitchensis* *Picea sp.* *Pinus banksiana* *Pinus contorta* *Pinus contorta* *Pinus echinata* *Pinus elliottii* *Pinus elliottii Engelm.* *Pinus massoniana* *Pinus nigra* *Pinus nigra Arnold* *Pinus palustris* *Pinus pinaster* *Pinus radiata* *Pinus serotina* *Pinus sibirica* *Pinus sp.* *Pinus sp.* *Pinus spp.* *Pinus strobus* *Pinus sylvestris*
	Source: Watkinson et al. (2023)	
Canada	*Abies balsamea* *Abies lasiocarpa* *Acer rubrum* *Acer macrophyllum* *Acer nigrum* *Acer saccharum* *Acer saccharinum* *Betula alleghaniensis* *Betula papyrifera* *Carya sp.* *Fagus grandifolia* *Fraxinus sp.* *Juglans nigra* *Juglans cinerea* *Larix laricina* *Larix occidentalis* *Picea engelmannii* *Picea glauca* *Picea mariana*	*Picea rubens* *Picea sitchensis* *Pinus banksiana* *Pinus contorta* *Pinus ponderosa* *Pinus resinosa* *Pinus strobus* *Populus tremuloides* *Pseudotsuga menziesii* *Quercus alba* *Quercus macrocarpa* *Quercus rubra* *Salix sp.* *Thuja plicata* *Thuja occidentalis* *Tilia americana* *Tsuga canadensis* *Tsuga heterophylla* *Ulmus americana*
	Source: Natural Resources Canada, Canadian Forest Service. Farrar, J. L. (2017) in Duchesne et al. (2023) and Trees in Canada	
Chile	*Alnus glutinosa* *Araucaria araucana* *Aristotelia chilensis* *Betula pendula*	*Nothofagus alpina* *Nothofagus dombeyi* *Nothofagus obliqua* *Nothofagus pumilio*

	Cariniana legalis *Castanea sativa* *Cedrela odorata* *Clarisia racemosa* *Dipteryx odorata* *Drimys winteri* *Eucalyptus globulus* *Eucalyptus nitens* *Eucalyptus regnans* *Fagus sylvatica* *Gevuina avellana* *Handroanthus impetiginosus* *Juania australis* *Jubaea chilensis* *Juglans regia* *Laurelia sempervirens* *Laureliopsis philippiana*	*Phyllostylon rhamnoides* *Pinus radiata* *Podocarpus nubigenus* *Prunus avium* *Pseudotsuga menziesii* *Puya chilensis* *Quercus ilex* *Quercus rubra* *Quercus suber* *Quillaja saponaria* *Rosa eglanteria* *Sequoia sempervirens* *Weinmannia trichosperma*
	Source: Campos (2023) and Instituto Forestal (2023)	
People's Republic of China	*Aquilaria sinensis* *Bulnesia sarmientoi* *Cedrela odorata* *Dalbergia cochinchinensis* *Dalbergia granadillo* *Dalbergia latifolia* *Dalbergia louvelii* *Dalbergia melanoxylon* *Dalbergia oliveri* *Dalbergia stevensonii* *Fraxinus mandshurica* *Gonystylus bancanus*	*Guaiacum sanctum* *Guibourtia demeusei* *Guibourtia tessmannii* *Paubrasilia echinata* *Pericopsis elata* *Pinus koraiensis* *Pterocarpus erinaceus* *Pterocarpus tinctorius* *Quercus mongolica* *Swietenia macrophylla* *Swietenia mahagoni* *Taxus chinensis*
	Source: The above CITES- listed timber species are referred to Yin et al. (2022) and Yin et al. (2023). For more timber species, please refer to Chinese Standard GB/T 18513-2022 Name of main imported into China.	
Indonesia	*Acacia spp.* *Acacia auriculiformis* *Acacia tomentosa* *Adenanthera spp.* *Adina minutiflora* *Adinauclea fagifolia* *Agathis sp.* *Agathis spp.* *Albizia lebbekoides* *Albizia procera* *Alphonsea spp.* *Alstonia scholaris* *Altingia excelsa* *Anisoptera spp.* *Anthocephalus cadamba* *Anthocephalus spp.* *Artocarpus spp* *Artocarpus elasticus* *Artocarpus heterophyllus* *Avicennia sp.* *Berrya cordofolia* *Buchanania spp.* *Calliandra calothyrsus* *Calophyllum inophyllum* *Campnosperma spp.* *Cananga sp.* *Canarium indicum* *Castanopsis argentea* *Ceiba pentandra* *Celtis spp.* *Cinnamomum spp.* *Cordia spp.*	*Mangifera indica* *Manikara kanosiensis* *Manilkara spp.* *Maesopsis eminii* *Mastixia rostrata* *Mastixiodendron spp.* *Melaleuca spp.* *Melaleuca leucadendra* *Melia spp.* *Melia azedarach* *Metrosideros spp.* *Mezzetia parviflora* *Michelia spp.* *Mimusops elengi* *Myristica spp.* *Nauclea spp.* *Ochroma bicolor* *Octomeles sumatrana* *Palaquium spp.* *Paraserianthes falcataria* *Parashorea spp.* *Parartocarpus spp.* *Payena spp.* *Peronema canescens* *Pentace spp.* *Pericopsis mooniana* *Phyllocladus spp.* *Pinus merkusii* *Podocarpus spp.* *Polyalthia glauca* *Pometia spp.* *Pongamia pinnata*

	Cratoxylum spp.	*Pterocarpus indicus*
	Dacrydium spp.	*Pterospermum javanicum*
	Dacrydium junghuhnii	*Pterygota spp.*
	Dacryodes spp.	*Quercus spp.*
	Dactylocladus stenostachys	*Rhizophora sp.*
	Dalbergia latifolia	*Samanea saman*
	Delonix regia	*Sandoricum spp.*
	Dialium spp.	*Santalum album*
	Dillenia spp.	*Santiria spp.*
	Diospyros celebica	*Scaphium macropodum*
	Diospyros rumphii	*Schima spp.*
	Diospyros spp.	*Scorodocarpus borneensis*
	Dipterocarpus spp.	*Senna* spp.
	Dracontomelon spp.	*Serianthes minahassae*
	Dryobalanops spp.	*Schleichera oleosa*
	Duabanga moluccana	*Shorea sp.*
	Durio spp	*Shorea acuminatissima*
	Dyera spp.	*Shorea balangeran*
	Endospermum spp.	*Shorea palembanica*
	Elateriospermum tapos	*Shorea virescens*
	Eucalyptus spp.	*Sloetia elongata*
	Eusideroxylon zwageri	*Sindora spp.*
	Exbucklandia populnea	*Sonneratia caseolaris*
	Ficus carica	*Spondias spp.*
	Fragraea spp.	*Sterculia spp.*
	Gliricidia sepium	*Swietenia spp.*
	Gluta aptera	*Swietenia mahogany*
	Gluta renghas	*Swintonia spp.*
	Gmelina arborea	*Syzygium spp.*
	Gonystylus bancanus	*Syzygium polyanthum*
	Hevea brasilliensis	*Tamarindus indica*
	Homalium foetidum	*Tarrietia spp.*
	Homalium tomentosum	*Tectona grandis*
	Hopea spp.	*Terminalia spp.*
	Hopea dyeri	*Tetramerista glabra*
	Intsia bijuga	*Toona sureni*
	Irvingia malayana	*Timonius spp.*
	Kandelia candel	*Trioma spp.*
	Knema spp.	*Tristaniopsis merguensis*
	Koompassia malaccensis	*Vatica spp.*
	Koordersiodendron pinnatum	*Vachellia leucophloea*
	Lagerstroemia speciosa	*Vernonia arborea*
	Lophopetalum spp.	*Vitex spp.*
	Macaranga spp.	*Xanthophyllum spp.*
	Madhuca spp.	*Xanthostemon spp.*
		Xylocarpus granatum
		Xylopia spp.
	Source: Ministry of Environment and Forestry (2023) and Siregar et al. (2023)	
Japan	***Coniferous and hardwood species from Japan:***	***Coniferous and hardwood species from North America, Central and South America, Africa, and Southeast Asia***
	Acacia spp.	*Abies amabilis*
	Abies firma	*Abies balsamea*
	Abies sachalinensis	*Abies concolor*
	Abies spp.	*Abies grandis*
	Acer amoenum	*Abies procera*
	Acer pictum	*Acacia auriculiformis*
	Acer rufinerve	*Acacia mangium*
	Acer spp.	*Acer rubrum*
	Acer spp.	*Acer saccharinum*
	Aesculus spp.	*Acer saccharum*
	Aesculus turbinata	*Acer spp.*
	Aleurites cordata	*Acer spp.*
	Alnus firma	*Afzelia africana*
	Alnus hirsuta	*Agathis spp.*
	Alnus japonica	*Aglaia spp.*
	Alnus spp.	
	Aphananthe aspera	

	Betula ermanii	Albizia spp.
	Betula grossa	Aleurites spp.
	Betula maximowicziana	Alnus rubra
	Betula platyphylla	Alstonia spp.
	Betula spp.	Amoora spp.
	Betula spp.	Anisoptera spp.
	Buxus microphylla var. Japonica	Anthocephalus chinensis
	Carpinus spp.	Antiaris toxicaria (A. africana, A.
	Carpinus spp.	welwitschii)
	Castanea crenata	Antrocaryon spp.
	Castanea spp.	Aquilaria malaccensis
	Castanopsis cuspidata	Araucaria
	Castanopsis sieboldii	Araucaria hunsteinii
	Castanopsis spp.	Araucaria spp.
	Celtis sinensis var. Japonica	Artocarpus spp.
	Cercidiphyllum japonicum	Aucoumea klaineana
	Chamaecyparis	Azadirachta excelsa
	Chamaecyparis pisifera	Azadirachta indica
	Cinnamomum camphora	Baillonella toxisperma (Mimusops
	Cornus controversa	djave)
	Cornus kousa	Beilschmiedia spp.,
	Cryptomeria japonica	Callitropsis nootkatensis
	Dalbergia spp.	(Xanthocyparis nootkatensis,
	Diospyros kaki	Chamaecyparis nootkatensis)
	Distylium racemosum	Calocedrus decurrens (=Libocedrus
	Ehretia ovalifolia	decurrens)
	Eleutherococcus sciadophylloides	Calophyllum spp.
	Eucalyptus spp.	Campnosperma spp.
	Euonymus	Canarium schweinfurthii
	Fagus spp.	Canarium spp.
	Fagus spp.	Carya spp.
	Fraxinus japonica	Cassia siamea
	Fraxinus lanuginosa, F. apertisquamifera, F.	Castanea dentata
	sieboldiana, F. Longicuspis	Castanopsis spp.
	Fraxinus mandshurica var. Japonica	Casuarina spp.
	Fraxinus spaethiana	Ceiba pentandra
	Fraxinus spp.	Ceiba pentandra
	Fraxinus spp.	Chamaecyparis lawsoniana
	Ginkgo biloba	Combretocarpus rotundatus
	Hovenia dulcis	Cotylelobium spp., Upuna spp., Vatica
	Ilex integra	spp.
	Juglans mandshurica var. Sieboldiana	Cratoxylum
	Juglans spp.	Cratoxylum spp.
	Juglans spp.	Dacryodes buettneri, D. Pubescens
	Juniperus chinensis = Sabina chinensis	Dactylocladus stenostachys
	Kalopanax	Dalbergia cochinchinensis
	Larix kaempferi	Dalbergia latifolia
	Larix spp.	Dalbergia melanoxylon
	Lindera umbellata	Dillenia spp.
	Maackia amurensis	Diospyros crassiflora, D. Mespiliformis
	Machilus thunbergii	Diospyros discolor
	Magnolia obovata	Diospyros spp.
	Magnolia praecocissima	Diospyros virginiana
	Melia azedarach	Dipterocarpus spp.
	Morus bombycis	Dracontomelon dao
	Ostrya japonica	Dracontomelon puberulum
	Paulownia tomentosa	Dryobalanops spp.
	Phellodendron amurense	Duabanga moluccana
	Phyllostachys bambusoides	Durio spp.
	Phyllostachysheterocycla	Dyera spp.
	Picea glehnii	Endospermum spp.
	Picea jezoensis	Entandrophragma angolense, E.
	Picea spp.	kongoense
	Pinus densiflora	Entandrophragma candollei
	Pinus koraiensis	Entandrophragma cylindricum
	Pinus luchuensis	Entandrophragma utile
	Pinus parviflora	Eucalyptus deglupta

	Pinus parviflora *Pinus spp.* *Pinus spp.* *Pinus thunbergii* *Podocarpus macrophyllus* *Populus maximowizcii* *Populus sieboldii* *Populus spp.* *Prunus grayana (Padus grayana)* *Prunus jamasakura (Cerasus jamasakura)* *Prunus lannesiana var. speciosa (Cerasus lannesiana var. speciosa)* *Prunus spp.* *Prunus spp.* *Prunus ssiori (Padus ssiori)* *Pterocarpus spp.* *Pterocarya rhoifolia* *Quercus* *Quercus acuta* *Quercus acutissima* *Quercus crispula (Q. mongolica var. grosseserrata)* *Quercus gilva* *Quercus glauca* *Quercus myrsinifolia* *Quercus salicina* *Quercus serrata* *Quercus spp.* *Quercus spp.* *Quercus spp.* *Quercus variabilis* *Robinia pseudoacacia* *Salix bakko* *Salix spp.* *Salix spp.* *Schima wallichii* *Sciadopitys verticillata* *Shorea spp.* *Styrax japonicus* *Styrax obassia* *Taxus cuspidata* *Thuja standishii* *Thujopsis dolabrata* *Thujopsis dolabrata var. Hondae* *Thujopsis dolabrata var. Hondae* *Thujopsis dolabrata,* *Tilia spp.* *Tilia spp.* *Torreya nucifera* *Toxicodendron succedaneum* *Toxicodendron vernicifluum* *Tsuga sieboldii* *Tsuga spp.* *Ulmus davidiana* *Ulmus laciniata* *Ulmus spp.* *Ulmus spp.* *Zelkova serrata*	*Eusideroxylon zwageri* *Fagus grandifolia* *Fraxinus americana* *Gardenia spp.* *Gluta spp.,* *Gmelina arborea* *Gonystylus spp.* *Gossweilerodendron balsamiferum* *Guarea cedrata, G. Laurentii* *Guarea thompsonii* *Guibourtia arnoldiana* *Guibourtia ehie* *Guibourtia spp.* *Gymnacranthera spp., Horsfieldia spp., Knema spp., Myrstica spp.* *Hevea brasiliensis* *Hibiscus cannabinus* *Homalium foetidum* *Hopea spp.* *Intsia bijuga* *Juglans cinerea* *Juglans nigra* *Khaya spp.* *Koompassia* *Koompassia excelsa* *Larix laricina* *Larix occidentalis* *Liquidambar styraciflua* *Liriodendron tulipifera* *Lithocarpus spp.,* *Litsea spp.,* *Lophira alata* *Lophopetalum spp.* *Lovoa trichilioides (L. klaineana, L. brownii)* *Macaranga spp.* *Madhuca spp.* *Mangifera spp.* *Mansonia altissima* *Melaleuca leucadendron, M.* *Melanorrhoea spp.* *Microberlinia brazzavilensis* *Milicia excelsa (Chlorophora excelsa)* *Millettia laurentii* *Nauclea diderrichii* *Nesogordonia kabingaensis (N. papaverifera, Cistanthera* *Ochroma pyramidale* *Octomeles sumatrana* *Oxystigma oxyphyllum (Pterygopodium oxyphyllum)* *Palaquium spp.,* *Paraserianthes falcataria (Albizia falcataria)* *Parashorea spp.* *Parinari spp.* *Pentace spp.* *Pericopsis elata (Afrormosia elata)* *Pericopsis spp.* *Peronema canescens* *Picea engelmannii* *Picea glauca* *Picea mariana* *Picea rubens* *Picea sitchenis* *Pinis palustris* *Pinus spp.*

