

Specificities of Tropical Wood Drying Prior to Processing Stages: How to Choose a Dryer in the City of Mbalmayo, Cameroon

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How to cite this paper: Rene, A. F., Aimé, A. S., & Rufis, T. T. (2026). Specificities of Tropical Wood Drying Prior to Processing Stages: How to Choose a Dryer in the City of Mbalmayo, Cameroon. *Open Journal of Forestry*, 16, 255-275.

<https://doi.org/10.4236/ojf.2026.163016>

Received: January 22, 2026

Accepted: July 4, 2026

Published: July 7, 2026

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Abstract

Due to the technological lag affecting African countries in general, and those of Central Africa in particular, significant challenges arise in the drying of timber from the first to the third stages of transformation. This difficulty is especially evident in the city of Mbalmayo, where numerous processing structures are located. Consequently, the selection of an appropriate kiln becomes crucial in order to save time by using one of the seven available timber drying tables in the city of Mbalmayo. Drying represents an essential stage in wood processing, conferring upon it the characteristics required for rational and efficient use: dimensional stability, improved mechanical properties, protection against certain biological agents, suitability for gluing, and the capacity to receive finishing treatments. In response to the absence of such a critical stage in Mbalmayo (Cameroon in particular and the Congo Basin more broadly), this article examines the following shortcomings, which must be understood in the drying process employed during the manufacture of artistic objects in Mbalmayo: a) The wood's moisture content, b) existing processes and equipment, c) operational guidance and selection criteria, and d) the influence of the average lifespan of the dried species. The analysis aims to demonstrate that drying is a key operation in the transformation of timber.

Keywords

Wood, Moisture Content, Drying Gradient, Mbalmayo-Cameroon

1. Introduction

The paper investigates how inadequate control of timber moisture content affects product quality and service life in Mbalmayo's wood-processing sector. Using

field surveys of 43 enterprises, basic moisture measurements, hedonic price decomposition and the Herfindahl-Hirschman Index, the author link drying practices to market concentration and pricing. They argue that selecting an appropriate kiln and monitoring drying gradients below 5.5% are critical for extending product lifespan and sustaining local industry competitiveness. The management of timber resources is a major concern for all processing industries involved in the wood sector. Artistic wood products, in particular, require well-defined specific characteristics. Thus, the planning and organization of logging and processing activities by institutions responsible for artistic wood has become indispensable (Hoebeek, 2020). An inventory of ligneous resources is a crucial step toward such planning, as it makes it possible to estimate the stock of available timber and, beyond that, to ensure compliance with specific procedures for the optimal utilization of wood in its potential applications. Assessing the volume of this potential requires the use of several tools, such as the determination of moisture content, the study of moisture sorption hysteresis, the orthotropic properties of wood, the handling and transport of timber, the storage and conservation of forest products, wood processing technologies, creep-recovery behavior, and the mechano-sorption properties of wood. The present study seeks to broadly define the dominant parameters within the variability of probable characteristics of moisture content, as applied in the manufacture of artistic objects in the city of Mbalmayo — a major hub for wood processing and research. The city is located in the Congo Basin, a region subject to intensive forestry activity in Central Africa.

2. Context

The Law No. 94/01 of 20 January 1994 on the forestry, Wildlife, and Fisheries Regime in Cameroon stipulates in Article 23 (Law No.94/01, Cameroon 1994) that the management of a permanent forest is defined as its implementation on the basis of predetermined objectives and a plan, involving a series of activities and investments aimed at the sustainable protection of forest products and services. This must be done without undermining the intrinsic value of the forest, without compromising its future productivity, and without causing undesirable effects on the physical and social environment (Bayol et al., 2012).

Accordingly, the reference framework of best practices established by the Cameroonian Forestry Code constitutes the guiding document that sets forth general principles for enterprises and other manufacturers of wooden objects wishing to engage in such activities, providing them with a common foundation. This framework outlines a series of indicators that enable comparisons among wood-based products belonging to the same category, which are examined in this article.

The guide also aims to explain and disseminate certain concepts and requirements of the reference framework relating to selected wood products, thereby allowing all stakeholders to understand the rationale behind the choices made and to contribute to the elaboration of a future framework for wood-based products in Cameroon.

In this regard, a broader reflection on the wood sector in Cameroon is undertaken. It should be noted that this pilot project will be carried out by the University Institute of Wood Technology in Mbalmayo (IUT-Bois), University of Yaoundé I, with the objective of furthering studies on wooden constructions and other related applications.

