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Air-Drying Time and Moisture Loss Dynamics of Short-Length Commercial Green Falcata (*Falcataria falcata* (L.) Greuter & R. Rankin) Lumber: Implications for Small-Scale Lumber Processing in Caraga Region, Philippines

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ABSTRACT

This study examined the air-drying rate of 2" x 4" x 4' short-length commercial green falcata (*Falcataria falcata*) lumber in Butuan City, Philippines, from September to December 2024. It aimed to determine the drying duration required to achieve moisture contents of 15%, 20%, and 25%, which are critical for preventing fungal decay and improving lumber stability and usability. A total of 24 lumber samples were collected and monitored under ambient conditions, with 2" sample segments taken from lumber ends periodically, including ¼" trim ends. From each lumber specimen, a 2-inch segment was removed from one end, and an additional ¼-inch slice was trimmed off to eliminate surface irregularities and possible drying defects. The 2-inch sample was immediately weighed using a precision balance, then oven-dried at 105 °C for 24 hours or until its mass stabilized to obtain the oven-dry weight needed for moisture content determination. For the drying assessment, the remaining length of each board was gradually reduced by cutting 2-inch sections from alternating ends. This procedure was repeated until the lumber reached a moisture content of less than 15%. The results revealed significant variation in drying times across stacking months, with September showing the fastest drying (20 days to 15% MC) and December the slowest (77 days). The regression analyses showed that the drying process is best described by polynomial and exponential models, indicating that moisture loss does not occur at a constant rate. Instead, drying is typically faster during the early stages when the lumber still contains high free water and gradually slows as the moisture content approaches fiber saturation. These findings provide a localized and practical reference for air-drying estimates, contributing to efficient and sustainable lumber processing practices in the Caraga Region.

Keywords: *drying behavior, seasonal variation, lumber handling practices*

1 Introduction

Falcata (*Falcataria falcata*) is a large, fast-growing tree native to Southeast Asia that can reach heights exceeding 30-40 meters (Hassan and Rahman 2019, Hughes et al. 2024). It is one of the most used raw materials in the wood industry, and plays a significant role in the Philippine timber industry. It is extensively cultivated as a fast-growing industrial plantation species across tropical regions (Krisnawati 2011). It is recommended for harvest at a minimum age of seven years to ensure optimum wood quality (Listyanto 2018). It has become one of the principal raw materials for veneer and plywood production (Jimenez et al. 2015). Research demonstrates that young falcata trees, aged 3-7 years, can be successfully processed into veneer and plywood, with all age groups meeting glue bond requirements, despite some quality variations in lathe checks (Jimenez et al. 2022).

According to the DOST-FPRDI (2020), falcata is the dominant plantation species in the Caraga Region, and of the approximately 733,500 m³ of plantation logs produced in 2017, 67% came from Caraga, with 91 % of these being falcata. Freshly sawn falcata lumber contains high moisture content, making it prone to warping, shrinkage, fungal attack, and dimensional instability if not properly dried. Wood drying is a crucial operation in wood processing that ensures the physical integrity and stability of wood during remanufacturing and use (Elustondo et al. 2023). Proper drying, handling, and storage minimize undesirable changes in moisture content during service, helping to avoid major dimensional change problems (Simpson 2010, Bergman 2021). Although kiln drying offers controlled conditions, air drying remains the most common method in the Philippines due to its low cost and accessibility, particularly for small-scale farmers. In the Philippines, lumber used for construction or indoor applications is typically dried to a moisture content of 12–15%, with 15% widely accepted as the practical target for air-dried lumber under local climatic conditions.

Air drying rates depend on wood species, dimensions, and local climate, making it difficult to establish a single standard drying schedule. Methods such as those developed by Simpson and Hart (2001) have demonstrated that stacking date and geographic location significantly affect drying times, with differences of several weeks observed under varying conditions. However, despite such advances, there is limited information on the air-drying behavior of falcata under Philippine conditions, particularly in the Caraga Region, where the species dominates plantation forestry.