		Pinus spp. *Pinus spp.* *Pinus spp.* *Pinus spp.* *Pinus banksiana* *Pinus contorta* *Pinus echinata* *Pinus elliottii* *Pinus khasia* *Pinus merkusii* *Pinus monticola* *Pinus ponderosa* *Pinus resinosa* *Pinus rigida* *Pinus strobus* *Pinus taeda* *Piptadeniastrum africanum (Piptadenia* *Podocarpus spp.)* *Pometia spp.* *Populus deltoides* *Populus grandidentata (Bigtooth aspen), Populus tremuloides (Quaking* *Pouteria aningeri (Aningeria robusta)* *Prunus serotina* *Pseudotsuga menziesii* *Pterocarpus angolensis* *Pterocarpus macrocarpus, P. indicus* *Pterocarpus santalinus* *Pterocarpus soyauxii* *Pterocymbium beccarii* *Pterygota macrocarpa, P. Bequaertii* *Pycnanthus angolensis (P. kembo)* *Quercus alba* *Quercus rubra* *Quercus spp.* *Rhizophora spp., Bruguiera spp.* *Robinia pseudoacacia* *Samanea saman* *Santalum album* *Scaphium spp.* *Sequoia sempervirens* *Shorea albida* *Shorea sect. Anthoshorea spp.* *Shorea sect. Richetioides spp.* *Shorea sect. Rubroshorea spp.* *Shorea sect. Shores spp.* *Shorea spp., Parashorea spp.,* *Sindora spp.* *Sterculia oblonga (Eribroma oblonga)* *Sterculia spp.* *Swartzia fistuloides (Bobgunnia fistuloides)* *Swietenia spp.* *Swintonia spp.* *Syzygium spp.* *Tarrietia spp.* *Tarrietia utilis (Heritiera utilis), Tarrietia densiflora* *Taxodium distichum* *Tectona grandis* *Terminalia ivorensis* *Terminalia spp.* *Terminalia spp.* *Terminalia spp.* *Terminalia superba* *Tetramerista glabra* *Thuja plicata*

		Tieghemella heckelii, T. africana (Dumoria africana) *Tilia americana* *Toona calantas* *Triplochiton scleroxylon* *Tsuga canadensis* *Tsuga heterophylla* *Turraeanthus africanus* *Ulmus americana* *Xylia spp.*
	Source: National Federation of Wood Cooperatives (2023) and Kagawa et al. (2023)	
Republic of Korea	*Abies sp.* *Acacia sp.* *Acer sp.* *Albizia sp. (Paraserianthes sp.)* *Anthocephalus sp.* *Artocarpus sp.* *Betula sp.* *Campnosperma sp.* *Canarium sp.* *Ceiba sp.* *Chamaecyparis sp.* *Cinnamomum sp.* *Cryptomeria sp.* *Dalbergia sp.* *Dillenia sp.* *Diospyros sp.* *Dipterocarpus sp.* *Durio sp.* *Endospermum sp.* *Eucalyptus sp.* *Eugenia sp.* *Fagus sp.* *Fraxinus sp.* *Garcinia sp.* *Hevea sp.* *Hopea sp.*	*Juglans sp.* *Larix sp.* *Liriodendron sp.* *Macaranga sp.* *Mangifera sp.* *Melaleuca sp.* *Octomeles sp.* *Palaquium sp.* *Paulownia sp.* *Picea sp.* *Pinus sp.* *Pinus radiata* *Pometia sp.* *Populus sp.* *Prunus sp.* *Pseudotsuga sp.* *Quercus sp.* *Shorea sp.* *Styrax sp.* *Swietenia sp.* *Tectona sp.* *Terminalia sp.* *Tilia sp.* *Tsuga sp.* *Ulmus sp.* *Xanthophyllum sp.* *Xylopia sp.*
	Source: Jiyoung et al. (2023)	
Malaysia	*Anisoptera sp.* *Aquilaria malaccensis* *Dipteracarpus cornutus* *Dipterocarpus sp.* *Dryobalanops aromatica* *Dryobalanops oblongifolia* *Hevea brasiliensis* *Intsia bijuga* *Intsia palembanica*	*Koompassia malaccensis* *Koompassia malaccensis* *Neobalanocarpus heimii* *Rhizophora apiculata* *Rhizophora mucronata* *Shorea curtisii* *Shorea faguetiana* *Shorea leprosula* *Shorea platyclados*
	Source: Leong et al. (2024)	
New Zealand	*Agathis australis* *Beilschmiedia tawa* *Dacrycarpus dacrydioides* *Dacrydium cupressinum* *Eucalyptus grandis* *Monterey cypress* *Nothofagus menziesii* *Pinus radiata* *Prumnopitys taxifolia (Podocarpus spicatus, Dacrydium taxifolium)* *Schoenoplectus californius*	*Apuleia leiocarpa* *Dacrydium nausoriense* *Dalbergia nigra* *Decussocarpus vitiensis* *Entandrophragma cylindricum* *Eucalyptus marginata* *Fagus sylvatica* *Intsia bijuga* *Larix decidua* *Mahogany sp.* *Peltogyne spp.* *Thuja plicata* *Quercus robur* *Quercus garryana* *Vitex agnus-castus*
	Source: Hurford's (2023) and Donaldson (2023)	
Papua New Guinea	*Aleuritea moluccana*	*Eucalyptus deglupta*

	Bishofia javanica	*Euodia bonwickii*
	Canariun spp. incl. C. oleosum	*Euodia elleryana*
	Celtis nymanii, C. kajewakii	*Ficus app.*
	Celtis philippinensis, C. latifolia	*Flindersia achottiana*
	Chrysophylwn roxburghii	*Flindersia amboinenais*
	Halfordia papuana	*Flindersia ifflaina*
	Maranthes corymbosa	*Flindersia laeviearpa*
	Melaleuca spp.	*Flindersia pimenteliana*
	Octomeles sumatrara	*Galbulimima belgraveana*
	Oreocallis wickhamii	*Gluta papuana*
	Pleiogyniun timorense	*Gordonia spp.*
	Podocarpus spp., Decusaocarpus app.,	*Heritiera littoralis*
	Dacrycarpus app.	*Hernandia papuana*
	Polyalthia oblongifolia	*Homlium foetidum*
	Pterocarpus indicus	*Hopea forbesii, c. papuana, H. similia,*
	Sloanea spp.	*H. celtidifolia*
	Spondias cytherea	*Hopea iriana, H. glabrifolia*
	Xauclea orientalis, N.undulata	*Intsia bijuga, I. palembanica*
	Xylocarpus granaumr, X. moluccensis	*Koompassis grandiflora*
	Agathis dammara, A. labiltardieri	*Libocedrus papuanus*
	Aglaia spp.	*Lithocarpus spp.*
	Ailanthus integrifolia	*Litsea spp.*
	Albizia falcataria	*Lophopetalum torricellense*
	Alstonia braasii, A. glabriflora, A. opectabilis	*Mangifera spp.*
	Alstonia scholaris	*Manilkara kanosiensis*
	Amoora cucullata	*Maniltoa app.*
	Anisoptera thurifera, A. costata	*Mastixiodendron pachyclados M.*
	Anthocephalus chinensis	*plectocarpum; M. stoddardii*
	Antiaris toxicaria	*Myriatica app.*
	Araucaria cunninghamii	*Neonauclea spp.*
	Araucaria hunateinii	*Neoscorteahinia forbesii*
	Bibiscus papuodendron	*Nothofagus spp.*
	Bruguisra gymtorrhisa, B parviflora	*Palaquium spp.*
	Buchanania spp.	*Pericopeis mooniana*
	Burckella app.	*Phyllocladus hypophyllus*
	Calophyllum spp.	*Pimeleodendron amboinicum*
	Campnosperma brevipetiolatum, C. montana	*Planchonella kaernbachiana*
	Cananga odorata	*Planchonella torricellenais*
	Canariur indicwn	*Planchonia papuana*
	Canophyllum fatcatwn	*Pometia pinnata f. pinnata, Pometia*
	Castanopeis acwninatisaima	*pinnata f. glabra*
	Ceratopetatum succirubrwn	*Pterocymbiun beccarii*
	Cerbera floribunda	*Pterygota horefieldii*
	Chisocheron spp.	*Qnelina moluccana*
	Coijera salicifolia	*Rhizophora apiculata, R. mucrowta*
	Cryptocarya spp.	*Schizomeria app.*
	Dacrydium nidulum	*Sterculia spp.*
	Dillenia spp.	*Syzygium spp.*
	Diospyros ferrea	*Terminalia arehipelagi, T. eddowesii,*
	Drypetes spp.	*T. kaernbachii, T. microcarpa*
	Duabanga moluccana	*Terminalia brwsii*
	Dysoxylum spp.	*Terminalia complanata, T.*
	Elaeocarpus spp.	*longespicata*
	Elmerrillia papuana	*Terminalia sepioana, T. solomonesis*
	Endospemum medultosum	*Toona sureni*
	Eucalyptosis papuana	*Triatania spp.*
		Xanthophyllwn papuanwn
		Xanthostmon spp.
	Source: Eddowes et al. (1977) and Marai et al. (2023)	
Peru	*Apuleia leiocarpa*	*Hymenaea oblongifolia*
	Brosimum alicastrum	*Jacaranda copaia*
	Brosimum lactescens	*Machaerium inundatum*
	Brosimum rubescens	*Manilkara bidentata*
	Brosimum utile	*Matisia cordata*
	Cachimbo blanco	*Micropholis egensis*
	Calycophyllum spruceanum	*Myroxylon balsamum*
	Cariniana decandra	*Ochroma pyramidale*

	Cariniana domestica *Cariniana estrellensis* *Cedrelinga cateniformis* *Ceiba pentandra* *Citrus aurantifolia* *Clarisia racemosa* *Copaifera paupera* *Copaifera reticulata* *Couratari guianensis* *Dipteryx micrantha* *Dipteryx odorata* *Eucalyptus globulus* *Guatteria elata* *Guazuma crinita*	*Olea europaea* *Ormosia coccinea* *Ormosia schunkei* *Otoba parvifolia* *Paramachaerium schunkei* *Persea americana* *Poulsenia armata* *Prosopis pallida* *Salix humboldtiana* *Schinus molle* *Schizolobium amazonicum* *Simira rubescens* *Tamarindus indica* *Terminalia amazonia* *Terminalia oblonga*
	Source: Olivia et al. (2023)	
The Republic of the Philippines	*Export:* *Acacia auriculiformis* *Acacia mangium* *Anisoptera thurifera* *Dipterocarpus grandiflorus* *Eucalyptus camaldulensis* *Falcataria falcata* *Gmelina arborea* *Hevea brasiliensis* *Leucaena leucocephala* *Parashorea malaanonan* *Pterocarpus indicus* *Samanea saman* *Shorea astylosa* *Shorea contorta* *Shorea negrosensis* *Shorea ovata* *Shorea polysperma* *Swietenia macrophylla* *Tectona grandis* *Vitex parviflora*	*Import:* *Celtis occidentalis* *Dalbergia latifolia* *Fraxinus americana* *Instia bijuga* *Juglans nigra* *Juglans regia* *Pometia pinnata* *Quercus robur* *Shorea albida* *Shorea parvifolia*
	Source: Estudillo (2023)	
Chinese Taipei	*Abies spp.* *Acer spp.* *Agathis spp* *Araucaria sp.* *Aucoumea klaineana* *Betula pendula* *Calocedrus spp.* *Castanea fagus* *Chamaecyparis spp.* *Cinnamomum kanehirae* *Cunninghamia lanceolata spp* *Dactylocladus stenostachys* *Dipterocarpus spp.* *Dyera spp.* *Entandrophragma cylindricum* *Entandrophragma sp.* *Entandrophragma utile* *Eucalyptus spp.* *Fraxinus spp.* *Gonystylus spp.* *Intsia spp.* *Khaya sp.* *Koompassia malaccensis* *Lophira alata*	*Lovoa sp.* *Malacca albizia* *Mansonia altissima* *Milicia excelsa* *Ochroma pyramidale* *Ocotea porosa (syn. Phoebe porosa)* *Picea spp* *Pinus spp.* *Populus sp.* *Populus spp.* *Prunus serotina* *Pseudotsuga spp* *Pycnanthus angolensis* *Quercus spp.* *Scop.* *Shorea spp.* *Swietenia spp.* *Tectona spp.* *Terminalia superba* *Thuja spp.* *Tieghemella heckelii* *Triplochiton scleroxylon* *Tsuga spp* *Virola spp.*
	Source: Wu (2023)	
Thailand	*Acacia spp.* *Afzelia spp.* *Anisoptera spp.* *Dialium spp.*	*Hopea spp.* *Intsia bakeri* *Koompassia spp.* *Mesua ferrea*

	Dipterocarpus spp. Eucalyptus spp. Hevea brasiliensis	Shorea spp. Tectona grandis Xylia spp.
	Source: Chadthasing (2023)	
The United States	Hardwood: Acer negundo Acer spp. Aesculus octandra Ailanthus altissima Alnus rubra Amelanchier spp. Arbutus spp. Avicennia spp. Betula spp. Carpinus caroliniana Carya spp. Castanea dentata Castanopsis chrysophylla Catalpa spp. Celtis spp. Conocarpus erectus Cornus florida Fagus grandifolia Fraxinus spp. Gleditsia triacantho Gymnocladus dioicus Halesia spp. Hamamelis virginiana Ilex spp. Juglans cinerea Juglans nigra Kalmia latifolia Liquidambar styraciflua Liriodendron tulipifera Lithocarpus densiflorus Maclura pomifera Magnolia spp. Magnolia virginiana Malus sylvestris Nyssa spp. Ostrya spp. Oxydendrum arboreum Platanus occidentalis Populus spp. Populus grandidentata Populus tremuloides Populus spp. Prosopis spp. Prunus serotina Quercus spp. Rhamnus spp. Rhus spp. Robinia pseudoacacia Salix nigra Sambucus spp. Sassafras albidum Tilia americana Ulmus spp. Umbellularia californica	Softwood: Abies spp. Mill. Abies amabilis Abies balsamea Abies concolor Abies grandis Abies lasiocarpa Abies magnifica Abies procera Chamaecyparis spp. Chamaecyparis lawsoniana Chamaecyparis nootkatensis Chamaecyparis thyoides Juniperus spp. Juniperus deppeana Juniperus occidentalis Juniperus silicicola Juniperus virginiana Larix spp. Larix laricina Larix occidentalis Libocedrus spp. Libocedrus decurrens Picea spp. Picea engelmannii Picea glauca Picea mariana Picea rubens Picea sitchensis Pinus L. Pinus banksiana Pinus clausa Pinus contorta Pinus echinata Pinus edulis Pinus elliottii Pinus flexilis Pinus glabra Pinus jeffreyi Pinus lambertiana Pinus monticola Pinus palustris Pinus ponderosa Pinus pungens Pinus radiata Pinus resinosa Pinus rigida Pinus serotina Pinus strobus Pinus taeda Pinus virginiana Pseudotsuga spp Pseudotsuga menziesii Sequoia spp. Sequoia sempervirens Taxodium spp. Taxodium distichum Taxus spp. Taxus brevifolia Thuja spp. Thuja occidentalis Thuja plicata Tsuga spp.

