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Durability and economic viability of *Neolamarckia cadamba* and *Falcataria falcata* for composite wood production

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Abstract. *Alamsyah EM, Sembada AA, Abdullah AF, Suhaya Y, Sutrisno, Darwis A, Sumardi I, Yustiana Y, Malik J, Munawar SS. 2026. Durability and economic viability of* Neolamarckia cadamba *and* Falcataria falcata *for composite wood production. Asian J For 10 (1): r100125. https://doi.org/10.13057/asianjfor/r100125.* The suitability of fast-growing tropical species for composite wood production depends on both biological durability and economic feasibility; however, empirical studies integrating these aspects remain limited. In Indonesia, *Neolamarckia cadamba* (jabon) and *Falcataria falcata* (sengon) are widely planted, yet their comparative performance in composite applications is insufficiently understood. This study addresses this gap by evaluating the natural durability and economic viability of both species in solid wood and Laminated Veneer Lumber (LVL) forms. Biological durability was assessed using a 3-month soil burial test conducted in accordance with ASTM standards, supported by visual deterioration ratings and statistical analysis. Economic performance was analysed based on timber transaction records from the West Java Provincial Forestry Department and raw material cost calculations. Results showed that sengon exhibited significantly lower weight loss than jabon in both solid and LVL forms ($p < 0.05$), with approximately 45-55% lower mass loss, indicating greater resistance to subterranean termites and decay fungi. LVL products of both species experienced slightly higher deterioration than solid wood, likely due to adhesive interface exposure and increased moisture penetration. Market analysis revealed that sengon dominates regional timber supply and displays wider price variability, reflecting high availability and strong demand, whereas jabon showed limited supply and higher, more concentrated prices. Cost analysis further indicated that producing one cubic meter of composite material from jabon requires approximately 26% higher raw material costs than sengon. Overall, the findings demonstrate that sengon offers a more favorable balance between durability and economic efficiency, supporting its broader suitability for composite wood production and industrial scaling.

Keywords: Biological durability, composite wood, *Falcataria falcata*, laminated veneer lumber, *Neolamarckia cadamba*

INTRODUCTION

The global demand for composite wood products continues to increase as construction, furniture, and packaging industries seek sustainable raw materials that reduce dependence on natural forests while maintaining reliable mechanical and service performance (Mensah et al. 2025; Kamaruddin et al. 2026). Veneer-based composites such as Laminated Veneer Lumber (LVL), Laminated Veneer Board (LVB), and plywood are widely used due to their efficient utilization of raw materials and suitability for engineered applications (Ramkumar et al. 2024). This trend has intensified interest in fast-growing plantation species that provide stable supplies, short rotation cycles, and predictable material characteristics. In Southeast Asia, particularly Indonesia, plantation-grown species have become strategic resources for supporting the composite wood industry (Sembada and Lenggoro 2024; Sembada et al. 2025).

Among these, *Falcataria falcata* (sengon) is one of the most widely utilized plantation species due to its rapid growth, extensive plantation coverage, and established market acceptance (Alamsyah et al. 2025). Despite its relatively low density and moderate durability, sengon remains a preferred raw material because of its high availability and low cost. In contrast, *Neolamarckia cadamba* (jabon) has emerged as a promising alternative species due to its comparable growth rate, straight bole, and suitability for plantation systems (Purwoko et al. 2023). Both species represent commercially important plantation woods with contrasting physical and durability characteristics (Dumil et al. 2025). Sengon, characterized by low density and limited natural durability, provides a relevant baseline for evaluating durability improvement strategies (Marasigan et al. 2022), while jabon exhibits better anatomical uniformity and increasing industrial potential as a substitute raw material (Dukarska et al. 2025). Compared to higher-density species such as *Acacia mangium* and *Eucalyptus* spp., which possess different structural and chemical properties (Ahmed et al. 2021; Longui et al. 2024), sengon and jabon represent a more realistic case for assessing the performance of low-density tropical plantation woods (Japarudin et al. 2020; Balan et al. 2025). Their widespread availability and short rotation cycles further support their importance in sustainable forestry systems (Sudomo et al. 2021; Pacaldo et al. 2025). However, the adoption of jabon in composite wood manufacturing remains limited due to uncertainties regarding its durability and economic competitiveness relative to sengon.