2 Materials and Methods

2.1 Lumber Sampling

Six rough-sawn, 2"×4" nominal (approximately 5 cm × 10 cm in radial and tangential directions, respectively) short-length *F. falcata* lumber specimens were collected monthly from a commercial lumber mill in Butuan City from September to December 2024. A total of 24 lumber samples were obtained over the four-month sampling period. All lumber specimens were sourced from a single commercial batch harvested from *F. falcata* trees belonging to the same plantation age class, which helped maintain consistency in growth characteristics. Each board was visually examined; only boards with comparable color, grain pattern, and no visible defects were included. The selected lumber size (2"×4"× 4') represents the most common commercial dimension in the local industry, as other lengths are typically produced on a made-to-order basis. Local standards in falcata log production are primarily 2' and 4', intended mainly for plywood manufacturing.

The initial moisture content (MC) of the samples was measured using a wood moisture meter (FPRDi-FA507) to confirm that the values exceeded 30%, thereby ensuring the wood was above the fiber saturation point (FSP). This step was necessary to validate that the samples were in a green condition suitable for drying evaluation.

2.2. Sample Preparation

From each lumber specimen, a 2" segment was cut from one end, and a ¼" trimming was discarded to remove surface irregularities and potential drying defects. The 2" sample segment was immediately weighed using a precision balance before being oven-dried (Memmert oven) at 103 ± 2 °C (ASTM standard) for 24 hours or until no further change in mass was observed.

For the drying test, the remaining lumber was progressively shortened by successively cutting 2" segments from alternating ends. This method was first adapted in this study to characterize drying behavior. The process continued until the measured MC of the lumber dropped below 15%. The cutting sequence is shown in Figure 1.

2.3 Oven-drying Method

The gravimetric method for determining the moisture content (MC) of a sample segment was calculated using Equation (1), as also used by Barański et al (2021), where MC is the moisture content (%), W1 is the initial weight (g), and W0 is the oven-dried weight of the wood sample (g). Sampled lumber was air-dried in the screened-sided workshop building of the Forest Products Innovation and Training Center at CarSU-CoFES, protecting the lumber piles from rain and excessive

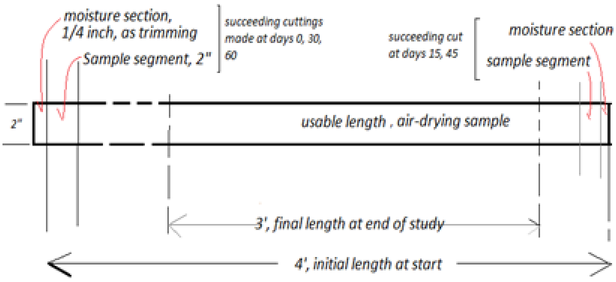

Figure 1. Scheme of preparation of the cut

sun exposure. The lumber was arranged with spacers and dry stickers on top of a dry table.

$$MC = \frac{W_1 - W_0}{W_0} \times 100\% \qquad (1)$$

2.4. Data Analysis

2.4.1. Air Drying Time

For each monthly batch, the average moisture content (MC) from the successive measurements was calculated and then plotted against the number of drying days to show how MC changed over time. To better understand this relationship, different trend lines were tested, including linear, exponential, and polynomial (second- to third-order), to determine which one best matched the drying pattern of the samples. The association between air-drying time (in days) and d, the average moisture content of subsequent measurements for each monthly set, was calculated and plotted. To determine fitness, the best-fit correlation was plotted, either linear or nonlinear (exponential or polynomial with two to three orders of magnitude). In a related study, Simpson (2004) estimated the air-drying time of lumber using multiple regression analysis. Following this approach, when the polynomial trend provided the closest fit for the falcata samples, the drying behavior could be expressed using the following Equation:

$$y = a^3 + bx^2 + cx + d$$

or, alternatively,

$$y = a^2 + bx + c$$

$$y = ax + b$$

and,

$$y = e^x$$

where, $y =$ MC(100%)

a,b,c,d = coefficients of the model

x = air-drying time, days

e = mathematical constant, approximately 2.718281

The regression coefficients of the equations were determined using the MS Excel Data Analysis tool pack add-in's regression tool. Using Equation 2, the air-drying time (days) for MC levels of 30%, 25%, 20%, and 15% for each piling month or stacking month was estimated.

2.4.2. Air-drying Estimate

An air-drying time estimate was established, showing corresponding curves of the relationship between stacking time in September, October, November, and December and drying time, which were plotted to provide a visual representation of the relationship. During the drying period from September to December, Butuan City generally experiences warm tropical conditions, with average temperatures ranging from 31°C to 33°C and monthly rainfall between 123 mm and 243 mm (Weather Atlas 2025). These values provide a general context for the drying environment, although the actual weather during the study was not recorded. The estimates were predicted based on the averages of each month. Three curves were plotted representing 15%, 20% and 25%.