		Tsuga canadensis *Tsuga heterophylla* *Tsuga mertensiana*
	Source: Alden (1995), Alden (1997), and Wiedenhoeft et al. (2023)	
Viet Nam	*Abies alba (Abies abies, Abies alpestris, Abies cinerea, Picea remontii)* *Abies sachalinensis (Abies akatodo, Pinus sachalinensis)* *Abies spp.* *Acacia auriculiformis (Acacia moniliformis, Racosperma auriculiforme, Fagus procera)* *Acacia harpophylla (Acacia harpopylla, Racosperma harpophyllum)* *Acacia mangium (Acacia glaucescens, Acacia holosericea, Mangium montanum, Racosperma mangium)* *Acacia melanoxylon (Acacia arcuata, Acacia melanoxylum, Mimosa melanoxylon, Racosperma melanoxylon)* *Acacia sp.* *Acacia spp.* *Acer macrophyllum (Acer auritum, Acer dactylophyllum, Acer flabellatum, Acer hemionitis)* *Acer platanoides (Acer dieckii, Acer fallax, Acer laciniatum, Acer lactescens)* *Acer pseudoplatanus (Acer abchasicum, Acer atropurpureum, Acer bohemicum, Acer dittrichii)* *Acer rubrum* *Acer saccharinum (Acer coccineum, Acer dasycarpum, Acer eriocarpum)* *Acer saccharum (Acer hispidum, Acer palmifolium, Acer saccharophorum)* *Acer sp.* *Acer spp.* *Adina polycephala* *Adina sessilifolia (Adina thanhoaensis, Nauclea dongnaiensis, Nauclea ovalifolia, Nauclea sericea, Neonauclea sessilifolia)* *Afzelia africana (Pahudia africana)* *Afzelia bella* *Afzelia bipindensis (Afzelia bella sensu, Afzelia caudata, Pahudia bequaertii)* *Afzelia pachyloba(Afzelia brieyi, Afzelia zenkeri, Pahudia brieyi)* *Afzelia quanzensis (Afzelia cuanzensis)* *Afzelia sp.* *Afzelia spp.* *Afzelia xylocarpa (Afzelia cochinchinensis, Afzelia siamica, Pahudia cochinchinensis, Pahudia xylocarpa)* *Agathis alba (Dammara alba)* *Agathis australis (Dammara australis, Dammara purpurascens, Salisburyodendron australis)* *Agathis spp.* *Aglaia cucullata (Aglaia tripetala, Amoora aherniana, Andersonia cucullata, Aphanamixis cucullata, Buchanania paniculata)* *Aglaia leptantha (Aglaia annamensis, Aglaia gamopetala, Aglaia glabriflora, Aglaia laevigata)* *Aglaia sp.*	*Hopea pierrei* *Hopea spp.* *Hydrochorea corymbosa (Albizia corymbosa, Arthrosamanea corymbosa, Mimosa corymbosa, Pithecellobium corymbosa, Pithecellobium subcorymbosa, Samanea corymbosa)* *Hydrochorea marginata var. panurensis (Arthrosamanea panurensis)* *Hydrochorea parviflorum* *Hymenaea courbaril (Inga megacarpa)* *Hymenaea oblongifolia (Cynometra zamorana)* *Hymenaea spp.* *Hymenolobium elatum* *Hymenolobium excelsum* *Hymenolobium flavum* *Hymenolobium heterocarpum* *Hymenolobium petraeum* *Hymenolobium sp.* *Hymenolobium spp.* *Intsia bijuga (Afzelia bijuga, Afzelia cambodiensis, Afzelia retusa, Eperua decandra, Intsia amboinensis)* *Irvingia gabonensis (Irvingia barteri, Irvingia barteri var. tenuifolia, Irvingia caerulea, Irvingia duparquetii, Irvingia erecta, Irvingia fusca)* *Irvingia malayana (Irvingella harmandiana, Irvingella malayana, Irvingella oliveri, Irvingia harmandiana, Irvingia longipedicellata, Irvingia oliveri)* *Iryanthera paraensis (Iryanthera elongata, Iryanthera sessilis)* *Juglans neotropica (Juglans columbiensis, Juglans equatoriensis, Juglans granatensis)* *Juglans nigra (Juglans nigra, Wallia nigra)* *Juglans regia (Juglans duclouxiana, Juglans fallax, Juglans kamaonia, Juglans orientis, Juglans sinensis)* *Juglans sp.* *Juglans spp.* *Julbernardia pellegriniana (Paraberlinia bifoliolata)* *Julbernardia seretii (Berlinia ledermannii, Julbernardia ogoouensis, Seretoberlinia seretii, Berlinia seretii, Seretoberlinia seretii)* *Juniperus virginiana (Juniperus alba, Juniperus bedfordiana, Juniperus caroliana, Juniperus dioica, Sabina fragrans, Sabina virginiana)* *Keteleeria evelyniana (Keteleeria dopiana, Keteleeria hainanensis, Keteleeria roulletii, Tsuga roulletii)* *Khaya anthotheca (Garretia anthoteca)* *Khaya ivorensis (Khaya caudata, Khaya klainei)*

	Aglaia spectabilis (Aglaia gigantea, Aglaia hiernii, Aglaia ridleyi, Amoora gigantea, Aphanamixis wallichii) *Aglaia spp.* *Alangium ridleyi (Marlea costata)* *Albizia ferruginea (Inga ferruginea, Inga malacophylla)* *Albizia multiflora (Acacia multiflora, Albizia paucipinnata, Arthrosamanea multiflora, Cathormion multiflorum, Pithecellobium multiflorum)* *Albizia saman* *Alchorneopsis floribunda (Alchorneopsis trimera)* *Allocasuarina fraseriana (Casuarina fraseriana, Casuarina nana)* *Allophylus cobbe (Pometia pinnata, Picrodendron arboreum)* *Allospondias lakonensis* *Allospondias sp.* *Alnus glutinosa (Alnus aurea, Alnus februaria, Alnus imperialis, Alnus nitens, Alnus suaveolens)* *Alnus incana (Alnus alisoviana, Alnus alnus, Alnus argentata)* *Alnus rubra (Alnus incana var. rubra, Alnus oregana, Alnus rubra var. pinnatisecta)* *Alnus sp.* *Alnus spp.* *Alstonia scholaris (Echites scholaris)* *Alstonia spp.* *Amphimas pterocarpoides* *Anacardium excelsum* *Anacardium occidentale (Anacardium rhinocarpus, Rhinocarpus excelsa)* *Anadenanthera colubrina (Acacia colubrina, Mimosa colubrina, Piptadenia colubrina)* *Andira coriacea (Andira wachenheimi)* *Andira inermis (Andira grandiflora, Andira jamaicensis, Geoffroea inermis, Vouacapoua inermis)* *Andira spp.* *Anisoptera costata (Anisoptera robusta, Anisoptera marginatoides, Anisoptera mindanensis)* *Anisoptera scaphula (Anisoptera glabra)* *Anisoptera spp.* *Anisoptera thurifera (Anisoptera brunnea, Anisoptera calophylla, Anisoptera lanceolata)* *Anogeissus acuminata (Anogeissus fischeri, Anogeissus harmandii, Anogeissus hirta)* *Anopyxis klaineana (Anopyxis ealaensis, Anopyxis occidentalis, Macarisia klaineana)* *Anthonotha fragrans (Macrolobium chrysophylloides, Macrolobium fragrans)* *Antiaris toxicaria var. africana (Antiaris kerstingii, Antiaris africana, Treculia affona)* *Antrocaryon klaineanum (Antrocaryon soyauxii, Spondias soyauxii)* *Aphanamixis polystachya (Aglaia aphanamixis, Aglaia beddomei, Aglaia cochinchinensis)* *Apuleia leiocarpa(Apoleya leiocarpa, Apuleia praecox, Leptolobium leiocarpum)*	*Khaya senegalensis (Swietenia senegalensis)* *Kokoona littoralis (Lophopetalum littorale)* *Kokoona sp.* *Kokoona spp.* *Koompassia excelsa (Abauria excelsa, Koompassia parviflora)* *Koompassia grandiflora* *Koompassia malaccensis (Koompassia beccariana, Koompassia borneensis)* *Koompassia spp.* *Lafoensia punicifolia (Calyplectus punicifolius, Lafoensia mexicana)* *Lagerstroemia angustifolia* *Lagerstroemia calyculata (Murtughas calyculata)* *Lagerstroemia loudonii* *Lagerstroemia sp.* *Lagerstroemia speciosa (Lagerstroemia flos- reginae)* *Lagerstroemia tomentosa (Lagerstroemia tomentosa var. caudata, Murtughas tomentosa)* *Larix kaempferi (Abies kaempferi, Abies leptolepis, Laricopsis kaempferi, Larix japonica)* *Larix sibirica (Larix altaica, Larix archangelica, Larix europaea, Larix pseudolarix, Larix russica, Larix sukaczewii)* *Larix sp.* *Lecomtedoxa klaineana (Mimusops klaineana, Nogo klaineana)* *Lecythis sp.* *Lecythis spp.* *Lecythis zabucajo (Lecythis crassinoda, Lecythis davisii, Lecythis hians, Lecythis lecomtei, Lecythis tumefacta, Lecythis validissima)* *Leucaena shannonii* *Leucochloron incuriale (Feuilleea incurialis, Mimosa incurialis, Pithecellobium incuriale, Pithecellobium martianum)* *Limonia acidissima (Schinus limonia)* *Liquidambar styraciflua (Liquidambar barbata, Liquidambar gummifera, Liquidambar macrophylla)* *Liriodendron sp.* *Liriodendron spp.* *Liriodendron tulipifera (Liriodendron fastigiatum, Liriodendron procerum, Liriodendron truncatifolium, Tulipifera liriodendrum)* *Lithocarpus corneus var. zonatus (Pasania hemisphaerica, Lithocarpus hemisphaericus, Quercus hemisphaerica, Synaedrys hemisphaerica)* *Lithocarpus ducampii (Pasania ducampii)* *Lithocarpus spp.* *Litsea aneityensis* *Litsea lancilimba*

	Aquilaria filaria (Aquilaria acuminata, Aquilaria tomentosa, Gyrinopsis acuminata, Pittosporum filarium) *Aquilaria malaccensis (Agallochum malaccense, Aloexylum agallochum, Aquilaria agallochum, Aquilaria moluccensis)* *Araliopsis tabouensis (Vepris tabouensis)* *Araucaria angustifolia (Araucaria brasiliana, Araucaria brasiliensis, Araucaria dioica, Araucaria saviana)* *Araucaria cunninghamii (Araucaria glauca, Eutacta cunninghamii, Eutassa cunninghamii)* *Artocarpus aspenula (Araucaria brasiliana, Araucaria brasiliensis, Araucaria dioica)* *Artocarpus heterophyllus (Artocarpus brasiliensis, Artocarpus maximus, Artocarpus nanca, Artocarpus philippensis)* *Artocarpus integer (Artocarpus integrifolius, Radermachia integra, Saccus integer)* *Artocarpus spp.* *Artocarpus tonkinensis* *Aspidosperma desmanthum (Aspidosperma chiapense, Aspidosperma cruentum, Aspidosperma matudae, Macaglia desmantha)* *Aspidosperma polyneuron (Aspidosperma dugandii, Aspidosperma peroba, Aspidosperma venosum)* *Aspidosperma sp.* *Aspidosperma spp.* *Astronium graveolens (Astronium gracile, Astronium planchonianum, Astronium zongolicum)* *Astronium lecointei (Astronium lecointei f. tomentosum, Astronium lecointei var. tomentosum)* *Aucoumea klaineana* *Autranella congolensis (Autranella boonei, Autranella le-testui, Mimusops boonei)* *Baccaurea ramiflora (Baccaurea cauliflora, Baccaurea pierardi, Baccaurea sapida, Gatnaia annamica, Pierardia sapida)* *Bagassa guianensis (Bagassa sagotiana, Bagassa tiliifolia, Laurea tiliifolia, Piper tiliifolium)* *Baillonella toxisperma (Baillonella djave, Baillonella obovata, Baillonella pierriana, Mimusops djave, Mimusops obovata, Mimusops pierreana, Mimusops toxisperma)* *Beilschmiedia mannii (Afrodaphne mannii, Oreodaphne mannii, Tylostemon kamerunensis, Tylostemon mannii)* *Berchemia discolor (Adolia discolor, Araliorhamnus punctulata, Araliorhamnus vaginata, Phyllogeiton discolor)* *Berlinia auriculata* *Berlinia bracteosa (Berlinia bracteosa, Berlinia platycarpa, Macroberlinia bracteosa)* *Berlinia confusa(Berlinia acuminata)* *Berlinia congolensis (Berlinia heudelotiana)* *Berlinia grandiflora (Berlinia heudelotiana, Berlinia laurentii, Westia grandiflora)* *Berlinia spp.* *Betula alleghaniensis (Betula excelsa, Betula lutea, Betula persicifolia)*	*Lophira alata (Lophira africana, Lophira barteri, Lophira macrophylla, Lophira procera, Lophira simplex, Lophira tholloni)* *Lophostemon suaveolens (Tristania suaveolens)* *Lovoa trichilioides (Lovoa klaineana)* *Loxopterygium sagotii* *Lysiloma divaricatum (Acacia divaricata, Lysiloma australe, Lysiloma australis, Lysiloma calderonii, Lysiloma chiapense, Lysiloma chiapensis, Lysiloma divaricata, Lysiloma kellermanii, Lysiloma salvadorense)* *Lythocarpus spp.* *Machaerium scleroxylon (Machaerium nyctitans var. scleroxylon)* *Machilus bonii (Persea bonii)* *Maclura tinctoria (Broussonetia plumeri, Chlorophora mollis, Fusticus glabra, Ioxylon mora, Maclura affinis, Maclura sempervirens)* *Madhuca pasquieri (Bassia pasquieri, Dasillipe pasquieri, Isonandra pasquieri, Madhuca subquincuncialis, Madhuca tsangii, Isonandra pasquieri, Madhuca subquincuncialis, Madhuca tsangii)* *Magnolia champaca (Michelia champaca, Champaca michelia, Magnolia membranacea, Michelia aurantiaca, Michelia blumei, Michelia champaca)* *Magnolia conifera (Manglietia conifera, Magnolia conifera var. conifera)* *Magnolia tsiampacca (Elmerrillia celebica, Elmerrillia sericea, Michelia arfakiana, Michelia celebica, Talauma papuana)* *Mallotus apelta (Croton chinensis, Mallotus castanopsis, Mallotus paxii, Mallotus tenuifolius, Ricinus apelta, Rottlera cantoniensis, Rottlera chinensis)* *Mangifera foetida* *Mangifera indica (Mangifera austroyunnanensis)* *Mangifera minor* *Mangifera sp.* *Manglietia fordiana (Magnolia fordiana)* *Manilkara bidentata (Kaukenia globosa, Manilkara balata, Manilkara darienensis, Manilkara williamsii, Mimusops bidentata, Sapota mulleri)* *Manilkara huberi (Manilkara huberi, Mimusops huberi)* *Manilkara kanosiensis (Manilkara multinervis)* *Manilkara letouzei (Manilkara multinervis)* *Manilkara obovata (Chrysophyllum holtzii, Kaukenia cuneifolia, Manilkara angolensis, Mimusops angolensis)* *Manilkara spp.* *Manilkara zapota (Achradelpha mammosa, Achras breviloba, Achras*