The performance of veneer-based composites is strongly influenced by intrinsic wood properties, including anatomical structure, chemical composition, and resistance to biological degradation (Sumardi et al. 2025a). Wood is a heterogeneous biopolymer composed mainly of cellulose, hemicellulose, lignin, and extractives, each contributing differently to material performance (Chen et al. 2020; Ferrari et al. 2022; Sumardi et al. 2025b). Cellulose provides mechanical strength, hemicellulose affects moisture sensitivity, while lignin and extractives contribute to resistance against biological attack (Wang et al. 2019; Gao et al. 2024; Blanchet et al. 2025). These components interact in complex ways, often leading to trade-offs between strength, durability, and processing behaviour.

Natural durability, defined as the inherent resistance of wood to degradation by fungi, termites, and other organisms, is a critical parameter in determining the suitability of plantation species for composite wood applications (Martín and López 2023). Durability directly influences service life, maintenance requirements, and long-term economic performance. Insufficient durability can result in premature deterioration, increased treatment costs, and reduced product reliability. Previous studies have demonstrated that durability varies significantly among species and environmental conditions (Santos et al. 2025), emphasizing the need for species-specific evaluation. Although previous studies have investigated growth performance, anatomical characteristics, and mechanical properties of *F. falcata* and *N. cadamba* (Japarudin et al. 2020; Maharani et al. 2025; Anna et al. 2025), comparative assessments of their natural durability remain limited. More importantly, most studies evaluate material properties in isolation, without integrating durability performance with economic factors such as market pricing and raw material costs (Anna et al. 2023). This gap may lead to suboptimal decision-making in material selection, pricing strategies, and plantation management, particularly as industries seek to diversify raw material sources. Therefore, this study aims to provide an integrated comparison of *F. falcata* and *N. cadamba* in the context of composite wood production. Specifically, this study (i) evaluates the natural durability of both species using standardized soil burial tests, (ii) analyzes timber market and pricing data derived from regional transaction records, and (iii) integrates biological and economic findings to support evidence-based decision-making in raw material selection, plantation management, and industrial applications.

MATERIALS AND METHODS

Materials and sample preparation

The primary materials used in this study were Laminated Veneer Lumber (LVL) and solid wood of *N. cadamba* (jabon) and *F. falcata* (sengon). All raw materials were sourced from plantation forests located in Cibugel Village, Sumedang District, West Java Province, Indonesia. Trees of *N. cadamba* and *F. falcata* were selected from the same plantation site to minimize variability associated with growth conditions in this study on composite wood durability and economic viability (age: 5-7 years, mean 6.1±0.8 years; Diameter at Breast Height (DBH): 18-24 cm, mean 21.3±2.1 cm). Logs used for LVL veneer production and solid wood specimens were obtained from the same tree lots to ensure comparability between material types. Sample specimens measured 40 cm in length, 2 cm in width, and 2 cm in thickness (Table 1). For both LVL and solid wood, specimens free from knots, cracks, decay, and other visible defects were selected. A total of twelve replicates were prepared for each species and material type, ensuring adequate replication for durability testing. LVL manufacturing was carried out using nine layers of rotary-cut veneers, each approximately 2 mm thick. Veneers used for LVL manufacture were obtained from the same log batches as the solid wood specimens to ensure material comparability. Prior to gluing, veneers were conditioned to an average moisture content of 8-10%, measured using the oven-dry method. The average air-dry density was 0.32±0.03 g cm^{-3} for *F. falcata* and 0.41±0.04 g cm^{-3} for *N. cadamba*, confirming consistency among veneer sheets and between LVL and solid wood specimens.

Veneers were visually inspected prior to assembly, and sheets exhibiting excessive lathe checks, tears, or thickness irregularities were excluded to ensure uniform quality. Phenol-Formaldehyde (PF) adhesive was applied at a spread rate of 25 g/m^2 using a mechanical glue spreader to ensure uniform distribution (Alamsyah et al. 2023). Adhesive type, spread rate, and pressing parameters were kept constant for all LVL panels to minimize variability.

Table 1. Wood sample specimens used in the study, including species, product type (solid wood and laminated veneer lumber, LVL), group codes, and specimen dimensions (2×2×40 cm). For each group, twelve replicates (n=12) were prepared

Wood species	Type	Group code
Jabon	Solid	JS
	LVL	JL
Sengon	Solid	SS
	LVL	SL

After adhesive application, veneer assemblies were pressed in two stages. Cold pressing was conducted at a pressure of 8 kg/cm^2 for 18 min, followed by hot pressing at 130 °C under the same pressure for 15 min, in accordance with standard LVL manufacturing practices. The resulting LVL panels were conditioned at room temperature (20-25°C) for seven days to stabilize moisture content (Alamsyah et al. 2024). Panel edges were trimmed to obtain clean and uniform surfaces, after which specimens were cut to final dimensions of 40 cm × 2 cm × 2 cm. Solid wood samples were prepared to identical dimensions to allow direct comparison with LVL specimens. The final specimens were classified into four groups: Jabon Solid (JS), Jabon LVL (JL), Sengon Solid (SS), and Sengon LVL (SL), as shown in Table 1. All prepared specimens were stored under controlled laboratory conditions (20-25°C, 60-70% relative humidity) until durability testing.