3 Results and Discussion

3.1. Air drying time of falcata lumber

The air-drying test of falcata lumber, conducted from September to December 2024 (Figure 2), aimed to determine the drying duration required to achieve moisture contents of 15%, 20%, and 25%. The lumber stacked in September had an initial moisture content of about 32% and showed a rapid decline during the first 15 days, reaching an approximately 16% moisture content. The target of 25% was achieved within the first 7 days, while the 20% level was reached after about 12 days. By the 20th day, the lumber attained the 15% moisture content target, and stabilized between 16-17% up to 45 days of drying (Fig. 2a). Most decay fungi and blue stain fungi cannot develop in wood with a moisture content below 20% (Zabel and Morrell, 2020). Which is why keeping wood dry is critical for long-term durability. The air-drying of six lumber samples stacked in October began with moisture contents ranging from 35.80% to 61.73%, with an average of 50.34% (Fig. 2b). The results of the study show that the October air-drying process lasted only 30 days. However, the multiple regression analysis of the data estimated that falcata lumber would need about 52 days to reach the target moisture content of 15%. At this point, the moisture content was estimated to be between 12.03% and 14.28%, with an average of 12.92%. The projected drying curve, along with the equilibrium moisture content (EMC) values recorded on selected days (Figure 4). In contrast, the September trial reached the same target moisture content in just 20 days, indicating that falcata lumber dried much more slowly in October.

The falcata lumber stacked and air dried in November has an initial MC of 26-45% down to 14-15% within 30 days (Figure 3c). The drying curve shows a fast initial moisture loss in the first 15 days, followed by slower drying as the wood approaches EMC. December air-drying time of six lumber samples showed that the green lumber started with MC ranging from a low of 34.36% to a high of 41.75% (an average of 37.80%). The samples reached 19.57% to 21.70% MC, with an average of 20.81%, after 60 days of air-drying (Fig. 3b). Figure 4 shows the average air-drying time of sample lumbers in December, as well as the equilibrium moisture contents on particular days. Research on favorable moisture conditions for wood-deteriorating organisms reveals that most decay fungi require moisture contents above the fiber saturation point (typically 25-30%) for optimal growth. However, some species can operate at lower levels (Carll and Highley 1999).

Wood contains two forms of moisture: bound water within cell walls and free water in liquid form within cell voids. According to Thybring and Fredriksson (2023), this shift reflects the transition from the loss of free water in the over-hygroscopic range to the slower diffusion of bound water in the hygroscopic range. Species-specific differences are distinct, as Braz et al. (2015) found that Acacia mangium boards dried more slowly than Tectona grandis boards under identical environmental conditions, recommending separate analysis for each species. The broken lines represent the equilibrium moisture content (EMC), which is the point at which wood naturally balances with the surrounding air. The drying curves of falcata lumber approach this line over time, indicating that the wood is gradually adapting to the local climate. The moisture content of the wood, given enough time, reaches equilibrium with its surrounding environment (Mitchell 2018). Jenkins first used the word "equilibrium moisture content" in (1934). This slower drying rate may be related to seasonal weather conditions, as factors such as relative humidity, temperature, and rainfall are known to influence air-drying performance. However, specific weather data were not recorded during the trials. The drying rate is affected by external drying conditions (Walker et al. 1993, Keey et al. 2000). The drying behavior of wood is influenced by anatomical characteristics, such as fiber diameter, lumen diameter, and cell wall thickness, which affect the intensity of drying (Eloy et al. 2021). According to Richter and Dallwitz (2000), falcata wood is diffuse-porous. Diffuse-porous species exhibit high sensitivity to environmental conditions during drying, varying with atmospheric and soil moisture levels (Meinzer et al. 2013). The drying process is further complicated by interactions between temperature, relative humidity, air velocity, and wood species characteristics (Chong et al. 2019).

Research on air-drying lumber has consistently demonstrated the effectiveness of multiple regression models for predicting drying times. Simpson (2004) developed multiple regression equations to estimate air-drying times of red oak, sugar maple, and ponderosa pine lumber using historical weather records of temperature and relative humidity. Simpson and Wang (2004) extended this approach to small-diameter logs, creating both linear and nonlinear regression models that relate daily moisture content loss to initial moisture content, temperature, relative humidity, and log diameter. Cai and Oliveira (2012) developed similar models for dimensional spruce/pine lumber, incorporating temperature, relative humidity, initial moisture content, and wind speed, while finding wind direction to be insignificant.

