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Enabling Real-time Timber Identification through Low-cost Mass Spectrometry for Sustainable Forest Management and Enforcement

INMETRO has developed low-cost, field-deployable analytical tools that can rapidly and confidently identify timber products in Brazilian export commerce

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The Challenge

Brazil hosts one of the world's richest biodiversities of tree species, with approximately 16,000 tree species, some of which are protected under environmental regulations. This includes thousands of commercially valuable tropical hardwood species used in construction, flooring, furniture, and international timber trade, including ipê (*Handroanthus spp.*), jatobá (*Hymenaea spp.*), mahogany (*Swietenia macrophylla*), and cedar (*Cedrela odorata*). Following harvesting, wood samples lose diagnostic botanical features (e.g., leaves, flowers, and fruits), rendering species identification extremely challenging. In practice, species identification still relies heavily on macroscopic anatomical analysis, a method that requires specialized expertise and often lacks sufficient discriminatory power among closely related species.

This limitation has represented a critical bottleneck for environmental enforcement agencies responsible for combating illegal logging and ensuring compliance with forest traceability systems and regulations. Illegal logging remains a major environmental and economic concern in Brazil, with a substantial share of timber production linked to unauthorized or fraudulent practices. The illegal timber trade affects public revenues, weakens legitimate forestry markets, and creates unfair competition for legally compliant producers. A common strategy involves misidentifying protected species as legally permitted ones, allowing illegal timber to enter formal supply chains. Consequently, there is a demand for rapid, reliable, and field-deployable analytical methods capable of supporting species-level discrimination.

The central issue was the lack of reliable, accessible measurement tools for identifying wood species in real-world enforcement settings. Although essential for regulatory enforcement, wood species identification becomes significantly more challenging after processing, as diagnostic botanical features are no longer available and identification relies heavily on specialized anatomical expertise. These approaches also presented significant limitations: they were either dependent on expert interpretation or insufficiently selective for closely related species. Other methods were restricted to only the analytical laboratory environments. As a result, wood inspections were often slow, uncertain, and difficult to scale.

This measurement gap had direct consequences for the Brazilian timber industry. Misidentified timber could be traded as legal, enforcement decisions lacked robust analytical support, and regulatory systems became vulnerable to fraud. In this context, independent verification of species identity within timber supply chain traceability systems was limited, difficult to reproduce consistently, and operationally challenging at scale.

The Solution

To address this gap, the National Metrology Institute of Brazil (INMETRO), in partnership with research institutions and other technical partners, developed a rapid analytical methodology based on mass spectrometry chemotyping for the identification of wood species. The approach relies on simple solvent extraction followed by direct analysis using a compact, low-cost mass spectrometer equipped with an Atmospheric Solids Analysis Probe (ASAP) ionization source. Mass spectra are acquired in approximately one minute and compared against a curated database of species-specific chemical fingerprints. The method operates under standardized analytical conditions, ensuring reproducibility and comparability of results.

Although designed for operational simplicity, the approach incorporates key metrological principles, including controlled measurement conditions, repeatability, and validation through statistical modeling. Importantly, the system was conceived for use beyond traditional laboratory settings, enabling deployment in ports, airports, inspection checkpoints, and mobile units. This represents a shift from centralized laboratory analysis to field-deployed measurement capabilities.

The overall workflow of the proposed methodology, from sample preparation to real-time species identification,¹ is illustrated in **Figure 1**. At this stage, the methodology has been validated under controlled laboratory conditions using wood samples representative of real-world enforcement challenges, including high-value tropical species frequently associated with fraudulent substitution in commercial trade. The proof-of-concept study evaluated whether reliable species discrimination could be achieved with a compact, low-cost mass spectrometer operating under simplified analytical conditions. The results demonstrated robust classification performance and operational simplicity, supporting the feasibility of future field-based applications.

A Quantifiable Impact

The method was validated using a dataset of tropical wood samples, including high-value species commonly subject to fraudulent substitution. Measurements were performed in instrumental triplicate to assess method repeatability, and quality control procedures included the analysis of blank and pooled samples to monitor spectral consistency and system stability. Data quality was supported by replicated analyses, statistical cross-validation, and standardized analytical conditions, demonstrating robust classification performance under intermediate-precision conditions.

¹ Thays V. C. Monteiro, Mariana Fioramonte, Renan Pirolla, Alexandre Bahia Gontijo, Cristiano S. Nascimento, Niro Higuchi, Mário Augusto Gonçalves Jardim, and Maíra Fasciotti. ACS Omega 2026 11 (10), 16687-16699. DOI: 10.1021/acsomega.5c13161