Natural durability testing

Natural durability was evaluated according to ASTM D1758-06 (Standard Test Method for Evaluating Wood Preservatives by Field Tests with Stakes) (Sabrina et al. 2021). Prior to burial, all specimens were sanded to obtain flat and uniform surfaces, and their initial moisture content was determined using the oven-dry method (ASTM D4442-20). Each specimen was then weighed, labelled, and prepared for field exposure. The graveyard (field-stake) test was conducted at the experimental field of the School of Life Sciences and Technology, Bandung Institute of Technology, West Java, Indonesia (Figure 1). Twelve replicates were used for each wood type. Specimens were randomly assigned to burial positions to minimize positional bias and were installed vertically at a depth of approximately 20-30 cm, leaving the upper portion exposed for inspection. Spacing between specimens was maintained at 30 cm within rows and 60 cm between rows to ensure uniform exposure to soil organisms and to prevent cross-contamination.

The burial site was characterized by a warm and humid tropical microclimate typical of low- to mid-elevation areas in West Java. During the 3-month exposure period, ambient air temperatures ranged from approximately 24 to 28°C. These temperature conditions fall within the optimal range for the activity and foraging behavior of subterranean termites as well as the growth of wood-decay fungi (Bagheri et al. 2022). Relative humidity at the site remained consistently high (>75%). The soil at the test location contained a high proportion of organic matter, evidenced by its dark coloration, friable structure, and the presence of decomposed plant residues (Ndzana et al. 2025). Natural biological activity was confirmed through direct field observations, including visible termite galleries in the surrounding soil, the presence of active worker termites during specimen excavation, and characteristic decay patterns on exposed wood surfaces. The test area had not been previously used for durability or preservative testing to avoid residual biological or chemical bias. After three months of exposure, specimens were excavated, gently cleaned of adhering soil, oven-dried to constant weight, and reweighed (Sembada and Faizal 2019). Durability assessment included (i) visual evaluation of the degree and form of biodeterioration following the general procedures described in ASTM D1758-06 and (ii) calculation of percentage weight loss based on initial and final oven-dry weights. Damage percentage was determined through visual assessment of the proportion of specimen surface area exhibiting biodeterioration symptoms (e.g., discoloration, softening, fungal colonization, and structural degradation). The affected area was expressed as a percentage of the total specimen surface area. In addition to surface damage estimation, durability class was assigned based on the percentage of cross-sectional penetration observed after the 3-month soil burial test. This duration is commonly applied as an initial evaluation period to capture early-stage biodegradation and to differentiate material performance under accelerated exposure conditions. Previous studies have shown that measurable physical and chemical changes, including moisture dynamics and cell wall degradation, can already be detected within 3-6 months of burial (Seo et al. 2020). In composite systems, significant reductions in mechanical properties and progressive mass changes have also been reported starting from the first 3 months of soil exposure, with degradation continuing over longer periods (Khalil et al. 2010). Therefore, the 3-month test in this study is intended as a comparative and accelerated durability screening rather than a full representation of long-term service performance.

The soil used for the burial test was characterized to ensure consistent and representative decay conditions. Soil pH was measured using a calibrated pH meter (S220, Mettler-Toledo International Inc., Ohio, USA) in a 1:2.5 soil-water suspension, yielding values in the slightly acidic to neutral range (approximately 6.2-6.8), which is favorable for fungal and microbial activity.