The regression coefficients and corresponding coefficient determination for each stacking month or pile month are shown (Table 1). The R2 ranges from 0.9 to 1. Analysis that fits well or fitted such that September, October follow a polynomial

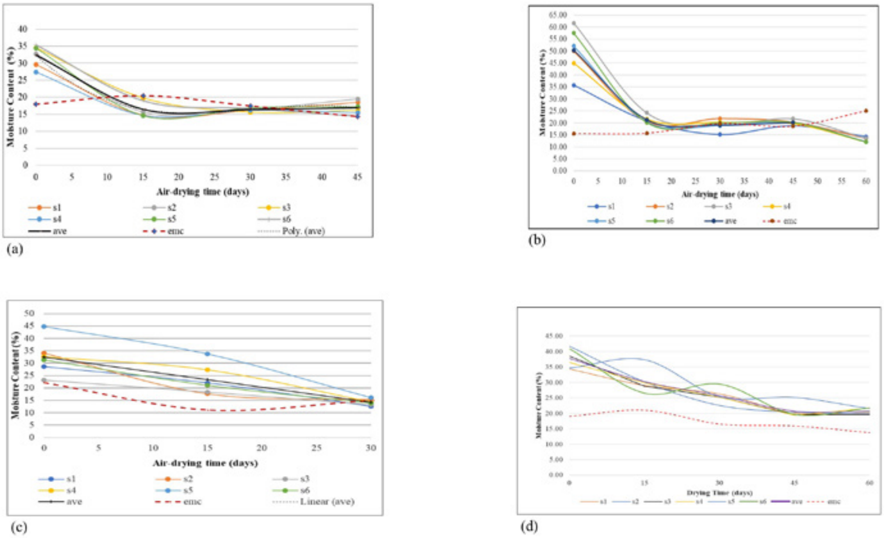

Figure 2. Drying curves of air-drying time of falcata lumber stacked in September 2024 (a). Drying curves of air-drying time of falcata lumber stacked in October 2024 (b). Drying curves of air-drying time of falcata lumber stacked in November 2024 (c). Drying curves of air-drying time of falcata lumber stacked in December 2024 (d). Legend: s1- sample 1; s2- sample 2; S3- sample 3; s4-sample 4; s5- sample; s6- sample

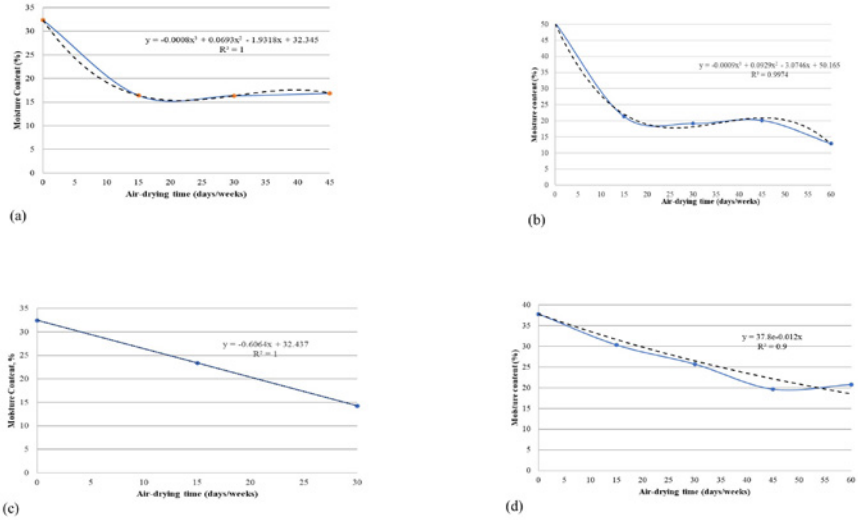

Figure 3. Average drying curves of air-drying time of falcata lumber stacked in September 2024 (a). Average Drying curves of air-drying time of falcata lumber stacked in October 2024 (b). Average Drying curves of air-drying time of falcata lumber stacked in November 2024 (c). Average Drying curves of air-drying time of falcata lumber stacked in December 2024 (d).