	Betula costata (Betula costata, Betula ermanii, Betula ulmifolia) *Betula dahurica (Betula dioica, Betula maackii, Betula maximowiczii, Betula wutaica)* *Betula nigra (Betula americana, Betula lanulosa, Betula rubra)* *Betula pendula (Betula verrucosa, Betula virgultosa, Betula aetnensis, Betula brachylepis, Betula cajanderi)* *Betula platyphylla (Betula ajanensis, Betula tauschii, Betula latifolia)* *Betula pubescens (Betula alba, Betula ambigua, Betula andreji, Betula asplenifolia)* *Betula sp.* *Betula spp.* *Bikinia le-testui (Monopetalanthus le-testui, Bikinia le-testui subsp. le-testui)* *Bobgunnia fistuloides (Swartzia fistuloides)* *Bobgunnia madagascariensis (Swartzia madagascariensis, Swartzia marginata, Swartzia sapini , Tounatea madagascariensis)* *Bocoa prouacensis (Swartzia prouacensis, Swartzia minutiflora)* *Bocoa viridiflora (Swartzia viridiflora)* *Brachystegia cynometroides* *Brachystegia eurycoma* *Brachystegia kennedyi* *Brachystegia laurentii (Macrolobium laurentii)* *Brachystegia leonensis* *Brachystegia mildbraedii (Brachystegia nzang, Cynometra pachycarpa)* *Brachystegia spp.* *Bridelia micrantha (Bridelia abyssinica, Bridelia mildbraedii, Bridelia stenocarpa, Bridelia zanzibarensis)* *Brosimum alicastrum (Alicastrum brownei, Brosimum conzattii, Brosimum gentlei, Brosimum terrabanum)* *Brosimum rubescens (Alicastrum brownei, Brosimum conzattii, Brosimum gentlei, Brosimum terrabanum)* *Buchenavia capitata (Brownlowia denysiana)* *Buchenavia sp.* *Buchenavia tetraphylla (Buchenavia capitata, Buchenavia ptariensis, Buchenavia vaupesana, Bucida angustifolia, Lithocardium tetraphyllum, Terminalia hilariana)* *Bulnesia arborea (Guaiacum arboreum, Zygophyllum arboreum)* *Bulnesia sarmientoi* *Burckella obovata (Bassia bawun, Bassia cocco, Bassia erskineana, Bassia hollrungii, Bassia kajewskii)* *Burckella sp.* *Burckella spp.* *Burretiodendron hsienmu (Burretiodendron tonkinense, Excentrodendron hsienmu, Parapentace tonkinensis, Pentace tonkinensis, Excentrodendron tonkinense)* *Caesalpinia paraguariensis (Acacia paraguariensis, Acacia paraguariensis, Caesalpinia melanocarpa)* *Callophyllum inophyllum*	*calderonii, Achras conzattii, Achras coriacea, Achras dactylina)* *Maniltoa spp.* *Mansonia altissima (Achantia altissima, Mansonia altissima var. altissima)* *Maranthes corymbosa (Exitelia corymbosa, Ferolia corymbosa, Grymania salicifolia, Maranthes speciosa, Parinari corymbosa, Petrocarya griffithiana)* *Markhamia stipulata (Bignonia stipulata, Dolichandrone cauda-felina, Dolichandrone stipulata, Markhamia cauda-felina, Markhamia pierrei)* *Marmaroxylon racemosum (Abarema racemosa, Pithecellobium racemiflorum, Pithecellobium racemosum)* *Martiodendron parviflorum (Martiusia parviflora)* *Martiodendron sp.* *Mastixiodendron pachyclados (Fagraea pachyclados, Mastixiodendron pachyclados var. tomentosum)* *Melanorrhoea laccifera (Gluta nitida, Penaea nitida)* *Melia azedarach (Azedara speciosa, Azedarach odoratum, Melia angustifolia , Melia sambucina)* *Metopium brownei (Cotinus metopium, Metopium linnaei, Rhus metopia, Rhus metopium, Terebinthus brownei)* *Microberlinia bisulcata (Berlinia bifurcata, Berlinia bisulcata)* *Microberlinia brazzavillensis* *Milicia excelsa (Chlorophora excelsa, Maclura excelsa, Milicia africana, Morus excelsa)* *Milicia regia (Chlorophora regia)* *Millettia laurentii* *Millettia leucantha (Millettia pendula)* *Millettia sp.* *Millettia stuhlmannii* *Misanteca aritu (Licaria aritu)* *Monopetalanthus sp.* *Monopetalanthus spp.* *Morus alba (Morus atropurpurea, Morus chinensis, Morus intermedia, Morus multicaulis)* *Morus sp.* *Morus spp.* *Myroxylon balsamum (Myrospermum toluiferum , Myroxylon toluiferum, Toluifera balsamum)* *Myroxylon peruiferum (Myrospermum pedicellatum)* *Nageia wallichiana (Decussocarpus wallichianus, Nageia blumei, Podocarpus agathifolius, Podocarpus latifolius, Podocarpus wallichianus)* *Nauclea diderrichii (Nauclea trillesii, Sarcocephalus badi, Sarcocephalus diderrichii, Sarcocephalus trillesii)* *Nauclea purpurea (Anthocephalus chinensis, Bancalus purpureus,*

	Callophyllum saigonensis Callophyllum sp. Calocedrus formosana Calophyllum brasiliense Calophyllum dryobalanoides Calophyllum inophyllum Calophyllum sp. Calophyllum spp. Calpocalyx aubrevillei Canarium album (Canarium album, Canarium album, Canarium tonkinense, Hearnia balansae, Pimela alba) Canarium indicum (Canarium amboinense, Canarium commune, Canarium grandistipulatum, Canarium mehenbethene, Canarium moluccanum) Canarium schweinfurtii (Canarium occidentale, Canarium thollonianum) Canarium sp. Canarium spp. Carallia sp. Careya sphaerica (Careya arborea, Barringtonia arborea, Careya orbiculata, Careya venenata, Cumbia coneanae) Cariniana domestica (Couratari domestica) Cariniana spp. Carpinus betulus (Carpinus carpinizza, Carpinus caucasica, Carpinus compressus, Carpinus intermedia, Carpinus nervata) Carya illinoinensis (Carya angustifolia, Carya diguetii, Carya oliviformis, Carya pecan, Carya pecan, Carya tetraptera) Carya ovata Carya sp. Carya spp. Carya tomentosa Caryocar gracile (Caryocar krukovii) Cassia siamea (Cassia siamea Lamk) Cassia sp. Castanea crenata (Castanea chinensis, Castanea kusakuri, Castanea pubinervis, Castanea stricta) Castanea sativa (Castanea castanea, Castanea prolifera, Castanea vesca, Castanea vulgaris, Fagus castanea) Castanea spp. Castanopsis argentea (Castanea argentea, Castanea argyrophylla, Castanea divaricata, Castanea martabanica, Fagus argentea, Quercus argyrophylla) Castanopsis indica (Castanea indica, Castanea indica, Castanopsis macrostachya, Castanopsis subacuminata) Cedrelinga cateniformis (Cedrelinga catenaeformis, Piptadenia catenaeformis, Pithecellobium catenaeformis) Cedrus sp. Ceiba pentandra (Bombax cumanense, Bombax guineense, Bombax guineensis, Bombax inerme, Bombax mompoxense, Bombax occidentale) Celtis occidentalis (Celtis audibertiana, Celtis cordata, Celtis cordifolia, Celtis crassifolia, Celtis floridana, Celtis heterophyla Raf., Celtis longifolia) Celtis sp. Centrolobium yavizanum	*Nauclea elliptica, Neonauclea purpurea) Nauclea spp. Nectandra lineata (Nectandra caucana, Nectandra fuscobarbata, Nectandra petenensis, Ocotea lineata) Neolamarckia cadamba (Anthocephalus cadamba, Anthocephalus morindifolius, Nauclea megaphylla, Samama cadamba, Sarcocephalus cadamba) Neonauclea sessilifolia (Adina sessilifolia, Adina thanhoaensis, Bancalus sericeus, Nauclea dongnaiensis, Nauclea ovalifolia, Nauclea ovalifolia, Nauclea sericea, Nauclea sessilifolia, Nauclea vestita) Neonauclea sp. Nephelium chryseum Newtonia aubrevillei (Piptadenia aubrevillei, Newtonia aubrevillei subsp. Aubrevillei) Nothofagus pumilio (Calusparassus pumilio, Fagus pumilio) Nyssa sp. Ochroma pyramidale (Ochroma bicolor, Bombax angulata, Bombax pyramidale, Ochroma obtusum, Ochroma lagopus) Ochroma spp. Ocotea neesiana (Gymnobalanus sprucei, Nectandra neesiana, Ocotea florulenta, Oreodaphne confusa) Octomeles sumatrana Oldfieldia africana Olea europaea (Olea alba, Olea amygdalina, Olea ferruginea) Ongokea gore (Aptandra gora, Aptandra gore) Ormosia balansae (Macroule balansae, Ormosia elliptilimba) Ormosia coarctata (Ormosia cuneata) Ormosia pinnata (Cynometra pinnata, Fedorovia pinnata, Ormosia hainanensis, Ormosia semicastrata auct. Non) Ormosia sp. Pachyelasma tessmannii Palaquium spp. Palaquium warburgianum Papuacedrus arfakensis (Libocedrus arfakensis, Papuacedrus papuana var. arfakensis) Paraserianthes falcataria (Adenanthera falcata, Albizia eymae) Parashorea stellata (Shorea stellata) Parinari anamensis (Parinari albida) Parinari excelsa (Ferolia amazonica, Parinari amazonica, Petrocarya excelsa) Parinari spp. Passiflora coccinea (Passiflora fulgens, Passiflora toxicaria, Passiflora velutina) Paulownia kawakamii (Paulownia rehderiana, Paulownia thyrsoidea, Paulownia viscosa)*

	Cerasus avium *Chaenomeles sinensis (Chaenomeles chinensis, Cydonia chinensis, Cydonia sinensis, Malus sinensis, Pseudocydonia sinensis, Pyrus sinensis)* *Chamaecyparis nootkatensis* *Chamaecyparis obtusa (Chamaecyparis acuta, Chamaecyparis andelyensis, Chamaecyparis breviramea, Chamaecyparis keteleri, Chamaecyparis lycopodioides)* *Chamaecyparis sp.* *Chamaecyparis spp.* *Chloroleucon mangense (Acacia micrantha, Acacia parvifolia, Albizia marthae, Albizzia marthae, Cathormion mangensis, Cathormium mangense, Enterolobium mangense, Feuilleea mangensis, Inga marthae, Mimosa antillarum, Mimosa mangensis, Mimosa parvifolia, Pithecellobium mangense)* *Chrysophyllum africanum (Gambeya africana, Chrysophyllum delevoyi, Chrysophyllum edule, Chrysophyllum macrophyllum, Chrysophyllum omumu, Gambeya africana, Gambeya kali, Planchonella africana)* *Chrysophyllum lacourtianum (Gambeya lacourtiana, Chrysophyllum autranianum)* *Chrysophyllum spp.* *Chukrasia sp.* *Chukrasia tabularis (Cedrela villosa, Chukrasia chickrassa, Chukrasia nimmonii, Chukrasia trilocularis, Dysoxylum esquirolii)* *Cinnamomum balansae* *Cinnamomum camphora (Camphora camphora, Camphora hippocratei, Camphora hahnemannii, Cinnamomum camphoriferum, Camphora vera)* *Cinnamomum culilawan* *Cinnamomum porrectum (Camphora chinensis, Cinnamomum inodorum, Cinnamomum malaccense, Laurus parthenoxylon, Phoebe latifolia)* *Cinnamomum tamala (Cinnamomum albiflorum, Cinnamomum reinwardtii, Cinnamomum zwartzii, Laurus tamala)* *Cinnamomum tetragonum* *Cinnamomum tonkinense (Cinnamomum albiflorum, Cinnamomum reinwardtii, Cinnamomum zwartzii, Laurus tamala)* *Clarisia racemosa (Cinnamomum albiflorum, Cinnamomum reinwardtii, Cinnamomum zwartzii, Laurus tamala)* *Coelostegia spp.* *Colophospermum mopane (Copaifera mopane)* *Combretum imberbe (Argyrodendron petersii, Combretum imberbe var. dielsii, Combretum imberbe var. petersii, Combretum primigenum, Combretum truncatum)* *Copaifera mildbraedii (Copaifera salikounda)* *Copaifera religiosa (Copaifera salikounda)* *Cordia alliodora (Cerdana alliodora, Cerdana cujabensis, Cordia andina, Cordia cerdana)*	*Paulownia sp.* *Paulownia spp.* *Paulownia tomentosa (Paulownia grandifolia, Paulownia imperialis, Bignonia tomentosa, Paulownia recurva)* *Pavieasia anamensis (Sapindus anamensis)* *Peltogyne altissima* *Peltogyne lecointei* *Peltogyne pubescens (Peltogyne amplissima, Peltogyne paniculata subsp. pubescens)* *Peltogyne venosa (Hymenaea venosa)* *Peltophorum dasyrrhachis (Peltophorum dasyrhachis, Baryxylum dasyrrhachis, Caesalpinia dasyrhachis)* *Peltophorum tonkinense (Peltophorum dasyrrhachis var. tonkinense, Peltophorum pterocarpum auct. non, Baryxylum tonkinense)* *Pentace spp.* *Pentaclethra macrophylla* *Pentaspadon velutinus* *Pericopsis elata (Afrormosia elata)* *Petersianthus macrocarpus (Combretodendron africanum, Combretodendron macrocarpum, Combretodendron viridiflorum, Petersia africana, Petersianthus minor)* *Phoebe cuneata* *Picea abies (Abies abies, Abies communis, Abies excelsa, Abies extrema)* *Picea glauca (Abies alba, Abies arctica, Abies canadensis)* *Picea jezoensis (Abies ajanensis, Abies jezoensis, Picea ajanensis, Picea austromandshurica)* *Picea sp.* *Picea spp.* *Picralima nitida (Picralima klaineana, Picralima macrocarpa, Tabernaemontana nitida)* *Pinus abies (Picea torano, Abies polita, Abies torano, Picea polita, Pinus polita, Pinus torano)* *Pinus contorta (Pinus bolanderi, Pinus inops, Pinus macintoshiana)* *Pinus elliottii (Pinus heterophylla, Pinus densa var. austrokeysensis)* *Pinus kesiya (Pinus khasya, Pinus khasyana, Pinus khasia, Pinus kasya)* *Pinus massoniana (Pinea massoniana, Pinus argyi, Pinus canaliculata, Pinus cavaleriei, Pinus nepalensis)* *Pinus merkusii (Pinus finlaysoniana, Pinus sumatrana)* *Pinus nigra (Abies marylandica, Abies novae- angliae, Pinus austriaca, Pinus banatica)* *Pinus palustris (Pinus australis, Pinus longifolia, Pinus palmieri)* *Pinus pinaster (Pinus corteana, Pinus detritis, Pinus glomerata, Pinus lemoniana, Pinus helenica)*