Figure 1. Graveyard (field-stake) test setup for evaluating natural wood durability according to ASTM D1758-06. Individual wood specimens (2×2×40 cm) were buried vertically in soil to a depth of 20-30 cm, leaving the upper portion exposed

Table 2. Components and parameters used to calculate the timber cost required to produce one cubic meter (1 m^3) of composite wood. Log prices are expressed in USD/m^3, veneer yield is expressed as a percentage (%), and log requirements are expressed in cubic meters (m^3)

Component	Explanation	Value
Price of wood (logs)	Market price of wood in log form (USD/m^3)	Jabon = USD 34.38 Sengon = USD 25
Veneer yield from 1 m^3 log (%)	Percentage of veneer volume obtained from 1 m^3 logs	Jabon = 47% Sengon = 43%
Log requirement for 1 m^3 composite wood output	Volume of logs (m^3) required to produce 1 m^3 of composite wood, calculated using veneer yield	Jabon = 2.13 m^3 Sengon = 2.33 m^3

Soil moisture content was determined gravimetrically by oven-drying samples at 105°C to constant weight and was maintained at approximately 60-80% of the soil water-holding capacity throughout the test period by periodic watering (Franzluebbers 2022). Microbial activity was assessed qualitatively based on the presence of visible fungal colonization and soil respiration indicators, as well as the natural occurrence of subterranean termites in the test environment (Chen et al. 2023). These combined physicochemical and biological conditions are known to strongly influence the rate and extent of wood decay (Marais et al. 2022), thereby supporting the reliability of the soil burial test as a method for comparative durability assessment. Penetration percentage was estimated by visually examining the cross-section of each specimen and determining the proportion of structural degradation relative to the total cross-sectional area. Specimens were categorized into seven durability classes based on penetration percentage as follows: Class 1: >95% penetration (extremely non-durable), Class 2: >90-95% penetration (very non-durable), Class 3: >75-90% penetration (non-durable), Class 4: >50-75% penetration (slightly durable), Class 5: >30-50% penetration (moderately durable), Class 6: >10-30% penetration (durable), and Class 7: 0-10% penetration (highly durable). This classification system was defined for the purpose of comparative durability ranking among wood types in this study. The classification based on cross-sectional penetration was adapted from decay assessment principles in field stake tests (European Norm [EN] 252) and durability classification concepts in EN 350 (Marais et al. 2022; Brischke et al. 2024). Similar approaches using depth or percentage of degradation as a quantitative indicator of durability have been reported in previous studies (Brischke and Rapp 2008; Meyer-Veltrup et al. 2017). To improve resolution and comparability among treatments, the durability classification was expanded into seven classes based on penetration percentage, which provides a more sensitive differentiation than conventional categorical systems. For quantitative analysis, each durability class was converted into a numerical percentage using the midpoint of the corresponding penetration range: Class 1 = 97.5%, Class 2 = 92.5%, Class 3 = 82.5%, Class 4 = 62.5%, Class 5 = 40%, Class 6 = 20%, and Class 7 = 5%. The reported durability (%) values represent the mean converted percentage across replicates (n = 12). The same durability testing procedure was applied to both LVL and solid wood specimens of jabon and sengon. Statistical analysis using one-way ANOVA was performed to determine significant differences in natural durability among species and material types.

Cost calculation

Timber sales price data were obtained as secondary data from the West Java Provincial Forestry Department for the period May-September 2025. Price distribution was analysed to describe market variability during the study period. The timber cost required to produce one cubic meter (1 m^3) of composite wood was calculated using the following relationship:

Timber cost per m^3 composite wood = (Log price per m^3) / (Veneer yield fraction)

The veneer yield fraction and corresponding log prices used in the calculation are presented in Table 2. Veneer yield was defined as the percentage of veneer volume obtained from one cubic meter of logs. The calculated timber cost represents the raw material contribution to composite wood production and allows direct economic comparison between jabon and sengon. For cost estimation, the modal log price was used as the representative market price because it reflects the most frequently observed transaction value and therefore better represents prevailing market conditions during the study period. Veneer recovery rates (47% for jabon and 43% for sengon) were derived from direct industrial production measurements, calculated as the ratio of usable veneer volume to initial log volume during rotary peeling operations. The recovery values incorporate processing losses including trimming, clipping, core residue, and grading rejection. Based on industrial production measurements, jabon yielded 4.7 m^3 veneer from 10 m^3 logs (47%), while sengon yielded 4.3 m^3 veneer from 10 m^3 logs (43%).