Table 1. Regression coefficients, and coefficient determinations for each stacking or pile-months and drying times of short-length falcata lumbers from September-December 2024.

Stacking/ Piling Month	a	b	c	d	R^2
September	-0.0008	0.0693	-1.9318	32.345	1
October	-0.0009	0.0929	-3.0746	50.165	0.9974
November*	-0.064	32.437			1
December**	37.8e				0.9

*Polynomial (3rd order); * Linear; ** Exponential*

(3rd order), November linear, and December, exponential. Simpson (2004) estimated air-drying times of lumber using multiple regression and demonstrated that the relationship between moisture content loss and initial moisture content during drying is nonlinear. Chanpet et al. (2020) described the average drying curves (time and moisture content) of rubberwood lumber at different velocities in Thailand, and the relationships are nonlinear. Bryś et al. (2021) determined model parameters of the drying characteristics of beech and willow sawdust as best described by linear, rational, and logarithmic equations.

3.2 Air drying Estimate

The estimated air-drying time of green 2"×4" ×4' commercial Falcata lumber varied considerably depending on the month of stacking. When stacked in September, lumber samples were predicted to reach a moisture content (MC) of 15% in approximately 20 days. However, this target was achieved in 52 days in October, 29 days in November, and as long as 77 days in December. At a target MC of 20%, the drying period was shortest in September, requiring only 9 days, compared to 18 days in October, 21 days in November, and 53 days in December. For the 25% MC level, the September stacking required only 5 days, while both October and November required 12 days, and December extended to 35 days (Figure 4). A similar trend was observed at 30% MC, where September stacking required just 2 days, in contrast to 9 days in October, 4 days in November, and 19 days in December. These estimates clearly demonstrate that the month of stacking has a strong influence on the air-drying rate of falcata lumber, with September providing the most favorable drying conditions and December the slowest.

3.6. Air-drying rate difference

Table 2 presents the drying rate of the sampled lumber, expressed as percent per day (%/day). The mean drying rate ranged from 0.28% in December to 0.62% in October. Analysis of variance under a Completely Randomized Design (ANOVA-CRD) revealed a statistically significant effect of stacking month on air-drying rate ($p = 0.0001857$) (Table 3). Post hoc comparisons using Tukey's Honestly Significant Difference (HSD) test (Tukey-Kramer) revealed significant differences among the pairs: September–October (x1–x2), September–November (x1–x3), October–December (x2–x4), and November–December (x3–x4). Conversely, no significant difference was observed between the pairs September–December (x1–x4) and October–November (x2–x3).

4 Conclusions

Results demonstrated that drying rates varied considerably across months, with September providing the most favorable conditions (20 days to reach 15% MC) and December the least favorable (77 days to reach 15% MC). Such variation shows the possible influence of seasonal climatic conditions on drying efficiency. Furthermore, the results show that the drying process is best explained by polynomial and exponential models, reflecting the nonlinear nature of moisture loss. The wood moisture is lost rapidly during the initial stage as free water evaporates, and then more slowly in later stages as bound water diffuses out from the wood structure. While these variables may influence drying performance, the present study did not collect data related to tree age or anatomical characteristics. Future studies incorporating these parameters would help strengthen the understanding of moisture-loss behavior and inform air-drying recommendations for falcata lumber.

Beyond these findings, the study shows several opportunities for strengthening future research. Factors such as tree age, the presence of heartwood and sapwood, and other inherent wood characteristics may also influence drying behavior and deserve further examination.

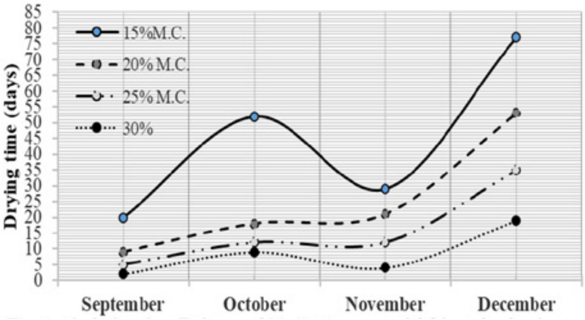

Figure 4. Air-drying time: Estimate of 2 "x 4" x4' commercial falcata lumber in green-rough condition.

Table 2. Drying rate, percent per day (%/day), of lumber based on Stacking Month.