	Cordia dodecandra (Cordia angiocarpa, Lithocardium angiocarpum, Lithocardium dodecandrum, Plethostephia angiocarpa) *Cordia elaeagnoides (Cordia exsucca, Gerascanthus elaeagnoides)* *Cordia gerascanthus (Cerdana gerascanthus, Cordia bracteata, Cordia geraschanthoides, Cordia langlassei, Cordia rothschuhii, Gerascanthus gerascanthoides, Gerascanthus lanceolatus, Gerascanthus vulgaris)* *Cordia spp.* *Corymbia calophylla (Eucalyptus calophylla, Eucalyptus glaucophylla, Eucalyptus splachnicarpa)* *Corymbia maculata (Eucalyptus maculata)* *Couratari spp.* *Cratoxylum cochinchinense (Cratoxylum ligustrinum)* *Cratoxylum formosum* *Cryptocarya obtusifolia (Nesodaphne obtusifolia)* *Cryptomeria japonica (Cryptomeria araucarioides, Cryptomeria compacta, Cryptomeria elegans, Cryptomeria fortunei, Cryptomeria generalis)* *Cunninghamia konishii (Cunninghamia kawakamii, Cunninghamia lanceolata var. konishii)* *Cunninghamia lanceolata (Abies batavorum, Abies lanceolata, Belis jaculifolia, Belis lanceolata, Cunninghamia jaculifolia)* *Cupressus funebris (Chamaecyparis funebris, Cupressus pendula , Juniperus quaternata, Platycyparis funebris)* *Cupressus nootkatensis (Chamaecyparis funebris, Cupressus pendula , Juniperus quaternata, Platycyparis funebris)* *Cupressus sp.* *Cupressus spp.* *Cupressus vietnamensis (Callitropsis vietnamensis, Xanthocyparis vietnamensis)* *Cylicodiscus gabunensis (Cyrtoxiphus staudtii, Erythrophleum gabunense)* *Cynometra ananta* *Cynometra ramiflora (Cymorium sylvestre, Cynometra bijuga, Cynometra bijuga, Cynometra carolinensis, Maniltoa carolinensis, Trachylobium verrucosum)* *Dacrycarpus imbricatus (Bracteocarpus imbricatus, Bracteocarpus kawaii, Dacrycarpus kawaii)* *Dacrydium elatum (Dacrydium pierrei, Corneria elata, Juniperus elata)* *Dacryodes buettneri (Canarium buettneri, Dacryodes buettneri, Dacryodes fraxinifolia)* *Dacryodes macrophylla (Canarium buettneri, Dacryodes buettneri, Dacryodes fraxinifolia)* *Dalbergia cochinchinensis* *Dalbergia frutescens (Dalbergia variabilis, Pterocarpus frutescens, Triptolemea glabra, Triptolemea latifolia, Triptolemea montana, Triptolemea ovata, Triptolemea pauciflora, Triptolemea platycarpa)* *Dalbergia lanceolaria subsp. paniculata (Dalbergia nigrescens, Dalbergia paniculata,*	*Pinus radiata (Pinus adunca, Pinus californica, Pinus insignis, Pinus montereyensis)* *Pinus sibirica (Pinus arolla, Pinus coronans, Pinus hingganensis)* *Pinus sp.* *Pinus spp.* *Pinus strobus (Leucopitys strobus, Pinus nivea, Pinus tenuifolia, Pinus umbraculifera, Strobus strobus, Strobus weymouthiana)* *Pinus sylvestris (Pinus binatofolio, Pinus borealis, Pinus tartarica, Pinus frieseana, Pinus hagenaviensis, Pinus resinosa)* *Pinus tabuliformis (Pinus leucosperma, Pinus sinensis, Pinus taihangshanensis, Pinus tokunagae, Pinus wilsonii)* *Pinus taeda (Pinus lutea, Pinus mughoides)* *Piptadenia flava (Mimosa buceragenia, Piptadenia leptocarpa, Pityrocarpa flava, Piptadenia suaveolens)* *Piptadeniastrum africanum (Piptadenia africana)* *Planchonella kaernbachiana (Pouteria kaernbachiana, Sideroxylon kaernbachianum)* *Planchonella torricellensis (Planchonella paludosa, Planchonella samoensis, Pouteria torricellensis, Rapanea torricellensis)* *Planchonia papuana* *Platanus occidentalis (Platanus densicoma, Platanus excelsa, Platanus integrifolia, Platanus lobata)* *Platanus sp.* *Platanus spp.* *Platonia insignis* *Platymiscium pinnatum (Amerimnon pinnatum, Platymiscium polystachyum, Platymiscium dubium, Platymiscium polystachyum)* *Platymiscium sp.* *Platymiscium trifoliolatum* *Platymiscium trinitatis (Platymiscium duckei, Platymiscium nigrum)* *Platymiscium yucatanum* *Podocarpus macrophyllus (Margbensonia forrestii, Nageia macrophylla, Podocarpus canaliculatus, Podocarpus sweetii)* *Podocarpus neriifolius (Margbensonia neriifolia, Nageia discolor, Nageia endlicheriana, Podocarpus endlicherianus, Podocarpus polyanthus)* *Pometia sp.* *Pometia spp.* *Populus × canadensis (Populus × euramericana, Populus bachelieri, Populus euramericana, Populus × robusta)* *Populus adenopoda (Populus silvestrii, Populus adenopoda var. adenopoda)*

	Amerimnon paniculatum, Dalbergia maymensis) *Dalbergia latifolia (Amerimnon latifolium, Dalbergia emarginata)* *Dalbergia melanoxylon (Amerimnon melanoxylon, Amerimnon stocksii, Dalbergia stocksii)* *Dalbergia oliveri (Dalbergia laccifera, Dalbergia prazeri)* *Dalbergia retusa (Amerimnon lineatum, Dalbergia hypoleuca, Dalbergia lineata, Amerimnon retusum)* *Dalbergia sp.* *Dalbergia tonkinensis* *Daniellia oliveri (Paradaniellia oliveri)* *Daniellia spp.* *Desbordesia insignis (Desbordesia glaucescens)* *Detarium macrocarpum* *Detarium microcarpum (Desbordesia glaucescens)* *Dialium aubrevillei* *Dialium bipindense (Dialium connaroides, Dialium fleuryi, Dialium connaroides)* *Dialium cochinchinensis* *Dialium guianense (Arouna divaricata, Arouna guianensis, Dialium acuminatum, Dialium divaricatum)* *Dialium indum (Dialium javanicum, Dialium laurinum, Dialium marginatum, Dialium turbinatum)* *Dialium platysepalum (Dialium ambiguum, Dialium havilandii, Dialium kingii, Dialium maingayi, Dialium wallichii)* *Dialium spp.* *Dicorynia guianensis (Dicorynia spruceana, Dicorynia paraensis)* *Didelotia africana* *Didelotia letouzeyi* *Didelotia sp.* *Dillenia indica (Dillenia elongata, Dillenia speciosa, Dillenia indica f. elongata)* *Dillenia papuana (Dillenia calothyrsa)* *Dillenia spp.* *Dinizia excelsa* *Diospyros borneensis (Diospyros fecunda, Diospyros tawaensis)* *Diospyros celebica* *Diospyros crassiflora (Diospyros ampullacea, Diospyros evila, Diospyros incarnata)* *Diospyros ebenum (Diospyros assimilis, Diospyros ebenaster, Diospyros glaberrima, Diospyros laurifolia, Diospyros melanoxylon, Diospyros membranacea, Diospyros timoriana)* *Diospyros kaki (Diospyros amara, Diospyros argyi, Diospyros bertii, Diospyros chinensis, Diospyros costata, Diospyros kaempferi)* *Diospyros malabarica (Diospyros siamensis)* *Diospyros melanoxylon (Diospyros dubia, Diospyros exsculpta, Diospyros roylei, Diospyros wightiana)* *Diospyros mun* *Diospyros pilosanthera (Diospyros carthei, Diospyros cubica, Diospyros elmeri,*	*Populus alba (Populus bolleana, Populus major, Populus nivea, Populus pseudonivea)* *Populus deltoides (Aigeiros deltoides, Populus angulata, Populus carolinensis)* *Populus hybrida* *Populus nigra (Aigiros nigra, Populus caudina, Populus neapolitana, Populus pyramidalis, Populus sosnowskyi, Populus thevestina)* *Populus sp.* *Populus spp.* *Populus tremula (Populus australis, Populus bonatii, Populus duclouxiana)* *Populus tremuloides (Populus aurea, Populus tremuloides f. tremuloides, Populus tremuloides var. tremuloides)* *Pouteria altissima (Aningeria altissima, Hormogyne altissima, Hormogyne gabonensis, Pouteria giordani)* *Pouteria pierrei (Aningeria robusta, Aningeria pierrei, Hormogyne pierrei, Malacantha robusta)* *Pradosia ptychandra (Pouteria ptychandra, Neopometia ptychandra, Voyara montana)* *Prioria oxyphylla (Oxystigma oxyphyllum)* *Prosopis glandulosa (Algarobia glandulosa, Neltuma constricta, Neltuma glandulosa, Prosopis juliflora, Prosopis chilensis sensu)* *Prunus arborea (Pygeum arboreum, Digaster sumatranus, Polydontia arborea, Pygeum diospyrophyllum)* *Prunus avium (Cerasus avium, Druparia avium)* *Prunus serotina (Cerasus serotina, Cerasus serotina, Prunus capuli, Prunus serotina var. serotina)* *Prunus serrulata (Cerasus serrulata, runus puddum, Padus serrulata)* *Prunus sp.* *Prunus spp.* *Pseudotsuga menziesii (Abies californica, Abies douglasii, Abies drummondii, Abies obliquata, Abietia douglasii)* *Pseudotsuga sp.* *Pseudotsuga spp.* *Pterocarpus angolensis (Pterocarpus bussei, Pterocarpus dekindtianus)* *Pterocarpus antunesii* *Pterocarpus brenanii* *Pterocarpus erinaceus (Lingoum erinaceum, Pterocarpus adansonii, Pterocarpus africanus)* *Pterocarpus indicus (Lingoum echinatum, Pterocarpus blancoi, Pterocarpus zollingeri, Pterocarpus papuanus)* *Pterocarpus macrocarpus (Lingoum cambodianum, Lingoum macrocarpum, Pterocarpus cambodianus, Pterocarpus parvifolius, Pterocarpus pedatus)*

	Diospyros helferi, Diospyros hierni, Diospyros moonii, Diospyros nidus) *Diospyros sp.* *Diospyros spp.* *Diplotropis purpurea (Bowdichia guianensis, Dibrachion guianense, Diplotropis guianensis, Tachigalia purpurea)* *Dipterix oleifera* *Dipterocarpus baudii (Dipterocarpus duperreana, Dipterocarpus scortechinii)* *Dipterocarpus costatus (Dipterocarpus artocarpifolius)* *Dipterocarpus gracilis (Dipterocarpus pilosus)* *Dipterocarpus grandiflorus (Dipterocarpus blancoi, Dipterocarpus griffithii, Dipterocarpus mottleyanus, Dipterocarpus pterygocalyx)* *Dipterocarpus retusus (Dipterocarpus tonkinensis, Dipterocarpus spanoghei, Dipterocarpus austroyunnanicus, Dipterocarpus luchunensis)* *Dipterocarpus sp.* *Dipterocarpus spp.* *Dipterocarpus turbinatus (Dipterocarpus jourdainii)* *Dipteryx odorata (Coumarouna odorata, Coumarouna tetraphylla, Dipteryx tetraphylla)* *Dipteryx oleifera (Dipteryx panamensis)* *Dipteryx polyphylla (Coumarouna polyphylla)* *Distemonanthus benthamianus (Distemonanthus laxus)* *Dolichandrone spathacea (Dolichandrone rheedei, Bignonia longissima, Bignonia spathacea, Dolichandrone longissima, Dolichandrone rheedei, Pongelia longiflora, Spathodea diepenhorstii, Spathodea grandiflora, Spathodea longiflora, Spathodea loureiroana, Spathodea luzonica, Spathodea rheedei, Spathodea rostrata)* *Dracontomelon dao (Comeurya cumingiana, Dracontomelon brachyphyllum, Dracontomelon celebicum, Dracontomelon cumingianum, Dracontomelon edule, Dracontomelon edule)* *Dracontomelon duperreanum (Dracontomelon sinense)* *Dryobalanops spp.* *Duabanga grandiflora (Duabanga sonneratioides, Lagerstroemia grandiflora, Leptospartion grandiflorum)* *Duboscia macrocarpa (Duboscia polyantha)* *Durio spp.* *Dyera costulata (Alstonia costulata, Alstonia eximia, Alstonia grandifolia, Dyera laxiflora)* *Dysoxylum acutangulum (Alliaria acutangula)* *Dysoxylum spp.* *Dysoxylum translucidum* *Ehretia acuminata (Cordia thyrsiflora, Cordia thyrsiflora, Ehretia argyi, Ehretia kantonensis, Ehretia onava, Ehretia ovalifolia, Ehretia pilosula, Ehretia polyantha, Ehretia pyrifolia)*	*Pterocarpus mildbraedii (Pterocarpus mildbraedii subsp. Mildbraedii)* *Pterocarpus soyauxii* *Pterocarpus sp.* *Pterocarpus spp.* *Pterocarpus tinctorius (Pterocarpus chrysothrix, Pterocarpus holtzii, Pterocarpus megalocarpus, Pterocarpus stolzii)* *Pterospermum truncatolobatum* *Pterygota macrocarpa* *Pterygota spp.* *Qualea albiflora (Qualea glaberrima, Ruizterania albiflora)* *Qualea coerulea* *Qualea paraensis* *Qualea rosea (Qualea melinonii, Qualea violacea)* *Qualea spp.* *Quercus alba (Quercus candida, Quercus nigrescens, Quercus ramosa, Quercus retusa)* *Quercus petraea (Quercus brevipedunculata, Quercus columbaria, Quercus coronensis, Quercus sessiliflora, Quercus decipiens)* *Quercus phellos (Quercus phellos f. intonsa, Quercus phellos var. viridis, Quercus phellos f. phellos)* *Quercus poilanei (Cyclobalanopsis poilanei, Quercus flavescens)* *Quercus prinus (Quercus michauxii, Quercus houstoniana)* *Quercus pubescens (Eriodrys lanata, Quercus aegilops, Quercus amplifolia, Quercus aspera)* *Quercus robur (Quercus abbreviata, Quercus acutiloba, Quercus aesculus, Quercus altissima, Quercus bedoi, Quercus pedunculata)* *Quercus rubra (Erythrobalanus rubra, Quercus acerifolia, Quercus ambigua, Quercus angulizana, Quercus borealis, Quercus cuneata, Quercus maxima, Quercus sada)* *Quercus sp.* *Quercus spp.* *Ricinodendron heudelotii (Barrettia umbrosa, Jatropha heudelotii)* *Robinia pseudoacacia (Robinia pringlei, Robinia pseudacacia)* *Roseodendron donnell-smithii (Cybistax donnell- smithii, Roseodendron millsii, Tecoma bernoullii, Tabebuia donnell-smithii)* *Roupala montana (Embothrium chaparro, Roupala arvensis, Roupala boissieriana)* *Sabicea spp.* *Sacoglottis gabonensis (Aubrya gabonensis, Humiria gabonensis)* *Sandoricum koetjape (Azedarach edule, Melia koetjape, Sandoricum maingayi, Sandorium indicum)* *Santalum album (Sirium myrtifolium)* *Santalum lanceolatum*

	Elateriospermum tapos (Elateriospermum rhizophorum) Elmerrillia papuana (Elmerrillia celebica, Elmerrillia sericea, Michelia arfakiana, Michelia celebica, Talauma papuana,Magnolia tsiampacca) Endiandra spp. Endopleura uchi (Sacoglottis uchi) Engelhardtia roxburghiana (Engelhardtia chrysolepis) Entandrophragma angolense (Entandrophragma candolleana, Entandrophragma casimirianum, Entandrophragma gregoireianum, Entandrophragma macrophyllum, Swietenia angolensis) Entandrophragma candollei (Entandrophragma choriandrum, Entandrophragma ferrugineum) Entandrophragma cylindricum (Entandrophragma cedreloides, Entandrophragma lebrunii, Entandrophragma pseudocylindricum, Entandrophragma rufum, Pseudocedrela cylindrica) Entandrophragma sp. Entandrophragma utile (Entandrophragma macrocarpum, Entandrophragma roburoides, Entandrophragma thomasii, Pseudocedrela utilis) Enterolobium cyclocarpum (Albizia longipes, Enterolobium cyclocarpa, Feuilleea cyclocarpa, Inga cyclocarpa) Enterolobium schomburgkii (Feuilleea schomburgkii, Mimosa wilsonii, Pithecellobium schomburgkii) Eperua falcata (Dimorpha falcata, Panzera falcata) Erisma uncinatum (Erisma pulverulentum) Erythrophleum africanum (Caesalpiniodes africanum, Gleditsia africana) Erythrophleum fordii Erythrophleum ivorense (Erythrophleum micranthum, Erythrophleum micranthum) Erythrophleum sp. Erythrophleum suaveolens (Erythrophleum guineense, Fillaea suaveolens) Eschweilera spp. Eucalyptopsis papuana Eucalyptus camaldulensis (Eucalyptus acuminata, Eucalyptus longirostris, Eucalyptus mcintyrensis) Eucalyptus cladocalyx (Eucalyptus corynocalyx, Eucalyptus langii) Eucalyptus deglupta (Eucalyptus binacag, Eucalyptus multiflora, Eucalyptus naudiniana) Eucalyptus diversicolor (Eucalyptus colossea) Eucalyptus dunnii Eucalyptus globulus (Eucalyptus glauca, Eucalyptus gigantea, Eucalyptus globulosus, Eucalyptus maidenii) Eucalyptus grandis Eucalyptus marginata (Eucalyptus floribunda, Eucalyptus hypoleuca, Eucalyptus mahoganii)	Santalum spicatum (Eucarya spicata, Fusanus cignorum, Fusanus spicatus) Sassafras albidum (Laurus sassafras, Sassafras officinalis, Sassafras variifolium) Schima crenata Schima wallichii Schizomeria sp. Schizomeria spp. Scleronema micranthum (Catostemma micranthum, Scleronema neblinense) Scytopetalum klaineanum Sequoia sempervirens (Condylocarpus sempervirens, Gigantabies taxifolia, Schubertia sempervirens, Sequoia pyramidata, Sequoia religiosa, Steinhauera semperviren, Taxodium nutkaense) Sextonia rubra (Ocotea rubra, Nectandra rubra) Shorea acuminata Shorea glauca Shorea hypochra Shorea obtusa Shorea roxburghii (Anthoshorea harmandii , Hopea floribunda, Shorea cochinchinensis, Shorea attopoensis, Shorea floribunda, Shorea harmandii, Shorea saigonensis, Shorea talura) Shorea spp. Shorea thorelii Shorea vulgaris Simarouba amara (Quassia alatifolia, Quassia dioica, Quassia glauca, Simarouba opaca, Zwingera amara) Sindora maritima (Sindora siamensis var. maritima) Sindora cochinchinensis (Sindora siamensis, Galedupa cochinchinensis, Galedupa siamensis) Sindora siamensis (Galedupa cochinchinensis, Galedupa siamensis, Sindora cochinchinensis) Sindora spp. Sindora tonkinensis Sindora wallichii (Galedupa intermediata, Galedupa wallichiana, Sindora intermedia) Sindoropsis letestui (Copaifera letestui, Detarium le-testui, Dialium letestui) Sloanea spp. Sophora sp. Spirostachys africana (Excoecaria africana , Excoecaria synandra , Sapium africanum, Spirostachys synandra) Spondias pinnata (Mangifera pinnata, Poupartia pinnata, Tetrastigma megalocarpum, Spondias mangifera) Staudtia kamerunensis Staudtia kamerunensis var. gabonensis (Staudtia stipitata) Sterculia apetala (Clompanus apetala, Helicteres apetala, Sterculia capitata) Strephonema sericeum