RESULTS AND DISCUSSION

Natural durability performance of jabon and sengon wood

The natural durability of jabon and sengon wood was evaluated based on weight loss and percentage of structural damage after a 3-month graveyard test. Weight loss, a standard indicator of biodeterioration because it reflects degradation of cell-wall components by fungi and termites (Martín and López 2023), varied from lowest to highest as follows: Sengon solid (29.1%), Sengon LVL (30.27%), Jabon solid (56.1%), and Jabon LVL (57.54%), while the percentage of damage ranged from 10-60% (Table 3). One-way ANOVA revealed that both weight loss and damage percentage differed significantly among wood types ($p < 0.01$). Effect size analysis showed a large influence of wood species and material form on durability outcomes, with eta squared (η^2) values of 0.78 for weight loss and 0.81 for damage percentage. These results indicate that more than 75% of the observed variation in biodeterioration parameters was attributable to differences among wood types, statistically confirming the substantially lower natural durability of jabon compared to sengon under soil-contact exposure conditions. Jabon LVL and Sengon LVL showed slightly greater weight loss than their solid counterparts. This pattern aligns with findings from Alamsyah et al. (2025), who noted that although Jabon LVL and Sengon LVL exhibit improved physical and mechanical characteristics, such as higher bending strength, better hardness, and acceptable delamination performance, the layered structure of LVL can create micro-gaps that facilitate moisture accumulation and biological intrusion. These structural interfaces, while beneficial for enhancing mechanical performance, may inadvertently reduce durability underground-contact or high-decay environments. Similarly, Awaludin et al. (2018) reported that despite the significant advancement in the engineering performance of Sengon LVL, its natural resistance to termite attack remains a concern, particularly when exposed directly to soil or high-humidity conditions. They highlighted that LVL made from fast-growing species may still inherit the lower natural durability of the parent wood, even when mechanical properties improve. This supports the present findings, where LVL products, regardless of species, experienced slightly greater biodeterioration than their solid wood counterparts due to increased accessibility for fungi and termites along the veneer–adhesive interfaces.

The deterioration of both solid and Jabon LVL samples reflects combined degradation by subterranean termites and fungal colonization, a synergistic interaction also noted by Noor Azrieda et al. (2015). Jabon showed the highest vulnerability despite its higher density, indicating that density is not the sole determinant of durability. Rather, natural resistance is strongly influenced by chemical composition: Jabon contains higher cellulose (52.4%) and lower lignin (25.4%) than sengon, and cellulose-rich woods are more readily consumed by termites and cellulolytic fungi, whereas lignin and phenolic compounds provide protective barriers (Shanbhag and Sundararaj 2013). Importantly, the LVL production process did not result in a marked improvement in the natural durability of jabon or sengon when compared with their solid-wood counterparts. Although LVL manufacturing involves veneer peeling, adhesive bonding, and hot pressing, which can reduce anatomical heterogeneity and partially seal wood surfaces, these processes alone are insufficient to inhibit biological degradation in the absence of preservative treatment (Huang et al. 2024). Rotary peeling exposes fresh cellulose-rich surfaces, while veneer lathe checks may increase permeability, potentially facilitating moisture ingress and biological access, particularly under ground-contact conditions.

Visual observations showed that jabon solid and LVL were classified as durability class 4 according to ASTM D1758-06, corresponding to 50-75% penetration, whereas Sengon Solid and LVL fell into class 6 with only 10-30% penetration. Visual assessment (Figure 2) further revealed pronounced longitudinal hollowing and extensive internal degradation in both solid and LVL Jabon samples (Figure 2.A-B), whereas sengon samples (Figures 2.C-D) exhibited only minor surface erosion and localized biological attack, with the overall structural form largely preserved. Damage ranged from light termite markings to severe longitudinal hollowing, especially in jabon samples. These findings agree with Trisatya et al. (2020), who classified sengon wood as natural durability class IV-V and jabon as class V, confirming sengon’s superior durability. Comparable results have been reported for LVL manufactured from other fast-growing species, such as poplar, rubberwood, and eucalyptus, where LVL production improved mechanical uniformity but did not significantly enhance resistance to termites or decay unless preservative-treated (Jin et al. 2016; Murata et al. 2021). This indicates that LVL should be regarded primarily as a structural optimization technique rather than a durability-enhancing process. Structural characteristics further explain these differences: Sengon wood has smaller vessels, denser fiber distribution, and lower porosity, which slow termite intrusion (Rahayu et al. 2024), whereas jabon wood has high porosity with large, open structures that facilitate entry and movement of termites and fungal hyphae (Herawati et al. 2024). Additionally, jabon’s typically higher moisture content may accelerate decay, as moist conditions enhance both fungal growth and termite activity (Nandika et al. 2021). The similarity in durability performance between solid wood and LVL observed in this study suggests that biological resistance remains predominantly governed by species-specific anatomical and chemical traits, rather than by composite configuration. Consequently, for fast-growing species with inherently low natural durability, LVL products intended for ground-contact or high-risk environments require additional protection measures, such as preservative impregnation or surface treatments, to achieve acceptable service life. This inherent vulnerability is consistent with its naturally low durability class. Based on the findings of Malik et al. (2022), untreated jabon wood is categorized as grade V (highly susceptible) to subterranean termites and grade IV (non-resistant) to drywood termites, confirming its poor natural defense against biological degradation. Overall, these results clearly demonstrate that sengon, both solid and LVL, exhibits significantly better natural durability than jabon underground-contact conditions.