	September	October	November	December
	0.25	0.36	0.53	0.23
	0.29	0.61	0.62	0.36
	0.41	0.80	0.33	0.32
	0.26	0.55	0.61	0.25
	0.38	0.67	0.96	0.22
	0.47	0.76	0.58	0.32
Mean	0.34	0.62	0.61	0.28

Table 3. ANOVA-CRD shows the significant difference in Air-drying rate.

Source	DF	Sum of Square	Mean Square	F Statistic	P-value
Groups (between groups)	3	0.003022	0.001007	10.8983	0.0001857*
Error (within groups)	20	0.001849	0.0000924		
Total	23	0.004871	0.0002118		

*Note: Figure in * indicates a significant difference.*

Table 4. Tukey HSD/Tukey Kramer shows the significant differences between months.

Pair	Difference	SE	Q	Lower Cl	Critical mean	P-value
x1-x2	0.02018	0.004	5.1408	0.004642	0.01554	0.008238*
x1-x3	0.01878	0.004	4.7852	0.003246	0.01554	0.0144*
x1-x4	0.005262	0.004	1.3405	-0.01028	0.01554	0.7797
x2-x3	0.001396	0.004	03556	-0.01414	0.01554	0.9942
x2-x4	0.02544	0.004	6.4813	0.009903	0.01554	0.00096*
x2-x4	0.02404	0.004	6.1257	0.008507	0.01554	0.0017*

*Note: Figure in *, indicates a significant difference.*

Exploring methodological improvements, such as using electric fans to accelerate air-drying and monitoring potential drying defects throughout the process, could provide deeper insights and enhance the practical application of air-drying techniques. Overall, the results of this study provide localized empirical evidence that can help refine drying time estimates and support improved lumber handling practices in the Caraga Region.

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6 Author Contribution

RN Cossid contributed to the supervision of the study, development of the methodology, data curation, and preparation of the original draft. CS Casilac Jr. was responsible for data curation and manuscript editing for publication. RL Palaso contributed to data curation and writing of the original draft. EP Cuenca, MF Almacen, and JC Illustrisimo contributed to the conceptualization of the study, data gathering, and writing of the original draft.

7 Statement of Conflict of Interest

The authors declare no conflict of interest associated with the conduct and publication of this manuscript.

8 Literature Cited

ASTM International. (2020). Standard test methods for direct moisture content measurement of wood andwood-based materials (ASTM D4442-20).ASTM International. https://www.astm.org/d4442-20.html

Barański, J., Suchta, A., Barańska, S., Klement, I.,Vilkovská, T., & Vilkovský, P. (2021). Wood moisture-content measurement accuracy of impregnated and nonimpregnated wood. *Sensors*, **21**(21), 7033.

Bergman, R. (2021). Drying and control of moisture content and dimensional changes. In FPL-GTR-282 (pp. 13-1).

Braz, R. L., Duarte, A. P. C., Oliveira, J. T. D. S., Motta, J. P., & Rosado, A. M. (2015). Characteristic air-drying curve for *Tectona grandis* and *Acacia mangium* lumber. *Floresta e Ambiente*,**22**(1), 117–123. https://doi.org/10.1590/2179-8087.037913

Bryś, A., Kaleta, A., Górnicki, K., Głowacki, S., Tulej, W., Bryś, J., & Wichowski, P. (2021). Some aspects of the modelling of thin-layer drying of sawdust. *Energies*, **14**(3), 726.

Cai, L., & Oliveira, L. C. (2012). An estimation of air drying time of dimensional lumber. *Drying Technology*, **30**(8), 827–831.

Carll, C. G., & Highley, T. L. (1999). Decay of wood and wood-based products above ground in buildings. *Journal of Testing and Evaluation*, **27**(2), 150–158.

Chanpet, M., Rakmak, N., Matan, N., & Siripatana, C. (2020). Effect of air velocity, temperature, and relative humidity on drying kinetics of rubberwood. *Heliyon*, **6**(10).

Chong, C. H., Law, C. L., Figiel, A., & Asni, T. (2019). Diffusivity in drying of porous media. In Heat and mass transfer in drying of porous media (pp. 37-54). CRC Press.

DOST-FPRDI. (2020, September 2). Initial study shows young falcata can be harvested. Forest Products Research and Development Institute. https://fprdi.dost.gov.ph/411-dost-fprdi-initial-study-shows-young-falcata-can-be-harvested

Eloy, E., Trevisan, R., Piecha, T. D. S., Fontoura, M. R.,Costa, H. W. D., & Caron, B. O. (2021). Anatomy and drying of wood of four species from an agroforestry system. *Floresta*, **51**(4), 910-917.