	Eucalyptus nitens (Eucalyptus goniocalyx var. nitens) *Eucalyptus obliqua (Eucalyptus procera, Eucalyptus pallens, Eucalyptus obliqua, Eucalyptus nervosa, Eucalyptus heterophylla,)* *Eucalyptus paniculata (Eucalyptus nanglei)* *Eucalyptus pilularis (Eucalyptus discolor, Eucalyptus incrassata, Eucalyptus persicifolia, Eucalyptus semicorticata)* *Eucalyptus regnans (Eucalyptus amygdalina var. regnans, Eucalyptus regnans var. fastigata)* *Eucalyptus robusta (Eucalyptus multiflora, Eucalyptus rostrata)* *Eucalyptus saligna (Eucalyptus saligna var. pallidivalvis, Eucalyptus saligna var. protrusa)* *Eucalyptus sideroxylon (Eucalyptus leucoxylon var. minor, Eucalyptus sideroxylon var. minor, Eucalyptus sideroxylon var. rosea)* *Eucalyptus sp.* *Eucalyptus spp.* *Eucalyptus tereticornis (Eucalyptus coronata, Eucalyptus insignis, Eucalyptus populifolia, Eucalyptus subulata, Eucalyptus umbellata, Leptospermum umbellatum)* *Eugenia spp.* *Eusideroxylon zwageri (Eusideroxylon borneense, Salgada lauriflora)* *Fagraea fragrans (Willughbeia fragrans, Cyrtophyllum fragrans, Cyrtophyllum giganteum, Cyrtophyllum lanceolatum, Cyrtophyllum peregrinum, Fagraea peregrina, Fagraea ridleyi)* *Fagus grandifolia (Fagus alba, Fagus americana, Fagus atropunicea, Fagus ferruginea, Fagus heterophylla, Fagus latifolia, Fagus nigra, Fagus purpurea, Fagus rotundifolia)* *Fagus sp.* *Fagus spp.* *Fagus sylvatica (Fagus aenea, Fagus asplenifolia, Fagus cochleata, Fagus comptoniifolia , Fagus crispa, Fagus cristata, Fagus cucullata)* *Falcataria moluccana (Albizia falcata, Adenanthera falcata, Adenanthera falcataria, Albizia fulva)* *Fernandoa brilletii (Hexaneurocarpon brilletii)* *Ficus auriculata (Covellia macrophylla, Ficus hainanensis, Ficus hamiltoniana, Ficus rotundifolia, Ficus scleroptera)* *Ficus religiosa (Ficus caudata, Ficus peepul, Ficus rhynchophylla, Ficus superstitiosa, Urostigma religiosum)* *Flacourtia jangomas (Flacourtia cataphracta, Stigmarota jangomas)* *Fleroya ledermannii (Adina ledermannii, Hallea ciliata, Hallea ledermannii, Mitragyna ciliata, Mitragyna ledermannii)* *Fokienia hodginsii (Chamaecyparis hodginsii, Cupressus hodginsii, Fokienia kawaii, Fokienia maclurei)* *Fokienia sp.*	*Styphnolobium japonicum (Sophora japonica, Sophora korolkowii, Sophora sinensis)* *Swartzia benthamiana (Tounatea benthamiana, Tounatea rosea, Tunatea benthamiana, Tunatea rosea)* *Swartzia cubensis (Swartzia lundellii, Tounatea cubensis)* *Swartzia leiocalycina* *Swietenia macrophylla (Swietenia belizensis, Swietenia candollei, Swietenia tessmannii)* *Swietenia mahagoni (Cedrela mahagoni, Swietenia acutifolia, Swietenia mahogani, Swietenia mahogoni)* *Swietenia mahogani* *Swintonia spp.* *Symphonia globulifera (Actinostigma speciosum, Aneuriscus aubleti, Aneuriscus exserens, Moronobea globulifera)* *Symplocos ferruginea (Symplocos cochinchinensis var. cochinchinensis, Symplocos ferruginea, Symplocos ferruginifolia, Symplocos javanica, Symplocos cochinchinensis)* *Synsepalum brevipes (Pachystela brevipes, Bakeriella brevipes, Bakerisideroxylon cinereum, Chrysophyllum batangense)* *Syzygium buettnerianum (Eugenia buettneriana, Eugenia buettnerianum)* *Syzygium chanlos (Eugenia chanlos)* *Syzygium polyanthum (Eugenia holmanii, Myrtus cymosa, Syzygium micranthum, Syzygium microbotryum)* *Syzygium sp.* *Syzygium spp.* *Syzygium zeylanicum (Acmena parviflora, Calyptranthes malabarica, Caryophyllus rugosus, Eugenia glandulifera, Jambosa bracteata, Syzygium lineare)* *Tabebuia capitata (Handroanthus capitatus)* *Tabebuia serratifolia (Bignonia araliacea, Bignonia serratifolia , Handroanthus araliaceus, Handroanthus serratifolius)* *Tabebuia sp.* *Talauma gioi (Magnolia gioi, Michelia gioi , Michelia hedyosperma, Michelia hypolampra, Talauma gioi, Magnolia hypolampra)* *Tamarindus indica (Tamarindus occidentalis, Tamarindus officinalis, Tamarindus umbrosa)* *Tarrietia cochinchinensis (Heritiera cochinchinensis)* *Tarrietia javanica* *Tarrietia utilis (Heritiera utilis, Triplochiton utile)* *Taxodium distichum (Cupressepinnata disticha, Cupressus americana, Cupressus disticha)* *Taxodium sp.*

	Fraxinus americana (Aplilia macrophyla, Calycomelia acuminata, Fraxinoides alba, Fraxinus acuminata, Fraxinus albicans, Fraxinus biltmoreana) *Fraxinus angustifolia (Fraxinus calabrica, Fraxinus dentata, Fraxinus elongatifolia, Fraxinus humilior, Fraxinus lentiscifolia, Fraxinus mixta, Fraxinus obtusa, Fraxinus orientalis)* *Fraxinus excelsior (Aplilia laciniata, Fraxinus acutifolia, Fraxinus amarissima, Fraxinus exoniensis, Fraxinus grandifolia)* *Fraxinus griffithii (Fraxinus bracteata, Fraxinus eedenii, Fraxinus formosana, Fraxinus guilinensis, Fraxinus minutepunctata, Fraxinus philippinensis, Fraxinus sasakii, Ligustrum vaniotii)* *Fraxinus sieboldiana (Fraxinus angustata, Fraxinus mariesii, Fraxinus quadrijuga, Fraxinus tobana)* *Fraxinus sp.* *Fraxinus spp.* *Garcinia fagraeoides* *Garcinia latissima* *Garcinia spp.* *Gilbertiodendron preussii (Gilbertiodendron taiense, Macrolobium preussii)* *Gleditsia sinensis (Gleditsia horrida, Gleditsia officinalis, Caesalpiniodes macracanthum, Caesalpiniodes sinense, Gleditsia indica, Gleditsia japonica)* *Gluta renghas* *Gluta spp.* *Gmelina arborea (Gmelina rheedei, Gmelina sinuata)* *Gmelina moluccana (Gmelina glandulosa, Gmelina salomonensis, Vitex moluccana)* *Gonystylus bancanus (Gonystylus hackenbergii, Aquilaria bancana)* *Gordonia amboinensis (Gordonia papuana, Gordonia brassii, Gordonia rumphii)* *Goupia glabra (Glossopetalum glabrum, Glossopetalum tomentosum, Goupia paraensis, Goupia tomentosa)* *Grevillea robusta (Grevillea umbratica, Grevillea venusta, Grevillea robusta var. compacta, Grevillea robusta var. forsteri)* *Guaiacum sanctum (Guaiacum guatemalense, Guaiacum multijugum, Guaiacum parvifolium, Guaiacum sloanei, Guaiacum verticale)* *Guarea cedrata (Guarea alatipetiolata, Khaya cunahailata, Trichilia cedrata)* *Guarea thompsonii (Guarea le-testui)* *Guibourtia arnoldiana (Copaifera arnoldiana, Copaiba arnoldiana, Copaifera arnoldiana)* *Guibourtia chodatiana (Copaifera chodatiana)* *Guibourtia coleosperma (Copaifera coleosperma)* *Guibourtia conjugata (Copaifera gorskiana)* *Guibourtia demeusei (Copaifera demeusei, Copaifera laurentii)* *Guibourtia ehie (Copaifera ehie)* *Guibourtia sp.* *Guibourtia spp.*	*Tectona grandis (Jatus grandis, Tectona theca, Theka grandis)* *Terminalia alata* *Terminalia amazonia (Chuncoa amazonia, Gimbernatia amazonia , Myrobalanus obovatus, Terminalia ovata)* *Terminalia brassii* *Terminalia calamansanay* *Terminalia chebula (Buceras chebula, Myrobalanus chebula, Myrobalanus gangetica, Terminalia acuta, Terminalia gangetica, Terminalia zeylanica)* *Terminalia dichotoma (Tanibouca guianensis)* *Terminalia ivorensis* *Terminalia myriocarpa (Myrobalanus myriocarpa, Terminalia myriocarpa var. myriocarpa)* *Terminalia spp.* *Terminalia superba* *Terminalia tomentosa* *Testulea gabonensis* *Tetraberlinia bifoliolata (Berlinia bifoliolata, Julbernardia bifoliolata, Westia bifoliolata)* *Tetraberlinia tubmaniana (Hymenostegia gracilipes)* *Tetrameles nudiflora (Tetrameles grahamiana, Tetrameles rufinervis)* *Tetrameles sp.* *Tetrameles spp.* *Thuja plicata (Libocedrus craigiana, Libocedrus gigantea,Thuja asplenifolia, Thuja californica,Thuja douglasii)* *Thuja sp.* *Thuja spp.* *Thujopsis dolabrata (Libocedrus dolabrata, Platycladus dolabrata, Thuja dolabrata, Thujopsis atrovirens, Thujopsis laetevirens)* *Tieghemella africana (Baillonella africana, Dumoria africana, Lecomtedoxa vazii, Tieghemella jollyana)* *Tieghemella heckelii (Baillonella heckelii, Dumoria heckelii, Mimusops heckelii)* *Tilia americana (Tilia americana var. americana)* *Tilia cordata (Tilia parvifolia)* *Tilia mandshurica (Tilia pekingensis)* *Tilia sp.* *Tilia spp.* *Toona sureni (Toona febrifuga)* *Triplochiton scleroxylon (Samba scleroxylon)* *Triplochiton sp.* *Tristania spp.* *Tristaniopsis obovata (Tristania obovata, Tristania spathulata)* *Tsuga canadensis (Abies americana, Abies canadensis, Abies curvifolia, Abies pectinata, Picea canadensis, Pinus americana , Pinus canadensis)*

	Guibourtia tessmannii (Copaifera tessmannii) *Gymnacranthera spp.* *Handroanthus capitatus (Tabebuia capitata, Tabebuia glomerata, Tabebuia hypolepra, Tecoma capitata)* *Handroanthus chrysanthus (Bignonia chrysantha, Tabebuia rufescens, Tabebuia chrysantha, Tecoma evenia)* *Handroanthus heptaphyllus (Bignonia heptaphylla, Handroanthus eximius, Tabebuia eximia, Tabebuia ipe)* *Haplormosia monophylla (Crudia monophylla)* *Helicia cochinchinensis (Helicia annularis, Helicia tonkinensis)* *Heriteria spp.* *Heritiera fomes (Amygdalus minor, Balanopteris minor, Fometica punctata, Heritiera minor)* *Heritiera littoralis (Amygdalus litoralis, Balanopteris tothila, Heritiera littoralis)* *Hevea brasiliensis (Hevea camargoana, Hevea granthamii, Hevea janeirensis, Hevea randiana, Siphonia brasiliensis)* *Hibiscus papuodendron* *Hieronyma alchorneoides (Hieronyma caribaea, Hieronyma chocoensis, Hieronyma ferruginea, Hieronyma heterotricha)* *Holoptelea integrifolia* *Homalium caryophyllaceum (Blackwellia caryophyllacea)* *Homalium ceylanicum (Homalium balansae, Homalium hainanense, Homalium laoticum)* *Homalium foetidum (Astranthus foetida, Blackwellia foetida)* *Hopea forbesii* *Hopea hainanensis* *Hopea iriana* *Hopea odorata (Hopea vasta, Hopea wightiana)* *cambodiensis, Afzelia retusa, Eperua decandra, Intsia amboinensis)* *Intsia palembanica (Afzelia bakeri, Afzelia palembanica, Intsia bakeri, Intsia plurijuga)* *Intsia spp.*	*Tsuga heterophylla (Abies albertiana, Abies bridgesii, Abies heterophylla, Abies microphylla, Pinus pattoniana, Tsuga albertiana)* *Tsuga spp.* *Tulipa sp.* *Tupelo sp.* *Ulmus glabra (Ulmus campestris, Ulmus cebennensis, Ulmus communis, Ulmus major)* *Ulmus parvifolia (Microptelea parvifolia, Planera parvifolia, Ulmus chinensis, Ulmus shirasawana)* *Ulmus rubra (Ulmus crispa, Ulmus fulva, Ulmus pendula, Ulmus pubescens)* *Ulmus sp.* *Ulmus spp.* *Vatairea erythrocarpa (Tipuana erythrocarpa)* *Vatairea guianensis (Andira amazonum, Andira bracteosa, Ormosia pacimonensis, Vatairea surinamensi, Vuacapua amazonum)* *Vatairea paraensis* *Vataireopsis speciosa* *Vataireopsis spp.* *Vatica fleuryana* *Vatica philastreana* *Vatica spp.* *Vatica thorelii* *Vatica tonkinensis* *Vernicia fordii (Aleurites fordii)* *Vitex cofassus (Vitex monophylla)* *Vitex pubescens (Vitex arborea, Vitex puberula, Wallrothia articulata, Vitex pinnata)* *Vochysia guianensis (Vochysia excelsa, Vochysia melinonii, Vochysia paraensis)* *Vochysia tomentosa (Cucullaria tomentosa)* *Xanthostemon sp.* *Xanthostemon spp.* *Xylia xylocarpa (Acacia xylocarpa, Inga xylocarpa, Mimosa xylocarpa, Xylia dolabriformis)* *Zanthoxylum gilletii (Fagara macrophylla, Fagara amaniensis, Fagara discolor, Fagara gilletii, Fagara inaequalis)* *Zelkova serrata (Planera acuminata, Ulmus keaki, Zelkova acuminata, Zelkova hirta)* *Zenia insignis* *Acacia shirleyi (Racosperma shirleyi)* *Adinandra forbesii* *Amburana cearensis (Amburana claudii, Torresea cearensis, Torresea cearensis)* *Artocarpus vriesianus* *Astronium urundeuva (Astronium juglandifolium Griseb., Astronium urundeuva var. urundeuva)* *Betula alnoides (Betula acuminata, Betula affinis, Betula nitida, Betulaster*