Although sengon showed significantly better natural durability than jabon, its weight loss of approximately 29-30% after only three months of soil exposure indicates that its resistance remains moderate rather than high. This suggests that untreated sengon, while clearly superior to jabon, may still require preservative treatment or protective design for prolonged ground-contact applications.

Nevertheless, when durability performance is considered alongside economic factors, such as higher market availability, lower raw material cost, and greater transaction volume, sengon emerges as the more practical choice for large-scale composite wood production, particularly for applications with moderate durability requirements. In contrast, jabon's poor natural durability limits its suitability for untreated use in biologically aggressive environments. However, its higher market price and limited supply indicate potential value for non-ground-contact or interior applications where mechanical performance or uniformity is prioritized. In such cases, Jabon-based LVL may be economically justified if durability is enhanced through treatment or surface protection, as LVL production alone does not substantially improve biological resistance. It should also be noted that the 3-month graveyard test provides a comparative rather than long-term assessment of durability. While effective for distinguishing species performance, extended exposure periods would be required to predict service life more accurately. Overall, integrating biological and economic findings highlights that sengon is better suited for cost-efficient, moderate-risk applications, whereas jabon may be viable for higher-value uses when durability limitations are appropriately managed.

Timber market analysis and economic evaluation

Timber price data were obtained from the official transaction records of the West Java Provincial Forestry Department for the period May-September 2025. These data represent realized market transactions in community-based timber markets and include information on transaction date, log volume (m^3), and total transaction value (IDR). Unit log prices (IDR m^{-3}) for jabon and sengon were calculated by dividing the total transaction value by the corresponding log volume for each recorded sale. This approach ensures consistency and allows replication of the analysis using equivalent forestry market datasets. For each species, descriptive statistics, including mean, median, and mode prices, were used to characterize market behavior and price variability. For both jabon and sengon, the mean price exceeded the median, indicating right-skewed price distributions driven by a limited number of high-value transactions. In the case of jabon, the mode price coincided with the median, suggesting relatively stable pricing with limited dispersion around the central market value. Conversely, sengon exhibited a median price higher than the mode, reflecting a broader distribution of transaction prices and greater variability in market valuation. Price variability was assessed by comparing the relative positions of the mean, median, and mode rather than relying on a single average price. This approach captures short-term log price fluctuations across multiple transactions and avoids overrepresentation of outliers. Because the dataset spans several months, temporal price variation due to market supply, demand, and harvesting cycles is inherently incorporated into the analysis.

Market activity during the study period was strongly dominated by sengon, with 1,632 recorded transactions involving approximately 78,000 m^3 of logs and generating a total revenue of IDR 51 billion (approximately USD 3.19 million). In contrast, jabon exhibited limited market penetration, with only 36 documented transactions and a cumulative revenue of IDR 200 million (approximately USD 12,500). These differences highlight not only contrasting price structures but also substantial disparities in market liquidity and commercial maturity between the two species. This substantial difference underscores the markedly higher availability and market penetration of sengon compared to jabon, consistent with earlier reports noting sengon's widespread cultivation and rapid rotation as a community forest species (Awaludin et al. 2018). Stewart et al. (2021) further demonstrated that sengon offers strong economic incentives for smallholders, with a profitable six-year rotation, a Net Present Value (NPV) of USD 1,015 ha^{-1}, and an Internal Rate of Return (IRR) of 20%. These favorable financial indicators make sengon a highly attractive species for community forestry, encouraging widespread planting and steady market supply. This economic advantage helps explain the significantly higher transaction volume and market dominance of sengon in West Java. In contrast, jabon has not achieved similar economic traction. Purwoko et al. (2023) reported that jabon cultivation in urban settings currently yields negative financial returns, with a low IRR (0.8%) and a negative NPV, classifying it as economically "not feasible" under existing management conditions. Although jabon is valued for its fast growth and potential role in expanding urban green spaces, its weaker financial performance limits adoption among smallholders and contributes to its lower availability in timber markets.