Elustondo, D., Matan, N., Langrish, T., & Pang, S. (2023). Advances in wood drying research and development. Drying Technology, 41(6), 890-914.

Hassan, A., & Rahman, N. F. A. (2019). Tree planting techniques of batai (*Paraserianthes falcataria*) and its soil nutrients. In Prospects and utilization of tropical plantation trees (pp. 101–126).CRC Press.

Hughes, R. F., Anderson, A., Clements, D. R., Norton, J., & Ostertag, R. (2024). Biology and impacts of Pacific Islands invasive species: *Falcataria falcata* (Miquel) Barneby and Grimes (Fabaceae). *Pacific Science*, **78**(1), 61–84.

Jenkins, J. H. (1934). Kiln-drying British Columbia lumber. Forest Products Laboratories of Canada, Ottawa, Ontario.

Jimenez, J. J. P., Escobin, R., & Conda, J. M. (2015). Profile of wood species used in local and imported plywood and their bond performance. *Philippine Forest Products Journal*, **6**, 43–58.

Jimenez Jr, J. P., Gilbero, D. M., & Alipon, M. A. (2022). Evaluation of young falcata plus-trees for veneer and plywood production in the Philippines. *Philippine Journal of Science*, **151**.

Keey, R. B., Langrish, T. A. G., & Walker, J. C. F. (2000). Kiln-drying of lumber. Springer.

Krisnawati, H., Yaris, E., Kalio, E., & Kaznninen, M. (2011). *Paraserianthes falcataria* (L.) Nielsen: Ecology, silviculture and productivity. Center for International Forestry Research (CIFOR).

Listyanto, T. (2018). Wood quality of *Paraserianthes falcataria* L. Nielsen syn. wood from three-year rotation of harvesting for construction application. *Wood Research*, **63**(3), 497–504.

Meinzer, F. C., Woodruff, D. R., Eissenstat, D. M., Lin, H. S., Adams, T. S., & McCulloh, K. A. (2013). Above-and belowground controls on water use by trees of different wood types in an eastern US deciduous forest. *Tree physiology*, **33** (4), 345-356.

Mitchell, P. H. (2018). Calculating the equilibrium moisture content for wood based on humidity measurements. *BioResources*, **13**(1), 171–175. https://doi.org/10.15376/biores.13.1.171-175

Richter, H.G & Dallwitz, M.J. (2000). 'Commercial timbers: descriptions, illustrations, identification, and information retrieval.' In English, French, German, and Spanish. Version: 4th May 2000. http://biodiversity.uno.edu/delta/.

Simpson, W. T. (2004). Estimating air drying times of lumber with multiple regression (No. 293). USDA Forest Service, Forest Products Laboratory.

Simpson, W. T. (2010). Drying and control of moisture content and dimensional changes. In Wood handbook: Wood as an engineering material (General technical report FPL-GTR-113, pp. 12.1–12.20). USDA Forest Service, Forest Products Laboratory.

Simpson, W. T., & Hart, C. A. (2001). Method for estimating air-drying times of lumber. *Forest Products Journal*, **51**(11/12), 56–63.

Simpson, W. T., & Wang, X. (2004). Estimating air-drying times of small-diameter ponderosa pine and Douglas-fir logs. *Forest Products Journal*, **54**(12), 24–28.

Thybring, E. E., & Fredriksson, M. (2023). Wood and moisture. In P. Niemz, A. Teischinger, & D. Sandberg (Eds.), Springer handbook of wood science and technology. Springer. https://doi.org/10.1007/978-3-030-81315-4_7

Walker, J. C. F., Butterfield, B. G., Langrish, T. A. G., Harris, J. M., & Uprichard, J. M. (1993). Primary wood processing. Chapman and Hall.

Weather Atlas. (2025). Butuan City, Philippines – climate & weather averages. Retrieved December 8, 2025, from https://www.weather-atlas.com/en/philippines/butuan-city-climate

Zabel, R. A., & Morrell, J. J. (2020). Factors affecting the growth and survival of fungi in wood. In R. A. Zabel & J. J. Morrell (Eds.), Wood microbiology (2nd ed., pp. 99–128). Academic Press. https://doi.org/10.1016/B978-0-12-819465-2.00004-8