		acuminata, Betulaster affinis, Betulaster nitida) *Callitris columellaris (Callitris arenosa, Callitris glauca, Callitris glaucophylla, Frenela columellaris, Frenela hugelii)* *Calophyllum calaba var. bracteatum (Calophyllum saigonense)* *Calophyllum lanigerum (Calophyllum frutescens)* *Campnosperma brevipetiolatum Volkens (Campnosperma brassii)* *Canarium oleosum (Amyris oleosa, Canarium laxiflorum, Canarium laxiflorum, Canarium microcarpum)* *Celtis philippensis (Bosea trinervia, Celtis brevinervis, Celtis collinsae, Celtis djungiel, Celtis hasseltii, Celtis insularis)* *Cupressus macrocarpa (Callitropsis macrocarpa, Cupressus hartwegii, Cupressus lambertiana, Cupressus reinwardtii, Hesperocyparis macrocarpa, Neocupressus macrocarpa)* *Dalbergia cearensis (Dalbergia variabilis var. bahiensis)* *Erythrophleum chlorostachys* *Eucalyptus crebra (Metrosideros salicifolia, Eucalyptus racemosa var. longiflora)* *Flindersia pimenteliana (Flindersia chrysantha, Flindersia mazlini)* *Gyrinops versteegii (Aquilaria versteegii, Aquilaria walla, Brachythalamus versteegii)* *Hymenolobium pulcherrimum* *Julbernardia globiflora (Berlinia eminii, Berlinia globiflora, Brachystegia globiflora, Isoberlinia globiflora, Julbernardia globifera, Pseudoberlinia globiflora, Pseudoberlinia globiflora)* *Magnolia obovata (Houpoea obovata, Liriodendron liliiflorum, Magnolia glauca, Magnolia hirsuta, Magnolia honogi, Magnolia hoonoki, Magnolia hypoleuca)* *Metopium brownei (Cotinus metopium, Metopium linnaei, Rhus metopia, Rhus metopium, Rhus oxymetopium, Rhus quinquefolia, Terebinthus brownei)* *Oxystigma oxyphyllum (Oxymitra mortehanii, Oxymitra oxyphyllum, Oxystigma mortehanii, Pterygopodium oxyphyllum)* *Paramachaerium schunkei* *Populus × tomentosa (Populus glabrata, Populus pekinensis, Populus tomentosa var. tomentosa)* *Saurauia tristyla (Saurauia oldhamii)* *Sclerocarya birrea (Poupartia birrea, Sclerocarya birrea, Spondias birrea)* *Sterculia oblonga (Eribroma oblonga, Clompanus oblonga)* *Vitis vinifera (Cissus vinifera, Vitis sylvestris, Vitis vinifera subsp. sativa, Vitis vinifera subsp. sylvestris)* *Canarium bengalense*

		Carallia brachiata *Caryocar glabrum* *Celtis rigescens* *Chisocheton sp.* *Dactylocladus stenostachys* *Didelotia brevipaniculata (Oubaouate brevipaniculata; Toubaouate brevipaniculata)* *Kingiodendron sp.* *Letestua durissima (Pierreodendron durissimum; Pierreodendron durissimum; Letestua floribunda)* *Monopetalanthus letestui (Bikinia le-testui)* *Nesogordonia fouassieri (Cistanthera fouassieri)* *Pseudo-acacia sp.* *Trichadenia philippinensis (Leucocorema latifolia)* *Tristiropsis sp.* *Xanthophyllum papuanum*
	Source: Ministry of Agriculture and Rural Development (2023) and Phuong (2023)	

4.7 Importance of Material Transfer Agreement and Xylarium Networking

The dynamic knowledge creation in wood identification research, technologies, and development is a baseline indicator for ascertaining the progress of wood identification applications in APEC member economies, particularly for forensic wood. The project and workshops indicate there is a strong demand in the APEC region for the exchange and use of materials and information to support wood identification technologies to combat illegal logging and to enhance legal timber trade.

With the various and intense demands of stakeholders from APEC member economies on the application of wood identification, developing cooperative tools and mechanisms could facilitate the exchange of materials and associated data on wood identification propositions. One of the potential tools that can facilitate the exchange of materials among member economies is a Letter of Agreement (LOA). The document is set up to provide basic written contractual terms of the agreed-upon services and conditions, holding the parties accountable for completing their duties in wood identification activities. The letter highlights an article on the importance of a material transfer agreement (MTA) for exchanging biological materials (e.g. wood samples) and is equipped with Plan of Operation (POO). MTAs are legally enforceable contracts undertaken among researchers in both academia and industry or between private and public sector institutions, non-profit and for-profit entities, to govern the transfer of materials and associated data from a provider to a user (Streitz et al. 2003, Mowery et al. 2007, Bubela et al. 2015). Depending on the needs and intentions of the parties, the MTA may be tailored, and may stipulate a definition of materials, and responsibilities and rights in terms of the use of materials, license rights, pre-license patent assessment, confidentiality, and/or publication (Rodriguez 2005). In addition, MTA will follow domestic and international legal frameworks, such as member economy policies, CITES agreements, international timber trade regulations, etc. Xylaria Networking is another option to support wood identification implementation for curbing illegal logging and associated trade. According to Deklerck et al. (2019), Xylaria are crucial sources—through their plant/leaf counterpart, herbaria, and wood samples—for wood identification databases, including data exploration and other outputs. By networking Xylarium in the APEC region, a reference database on wood identification can be obtained and enhanced to address illegal logging by characterizing the exchanged wood specimens using different technological instrumentations.

In the mini-survey and the Joint Research Discussions, participants offered suggestions on further developing these ideas. For instance, the Project's implementing agencies, BRIN and Indonesian MoEF, and other parties (universities, research institutes, private sectors, and industries) within APEC member economies are seeking to develop a multilateral MTA for use by Xylaria. In the Joint Research Discussion, many participants suggested the development of an open MTA, to enable broader sharing and use of biological materials based on the principles of 'openness' by wood identification scientists or institutions. Such an open MTA could emulate the BioBricks Foundation's OpenMTA (https://biobricks.org/openmta/), offering five openness principles: access, attribution, reuse, redistribution, and non-discrimination. Under these terms, an open MTA might reduce transaction costs associated with access, use, modification, and redistribution of materials, help minimize waste and redundancy in the scientific research process, and promote access to materials for researchers in less privileged institutions and world regions (OnePlant 2017).

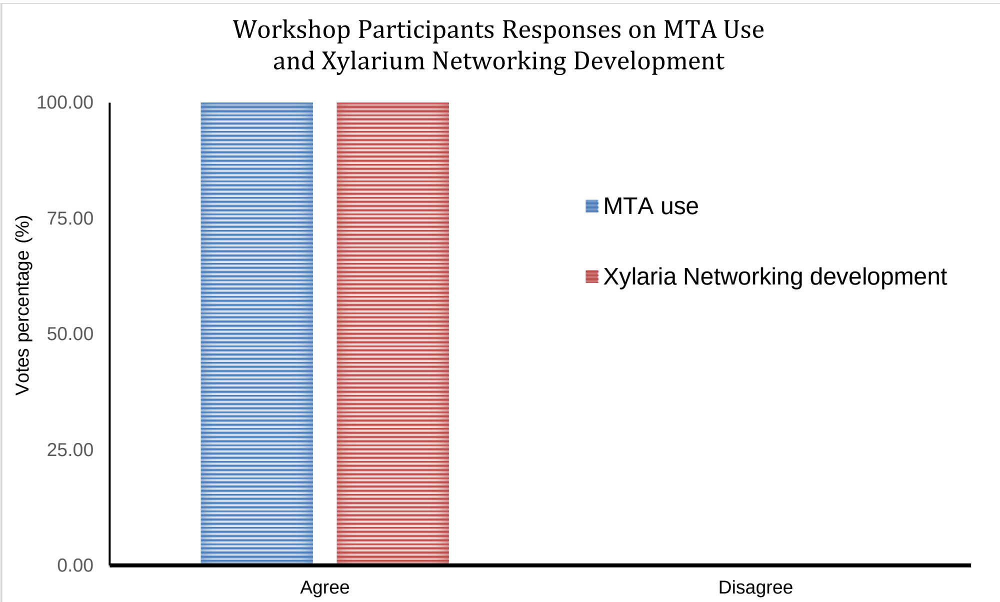


Figure 5. Workshop participants express interest in exploring options for the use of MTA for wood identification materials exchange and the potential development of Xylaria Networking

Kahl et al. (2018) stated that open MTA must deliver five principles, including 1) free access of any royalties or fees, 2) attribution or acknowledgement for the source of materials, 3) reused or modified materials to create a new substance, 4) redistribution of materials, and 5) no discrimination in transferring materials among stakeholders. An open MTA would be intended to respect knowledge, promote robust participation, and maximize interoperability. Workshop participants also suggested developing bilateral MTAs rather than a multilateral MTA. That is because bilateral MTA offers a faster and easier process to negotiate. In addition, the process is more flexible, allowing the parties to tailor the agreement to fit their unique needs and interests. To date, the Project has developed a standardized bilateral MTA template in which the terms are equally accepted and enforced by the involved parties (both provider and recipient) without any different requirements/expectations across jurisdictions.

The cooperation in MTA use is to facilitate the legal exchange of tangible materials, such as wood species data, wood samples, and wood identification technologies (Figure 6), that are important for the research, development, and application and wood identification methods. Many workshop participants welcomed the reciprocal sharing of wood databases with a vote percentage of 38.71% and wood samples with a vote percentage of 35.48%. The exchange of technologies and their adoption (19.35%) is also in demand, and it can facilitate the creating wood identification infrastructure and facilities, eventually enhancing and strengthening forensic wood identification laboratories and qualified human resources in APEC member economies. Furthermore, the exchange of these materials could help develop an integrated database of traded wood in APEC member economies as one of the pivotal performance indicators of Xylaria Networking establishment.

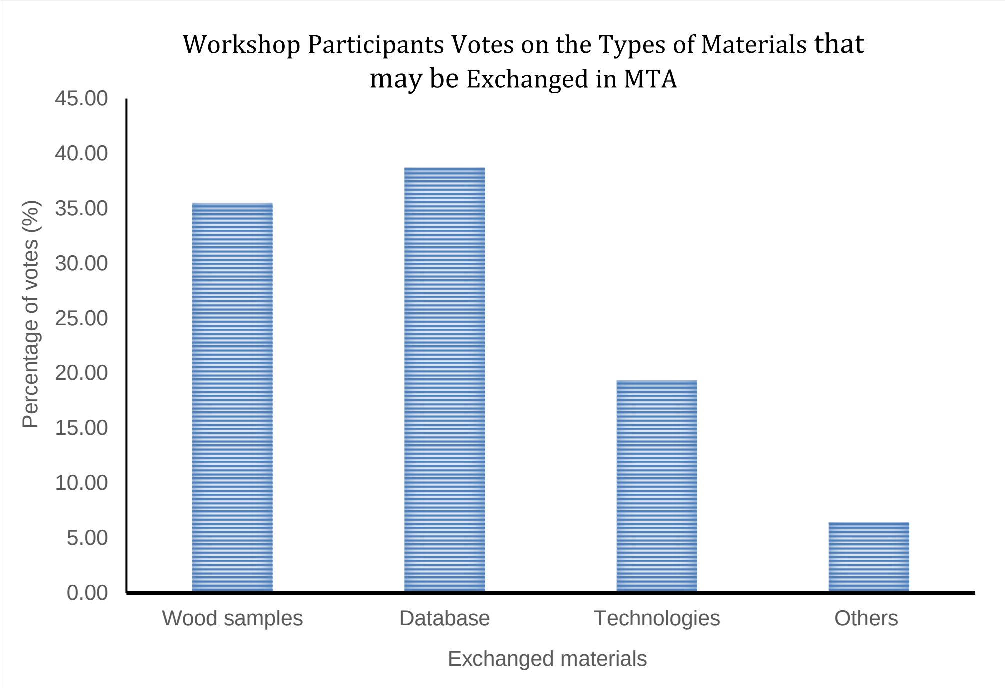


Figure 6. Materials may be exchanged through MTA in APEC member economies

However, the Project implementers recognize that MTAs also raise sensitive aspects of data sovereignty, producer transparency, intellectual property, research and publication purpose, and benefit sharing. Besides the concerns mentioned above, the Joint Research Discussion participants and APEC member economies representatives discussed the following proposal on the MTA:

1) Funding mobilization for bilateral MTAs and its following actions (research, technology adoption, capacity-building and skills enhancement) is required,
2) Some economies presuppose the development of a Memorandum of Understanding (MOU) or Letter of Agreement (LOA) prior to the processing of MTA,
3) MTA is used necessarily for biodiversity conservation, scientific collaboration, genetic research, sustainable resource management, legal and ethical compliance, data sharing, long-term conservation, intellectual property protection, international reputation, and traceability,
4) There is also an obligation to seek approval from their respective government while considering several purposes, such as tight connections and relationships among research institutes, construction of wood identification databases, adoption of wood identification technologies, and capacity-building for relevant personnel.

As highlighted in Figure 5, Xylaria Networking is another proposal from the Joint Research Discussion, intended as a Project milestone. Research Discussion participants recommended continuing the progress on establishing and developing Xylaria Networking while considering the availability of resources (finance, experts, wood identification technologies, etc.). The survey showed that many stakeholders from APEC member economies strongly supported this initiative. They also aspire to ensure the sustainable inter-operation of Xylaria Networking by connecting experts and Xylarium from the APEC region through the active involvement of multiple domestic agencies. In addition, they proposed Xylaria Networking for the following functions:

1. to serve as a centre of excellence in sharing valuable knowledge, resources, technologies on wood identification technologies and forensic wood updates,

2. to unite wood identification scientists with a common purpose,
3. to harmonize traded wood names (scientific, local, and commercial names) in the region with similarities (taxonomy, uses, and others),
4. to integrate wood data into more systemic management of Xylaria Networking system,
5. to digitize part of the Xylarium, primarily to make it available for public viewing and to update the inventory of their existing collections, softcopy at least,
6. to provide education, capacity-building, skills enhancement, and research collaboration, contributing to the assembly of information that should underpin management plans aiming at sustainable production of goods and services,
7. to advance joint efforts toward improving our effectiveness in providing accurate and reliable wood identifications,
8. to strengthen the wood identification capabilities of APEC member economies, contributing against illegal logging,
9. to strengthen APEC member economies' TLAS to be more efficient and reliable,
10. to provide a regional platform for determining and developing standardized methods that are efficient, accurate, and easy to identify wood species,
11. to assist domestic and regional collaborations between economies or institutions with different knowledge and competencies.