Table 3. Weight loss (%) and damage percentage (%) of jabon and sengon wood samples after a 3-month soil burial test

Parameters	JS	JL	SS	SL	*p*-value (ANOVA)
Weight loss (%)	56.1±5.7	57.54±5.7	29.1±2.7	30.27±2.7	0.00**
Damaged (%)	60±16.2	60±16.2	10±7.07	20±13.23	0.00**

Note: Values are presented as mean ± standard deviation (n=12). JS: Jabon solid, JL: Jabon LVL, SS: Sengon solid, SL: Sengon LVL. Statistical differences among wood types were analyzed using one-way ANOVA, with significance determined at $p < 0.01$. Damage (%) values were derived from ASTM D1758-06 visual rating classes converted to percentage midpoints and averaged across replicates (n = 12).**: Indicates significance at the 1% level

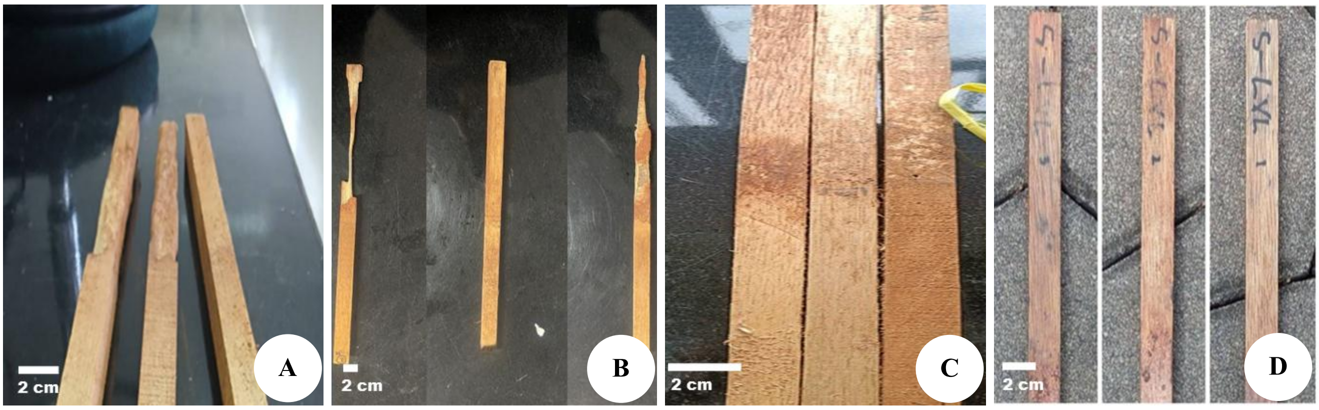

Figure 2. Visual appearance of wood samples after a 3-month soil burial test. A. Solid Jabon (JS) and B. Jabon LVL (JL) show severe degradation characterized by deep penetration, longitudinal hollowing, and substantial loss of structural integrity. In contrast, C. Solid Sengon (SS) and D. Sengon LVL (SL) exhibit only minor surface erosion with largely intact cross-sections, indicating superior resistance to biological deterioration. All samples had identical dimensions (2×2×40 cm) and were exposed to the same soil moisture and microbial conditions

The market price structure revealed distinct patterns between the two species (Table 4). Although the mode prices of jabon and sengon differ by only approximately IDR 100,000-150,000 (USD 6-9), sengon consistently exhibits a higher mean value, indicating the presence of more frequent high-price transactions. This aligns with findings by Alamsyah et al. (2025), who reported that although jabon has superior composite wood performance, its limited supply inflates its market price relative to sengon. The frequency distribution of prices further highlights this difference (Table 5). Approximately 67% of jabon transactions fall within the IDR 400,000-600,000 (USD 25-37.5) range, closely matching its mode price, whereas sengon transactions are distributed more widely across higher price categories, reflecting greater market variability. This distribution confirms that jabon maintains a more concentrated price pattern, whereas sengon displays a highly heterogeneous price structure, likely due to variations in quality, origin, and supply volume. It is important to note, however, that this market analysis is subject to several limitations. The transaction data were derived from a single province (West Java) and represent a relatively short observation period, which may not fully capture interregional price dynamics or seasonal fluctuations in timber supply. In addition, the number of recorded jabon transactions was substantially smaller than that of sengon, reflecting a limited market size that may amplify price stability while reducing statistical representativeness. Consequently, caution is required when extrapolating these findings to national or export-scale markets. From these findings, it can be concluded that jabon wood tends to be more expensive overall, despite some overlapping price categories. This higher price is a disadvantage for its utilization as a raw material for composite wood production, as it increases production costs (Tomec and Kariž 2022). However, the higher sales value can be advantageous for smallholder cultivators who manage jabon plantations (Snashall and Poulos 2023). At the same time, economic competitiveness is influenced not only by price but also by supply chain factors such as plantation scale, harvesting frequency, transportation efficiency, and processor familiarity. Sengon benefits from an established supply chain, shorter rotation cycles, and broader market acceptance, which collectively reduce transaction costs and price volatility. Conversely, targeted policy interventions, such as incentives for expanding jabon plantations, improved market access for smallholders, and the integration of jabon into public procurement or engineered wood programs, could help stabilize supply and reduce price disparities over time. Under such conditions, jabon's higher market value may shift from a cost constraint to a strategic advantage, particularly for smallholder growers seeking higher returns.