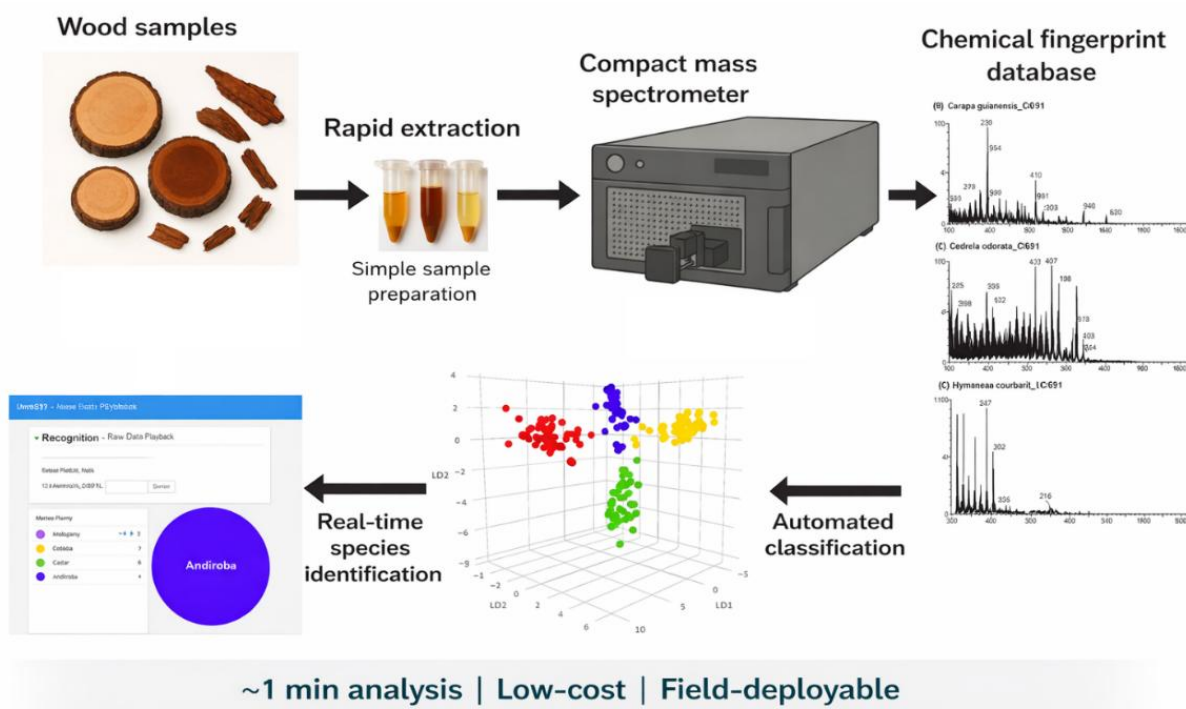


Figure 1. Simplified workflow of the proposed method for rapid wood species identification, including sample preparation, analysis using a compact mass spectrometer, and automated classification based on chemical fingerprinting. The approach enables fast, low-cost, and field-deployable measurements for timber identification.

Data analysis was conducted using statistical classification models based on principal component analysis combined with linear discriminant analysis (PCA-LDA) to evaluate performance. Model validation via cross-validation achieved approximately 95% accuracy, while tests simulating real-world conditions achieved 100 % correct classification of unknown samples. Distinct chemical fingerprints were observed in the mass spectra of andiroba, mahogany, jatoba, and cedar samples.

The developed methodology significantly improves the operational feasibility of rapid timber identification. Analysis can be performed in approximately one minute per sample, enabling high-throughput screening with minimal sample preparation.

A key advantage of the approach is the use of a compact, lower-resolution single-quadrupole mass spectrometer, specifically selected for fit-for-purpose species classification rather than detailed structural characterization. Unlike high-resolution time-of-flight (TOF) mass spectrometers, which typically cost between approximately USD 500 000 and USD 1 million and often require highly controlled laboratory environments, the complete RADIANT ASAP system costs approximately USD 100 000. This substantially

reduced cost, combined with lower infrastructure demands and reduced sensitivity to vibration, increases the feasibility of future decentralized deployment.

The analytical method demonstrated classification accuracy above 95 %, with full correct identification in validation tests involving unknown samples. These results demonstrate that robust species discrimination can be achieved using a simplified, comparatively low-cost analytical platform operating under controlled conditions.

Although field deployment has not yet been formally implemented, the methodology was specifically designed to support future applications at inspection checkpoints, ports, airports, and mobile laboratory environments. By enabling faster, potentially more accessible analytical verification of timber species, the approach may contribute to improved inspection efficiency, reduced reliance on centralized laboratory analysis, and strengthened timber supply chain verification systems. From an operational perspective, the method has the potential to enable on-site identification of timber, reducing dependence on specialized personnel and centralized laboratories. This is anticipated to increase inspection efficiency and expand the reach of enforcement activities, and discussions regarding potential pilot applications with environmental and regulatory agencies are expected as the methodology advances toward higher technology readiness levels. Compared with previous capabilities, measurements are now faster, more reliable, and more scalable. Overall, the approach is designed to strengthen timber traceability systems, improve detection of illegal logging, and support evidence-based decision-making.

This case illustrates how metrology can directly support environmental governance and public policy. By providing reliable, rapid measurement tools, the developed methodology enhances regulatory agencies' ability to enforce forest protection laws and combat illegal timber trade. The approach also contributes to improved monitoring of protected species, including those regulated under international frameworks such as CITES, and supports compliance with national and international environmental policies. It also reinforces the credibility of timber traceability systems by introducing objective, science-based verification.

At the marketplace level, the methodology has potential relevance across multiple stages of the timber supply chain, including raw material verification, export control, and downstream verification of processed wood products. Although a comprehensive economic impact assessment has not yet been performed, the approach may support more efficient enforcement actions and help reduce fraud-related losses associated with illegal timber trade.

From an institutional perspective, this case highlights the importance of developing accessible measurement technologies that can be deployed in real-world contexts. It demonstrates the role of National Metrology Institutes in addressing societal challenges and supporting sustainable development. More broadly, it shows that sustained investment in metrology

enables the translation of scientific advances into practical tools that directly impact environmental protection, regulatory enforcement, and sustainable resource management.

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² Thays V. C. Monteiro, Mariana Fioramonte, Renan Pirolla, Alexandre Bahia Gontijo, Cristiano S. Nascimento, Niro Higuchi, Mário Augusto Gonçalves Jardim, Maíra Fasciotti; Real-Time Wood Chemotyping Using a Low-Cost and Compact Mass Spectrometer. ACS Omega 17 March 2026; 11 (10): 16687–16699. <https://doi.org/10.1021/acsomega.5c13161>