Prior to the development of Xylaria Networking, fundamental issues on wood identification would need to be addressed. Unsustainable financing, lack of wood identification techniques, protocols, and specimens, and limited technologies, infrastructure, and open databases are the top challenges observed in the region. Other hurdles include limited knowledge sharing, capacity-building, and technical support; lack of qualified human resources or experts; and policy-based demands. Regarding policies or regulations, there is limited mainstreaming of forensic wood identification at the domestic and international levels. It means that while there are some applications of forensic wood identification technologies domestically, most APEC member economies and stakeholders apply such technologies in response to international measures. However, to date, high pressures of international have been identified through the enactment of several legislations on illegal wood trade, such as the Wild Animal and Plant Protection and Regulation of International and Interprovincial Trade Act issued in 1992 (Government of Canada 1992), Lacey Act issued in 1900 with amendments in 2008 (United States Congress 1990), EU Timber Regulation issued in 2010 (European Union 2010), Illegal Logging Prohibition Act issued in 2012 with amendments in 2021 (Office of Parliamentary Counsel 2021), and the Act on Promotion of Use and Distribution of Legally-Harvested Wood and Wood Products issued in 2016 (Government of Japan 2016). In addition, new rules related to the Convention on the International Trade in Endangered Species of Wild Fauna and Flora (2022) took effect on 2 January 2017, providing a legally binding framework on global wood trade that member economies must adopt their own national or domestic legislation to implement CITES treaties at the domestic level. As of 28 October 2022, 506 tree species are included in the CITES Appendices, of which 97% are listed in Appendix II, meaning that they can be traded, provided that they meet the Convention's provisions on sustainability, legality, and traceability.

These legislations profile and may require the checkup of plant identification and origin or member economy of harvest in which scientific verification has the potential to use, such as wood anatomy DNA, mass spectrometry, near-infrared spectroscopy, radiocarbon, and stable isotopes (Lowe et al. 2016). The results of this study align with the previous studies by Dormontt et al. (2015) and Cetera et al. (2021) on identified wood identification challenges. Dormontt et al. (2015) reported that there are also varied matters that must be considered regarding each technology of forensic wood, such as 1) the abilities of technologies to identify the genus, species, provenance, and individual; 2) cost- and time-effectiveness and efficiency; 3) equipment requirements and procedures for testing; 4) database reference; 5) forensic validation of methods; and 6) training on the equipment use and maintenance. Solikhin et al. (2023) also stated that some challenging issues in implementing forensic wood identification are the need for qualified experts, education and capacity-building, finance support, public and private commitment, infrastructure, reference database, laboratory equipment, and legal framework.

4.8 Regional Standards on Wood Identification and Its Implementation Challenges

The survey showed that stakeholders from APEC member economies had a solid interest to potentially develop Regional Standards on Wood Identification, indicating that 94.12% of the stakeholders commented on the standard development. They suggested that the Regional Standards can assist in assuring the quality and efficiency of the wood identification techniques, promoting effective legally harvested wood and products in the APEC region, and standardizing the wood identification techniques used by the different APEC member economies. It would be important not only to develop but also encourage the wide use of a standard. By referring to the findings of the mini-survey of the pre-Joint Research Discussions, participants of the APEC member economy workshop suggested several thematic issues that can be the baseline for the development of the standards:

1) Standardized guidance on shipping and logistics of traded wood and its products,
2) Harmonized domestic standards on wood identification methods forensic wood and their standards on operating procedures, i.e., tree-ring, stable isotopes, fingerprinting, chemical assessment, DNA barcode system, and computer vision method,
3) CITES/high commercial value-listed wood species identification, integrating all analyses or wood identification technologies,
4) Regional standards on proper wood identification procedures and its resources management (database, management, human resources, and funding),
5) Regional standards mainstreaming the compendium of tools/ methods for wood identification,
6) Mechanisms to verify and ensure the skills of wood identifiers,
7) Regional standards in wood sampling and specimen observation,
8) Standard protocols, documentation, and reporting; proficiency-based blind testing to establish “accreditation”; and evaluation metrics to validate new identification technologies;
9) Standards on establishing an economy-independent review body to update standards and establishing a regional consortium to support information exchange and development, training, and capacity-building,
10) Local language translation of the existing standards, for example, the Best Practice Guide for Forensic Timber Identification (United Nations Office on Drugs and Crime 2016).

As an example, referring to point 8, the WorldForestID, arranged by a consortium of government and non-government organizations, was formed to monitor and support authentication and compliance in the international trade of wood products (Gasson et al. 2022). The platform harnesses multiple wood identification technologies, such as anatomy, stable isotope ratio analysis, DNA analysis, and DART-TOFMS, to pinpoint provenance based on geo-locations. Regarding the Regional Standards, workshop representatives also suggested the affordable, easiest, swift, applicable, open, and reliable methods for wood identification, namely wood anatomy coupled with varied techniques, such as DART-TOFMS and DNA analysis. In addition, data generated from these identifications also should fit the purposes. With the growth of digitalization, artificial intelligence integrated with the wood anatomy database can create field deployable and portable technologies, such as XyloTron, AIKO, and other machine vision-based apps, that can generate near real-time results for the screening process. Afterwards, further laboratory tests, which use advanced and innovative technologies, are required to provide reproducible, reliable, and verified evidence.

4.9 Integration of Wood Identification into Timber Legality Assurance System

Mainstreaming wood identification into the Timber Legality Assurance System (TLAS) can be observed in the wood supply chain, in which the technologies of wood identification can be used to control the supply chain of unverified and illegal wood. However, it should be understood that each APEC member economy has different mechanisms to ensure the legality of traded wood and the measures to integrate wood identification in the TLAS. For instance, Indonesia; Malaysia; and Viet Nam have extensively and rigorously applied their TLAS by involving business operators, academics, researchers, field technicians, and civil society. These member economies have also used wood identification technologies for profiling species of wood, most notably, manual identification and herbarium collection by tree identifiers or quality control inspectors. The identification is performed at specific points of the wood supply chain, such as logging permits, harvesting, transportation, processing, export/import, and or sale.

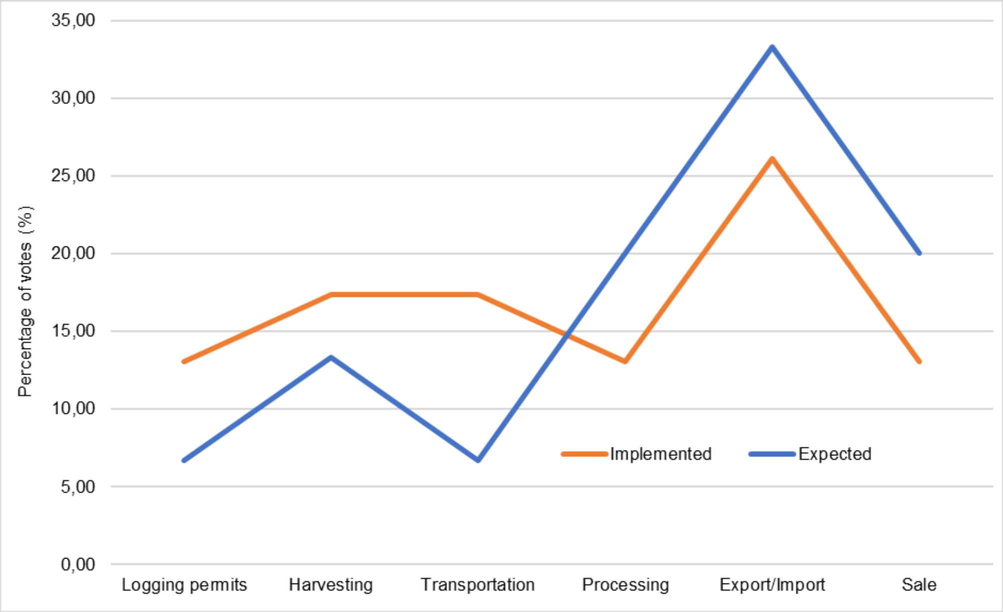


Figure 7. Current and future implementation of wood identification into APEC member economies' wood legality supply chain

Figure 7 shows the current integration of wood identification into the wood supply chain control. Mainly, APEC member economies have applied wood identification to check the wood and its products' legality at the export or import, harvesting, transportation and or logging permit issuance point. They also anticipated strengthening and enhancing the use of wood identification at export or import components or other components of the supply chain (processing and sale).

It is also recorded that many APEC member economies representatives suggested the importance of the potential integration of wood identification into TLAS or other relevant wood legality systems to profile risks of traded wood as stipulated in the documents of wood legality and trade, such as genus, species, provenance, individuals, and age. The other reasons for them to incorporate wood identification into TLAS or other similar systems are 1) to help governments verify due diligence claims and increase transparency, 2) to effectively monitor compliance and legislation requirements, 3) to help private industry assess risks through their supply chain, and 4) to help ensure the legality of wood and wood products at all stages of the supply chain. Different technologies can be used to respond to the phenomenon, especially in tracing and supporting legal supply chains (Dormontt et al. 2018, Kaulen et al. 2023, and Brusselen et al. 2023). With the presence of digitalization, it is counted that digital technologies can polish up wood identification, such as RFID, GPS-based tracking devices, light detection, and ranging (LIDAR) (Scholz et al. 2018). Workshop participants also proposed strategic measures to infiltrate wood identification into TLAS or similar systems during the Focus Discussion Group, including:

1) ensuring appropriate legal powers are included in TLAS legislation, enabling wood identification testing and the use of the results by the Government,
2) making sure policies, process documents, training procedures, and guidelines are in place to enable accurate sampling, testing, and interpretation of results,
3) having access to technologies and laboratories with appropriate equipment, skills, and talents to perform tests and generate accurate results,
4) working together between the public sector and private sector to build awareness,
5) accepting and increasing uptake of wood identification by the industry to assess risks throughout the supply chain,
6) encouraging certification systems involving wood identification to ensure that certified wood products are given preference due to their legality,
7) implementing advanced technologies, which complement the existing wood identification, for monitoring and tracking wood harvesting to trading,
8) mainstreaming wood identification of high-value and CITES-listed species along the wood supply chain, starting from the upstream to downstream flows,
9) integrating wood identification into the policies that have been implemented to ensure the legality of all forest products in the supply chain, such as due diligence systems and specific import declarations for forest products,
10) integrating simple, easy-to-operate, reliable, and highly accurate wood identification into TLAS voluntarily, with the agreement from Government, business associations, and civil society,
11) procuring small to large-scale industrial support and securing financial and technical resources for effective wood identification implementation.

5. CONCLUSIONS

Wood identification and its application for forensic wood have been studied intensively in APEC member economies, proven by the increase in published documents. Each APEC member economy has distinct technologies used for screening and diagnostic tests for forensic wood identification. The reason for utilizing forensic wood identification is to meet the demand of APEC member economies in identifying risks of illicit wood trade leading to illegal logging. Common forensic wood techniques used in APEC member economies include wood anatomy, DNA barcoding, machine vision, mass spectrometry, population genetics/phylogeography, spectroscopy, DNA fingerprinting, stable isotope, dendrochronology, and radiocarbon. For forensic wood, there is a solid need to harness multiple methods of wood identification tools (field deployable and laboratory modalities), which fit the purposes of acquiring more accurate, reliable, and reproducible scientific evidence.

Wood anatomy supported with DNA-based solutions, stable isotope, and spectroscopy are mostly advised to be utilized for forensic wood identification. Although extensive application has been observed at the level of capacity-building, education, skills enhancement, and regulations availability, the readiness level of APEC economies' forensic wood is, on average, at the research stage. It also can be seen that APEC member economies have applied forensic wood in practice, with at least utilization of wood anatomy and more advanced technologies used, such as DART-TOFMS, and DNA-based approaches. It is also documented that each APEC member economy has distinct wood species that are traded, and a list of the traded wood species can be explored to develop a wood identification database.

To accelerate this agenda, participants and guests from APEC member economies attending the Joint Research Discussions and Focus Discussion Group discussed the potential use of MTA and the development of Regional Standards on Wood Identification and Xylaria Networking. Normalizing forensic wood identification can be undertaken across the wood supply chain, which can be used to control the flow of legal wood from upstream to downstream. APEC member economies have mostly applied species wood identification in the supply chain control of TLAS. The undertaking is carried out at import/export entry points through supply chain auditing and scientific testing to build trust in wooden product claims. Different mechanism proposals of the economies are identified to develop or strengthen the mechanism of wood identification integration into TLAS, not only for species analysis but also for origin, age, individuals, and genus.

6. RECOMMENDATIONS

In this study, critical recommendations for APEC EGILAT are put forward for their consideration and further decision-making:

1. APEC member economies have extensively studied and published on wood identification technologies for specific purposes. Although the research and publication trend for forensic wood identification increases, continuous research followed by piloting projects and extensive application is recommended
2. The use of wood identification is not based on a one-size-fits-all approach. However, it should rely on and fit the purposes, considering the testing purposes, profiled risks, advantages and disadvantages of techniques, traded wood types, and analyzed products.
3. Field deployable techniques of wood identification must be scaled with laboratory modalities to produce more accurate and reliable scientific evidence. Machine vision and wood anatomy, which are complemented with DNA-based solutions, stable isotopes, and DART-TOFMS, are advised.
4. The Project is advised to promote mutual collaboration with other APEC sub-forums, such as the Sub-Committee on Customs Procedures, by transferring and exchanging the research results to them because the results become the interest of the Sub-Committee and its customs administrations of the region. Front-line customs personnel should know the wood identification technological tools available when deciding whether to release or detain wood cargo.
5. By understanding the readiness level of forensic wood application, the relevant forensic wood stakeholders in APEC economies can identify parameters that still become gaps to be narrowed down, such as limited technologies, infrastructure, and laboratories, no sustainable financing mechanism, lack of experts, no policies and legislation support, unavailable guidelines and protocols, uncompleted databases, and unstandardized wood identification methods.
6. Many stakeholders from APEC member economies who attended the workshops recommended to develop an online, open-accessed, and integrated system of traded wood lists in Asia and the Pacific region. The system would be used as a regional reference by wood scientists, tree identifiers, wood quality inspectors, law enforcement agencies, and other relevant stakeholders to curb forestry crimes and illicit wood trade. To support the due diligence process on imported and exported wood products, the development of Xylaria collection also needs to include wood data from the Economies of wood origin.
7. With a solid demand from stakeholders from APEC member economies for MTA use and Xylaria Networking development, the Project Management Core Team could commence these initiatives with the support of APEC EGILAT and Economies and with a possible project extension or continuation with the future APEC EGILAT Projects. Various strategic paces can be taken among APEC members to continuously support the development of Xylaria Networking, drafting of standardized LOA, POO, and MTA templates, development of wood identification scientists' consortium, exchange of wood identification technologies and experts, sharing of wood identification best practices, and further cooperative actions.
8. In terms of MTA, there was strong support from the workshop participants to create an open and multilateral MTA. To date, the Project Management Team has started the development of a standardized bilateral MTA templates, in which the materialization or use will be governed by domestic law. The challenges in developing open MTA are primarily due to different APEC member economies policies and prioritization on materials exchange, data sensitiveness and legal intellectual property, difficulties in benefit sharing mechanism, availability of substantial funding sources, and lengthy processes.

9. In developing an open and multilateral MTA, documents, policies, and procedures for materials exchange and collection in the APEC member economies may be gathered to provide a systemic analysis of how to develop the MTA and address the challenges in the MTA development.
10. In developing Xylaria Networking, the inter-connectivity of each Xylarium and wood identification experts in the APEC region should be fostered. Xylaria Networking could gather the relevant contacts of different APEC member economies' experts and related stakeholders (customs, plant quarantine, law enforcement agencies, etc.) supporting the implementation of forensic wood analysis. The experts could create the Wood Identification Consortium, providing knowledge services, for instance, for wood industries demanding wood identification analysis.
11. There are many proposals on the thematic issues that can be referred to in the development of Regional Standards on Wood Identification for APEC member economies. The Regional Standards can be used to accelerate the application of forensic wood in APEC members.
12. There is a strong demand for wood identification to be applied to forensic wood. APEC member economies are suggested to mainstream the integration and normalization of forensic wood into the operation of legal wood supply chains and other legality assurances of wood voluntarily.
13. APEC member economies that hold and apply TLAS, its regulation is expected to integrate the identification of wood species, at least, along the whole supply chain from upstream in the forests to downstream industries and marketplace. Genus, age, origin, and individual risks of identified wood are the other opportunities that can be applied to track the legality of woods in the supply chain lifecycle.

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