These price and yield differences translate directly into contrasting raw material costs for composite wood production (Table 6). When veneer recovery rates are considered, jabon requires an effective log cost of IDR 1,170,212.77 (~USD 73.14) per cubic meter of finished composite material, whereas sengon requires only IDR 930,232.56 (~USD 58.14), reinforcing sengon's economic advantage for large-scale production. These results indicate that jabon raw material costs are approximately 26% higher than those of sengon. The higher cost is attributed not only to the selling price but also to lower log availability, consistent with Alamsyah et al. (2025), who emphasized supply limitations as a barrier to industrial-scale jabon utilization. Nevertheless, the superior physical and mechanical properties of jabon-based composites, as documented in the same study, may justify the higher cost for applications requiring enhanced strength, hardness, and lower delamination. Overall, the pricing data highlights a clear trade-off: Sengon offers greater availability and lower cost, supporting its long-standing role in the composite wood industry, while jabon provides enhanced performance at a higher raw material cost, making it more suitable for value-added or specialty panel applications.

Table 4. Log prices of jabon and sengon wood expressed in USD per cubic meter (USD/m^3), converted from Indonesian Rupiah (IDR) using an exchange rate of IDR 16,000 = USD 1. Data represent market transactions recorded by the West Java Provincial Forestry Department during May-September 2025. Descriptive statistics include minimum, maximum, mean ± standard deviation, median, and mode, illustrating price variability and market dispersion

Parameter	Jabon (USD/m^3)	Sengon (USD/m^3)
Mode	34.38	25
Median	34.38	37.5
Mean	42.17	50.43

Table 5. Percentage frequency distribution (%) of jabon and sengon log prices across predefined price classes (USD/m^3). Jabon prices are concentrated within the USD 25-37.5 range, whereas sengon prices are distributed across a wider range, indicating greater market variability and heterogeneity in log valuation

Price range (USD/m^3)	Jabon	Sengon
<12.5	3%	0%
12.5-25	0%	37%
25-37.5	67%	15%
37.5-50	19%	14%
50-62.5	3%	14%
62.5-75	0%	5%
75-87.5	6%	5%
87.5-100	0%	3%
100-112.5	3%	5%
112.5-125	0%	0%
>137.5	0%	1%

Table 6. Estimated timber cost (USD/m^3) required to produce one cubic meter (1 m^3) of composite wood from jabon and sengon. Calculations incorporate modal log price (USD/m^3) as the representative prevailing market price and veneer recovery fraction (%). Jabon exhibits a higher estimated production cost than sengon due to both higher log prices and lower veneer yield efficiency

Parameter	Jabon	Sengon
Log price per m^3 (USD)	USD 34.38	USD 25
Recovery (%)	47%	43%
Wood needed for production (%)	100%	100%
Effective price of wood required to produce 1 m^3 of composite wood (USD)	USD 73.14	USD 58.14

In conclusion, this study showed that sengon wood, both solid and LVL, has substantially higher natural durability than jabon, as reflected by its lower weight loss and damage after soil burial. Jabon's greater vulnerability is linked to its anatomical and chemical characteristics, while the slightly higher deterioration of LVL products in both species is attributed to biological access along veneer-adhesive interfaces. Market analysis further indicates that sengon dominates timber transactions in West Java due to its strong financial performance, high availability, and stable supply, whereas jabon remains limited in supply and results in higher production costs, making composite wood production from jabon approximately 26% more expensive. Despite these economic constraints, jabon composites offer superior mechanical performance, making them suitable for selective, high-value applications. Future study should focus on improving jabon's durability through preservative or surface treatments, optimizing LVL manufacturing to reduce veneer interface vulnerability, and conducting long-term durability and life-cycle assessments to better guide material selection for engineered wood industries.

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