This analysis thus represents an exploratory approach intended to ensure that indicators are calculated in a consistent manner. The moisture content of processed timber, a central element of this study, should therefore assist in estimating the lifespan of wooden objects according to their uses and living environments. Consequently, as part of this analytical framework, we will specify the calculation methods and the Life Cycle Assessment (LCA) of wood based on its reference moisture content during the manufacture of associated objects, as well as the influence of the surrounding environment on the finished product (ADEME, 2018). Our evaluation will make it possible to identify the full range of potential impacts of wood-based products on the environment, including those related to their potential treatment. Such evaluations are internationally regulated by ISO 14040 and ISO 14044 standards, which nonetheless allow for certain methodological choices to remain open.

3. Materials and Methodology

3.1. Objectives of the Study

The overall objective of this analysis is to address certain shortcomings identified in terms of knowledge and challenges related to timber processing in Cameroon in general and in the processing structures of Mbalmayo in particular.

The specific objectives of our analysis are as follows:

- To help artisans and professionals in furniture-making and other wood-based artistic objects understand the decisive role of timber moisture content in the production of various articles, since this parameter is generally overlooked.
- To estimate the minimum and potentially maximum standard lifespan of selected wooden products, based on their initial moisture content and the density of the species.

In the Cameroonian carpentry sector, it has been demonstrated that timber, under local temperature and relative humidity conditions, does not immediately reach hygroscopic equilibrium. While the wood surface may be considered in equilibrium, the core requires a certain period to stabilize. The ratio between the moisture content at the core and at the surface, directly influences the lifespan of the finished wooden product. This value, which is common to all categories, is independent of specific design criteria of wood products linked to their reference moisture content. Lifespan will therefore be assessed in terms of minimum or maximum values (extremes).

To conduct this analysis, we focused on a sample of artisans in Mbalmayo, a city known for its high level of timber production and processing.

The **scientific scope** of our study lies in the classification and determination of

timber moisture content in relation to its future use and environment of application. The **economic scope** of the article is to evaluate the pricing of wood-based products according to their estimated lifespan and use. The foundation of this work stems from the observation that numerous solid-wood products easily deform and have reduced lifespans, as they tend to crack, absorb moisture, and swell. Ideally, the wood used should be stored long enough under shelter until its moisture content matches that of the environment in which the final product will be placed—a principle simple in theory but difficult to implement in practice.

3.2. Choice of Study Area and Data Collection



Source: MINAT-Cameroon.

Figure 1. Map showing the location of Mbalmayo/Akonolinga-Centre/Cameroon.

A survey conducted by students of the University Institute of Wood Technology (IUT-Bois) in Mbalmayo during the first five months of 2017, involving 43 enterprises and small-scale manufacturers, identified moisture content as a central issue in the timber sector of Mbalmayo (see **Figure 1**). Among the main factors explaining the potential deterioration of wooden objects, the following elements were selected:

- the intrinsic quality of the timber,
- the conditioning of the wood to allow for objective technical assessments, and
- the commercial advantage provided by regular and reliable supply flows.

3.3. Methods

To assess the artistic timber used in this study, several parameters were taken into account:

- The natural durability of wood according to the type of artistic piece to be produced. Wood exhibits a natural resistance to attacks by fungi and insects. If a species that is not naturally durable is used in a humid environment or in direct contact with air, soil, or water, it requires prior artificial preservation treatment, usually based on chemical products, in order to extend its service life. Some species demonstrate stronger resistance to fungal and/or insect attacks, as well as to natural physical conditions such as rain, heat, and solar radiation. Based on natural durability, five classes are identified according to the type of product and its service class, i.e., the environment in which the processed piece will be stored and used (**Table 1**).

Table 1. Classification of natural durability.

Class	Moisture Content and Characteristics	Uses
Class 1	Dry wood; moisture content always below 20%	Interior joinery or areas sheltered from moisture
Class 2	Dry wood occasionally exposed to moisture; moisture content above 20%	Frameworks and roof structures
Class 3	Wood frequently exposed to moisture; moisture content above 20%	Outdoor constructions such as cladding
Class 4	Dry, stable, rot-proof wood permanently in contact with fresh water	Exotic constructions
Class 5	Dry and highly durable wood permanently in contact with salt water	Exotic constructions

Source: norme NF EN 335, 2013.

In general, wood behaves much like a sponge, changing its volume and density depending on the water it contains. It deforms and shrinks differently according to the species. Once felled wood loses water naturally and irregularly in the following way:

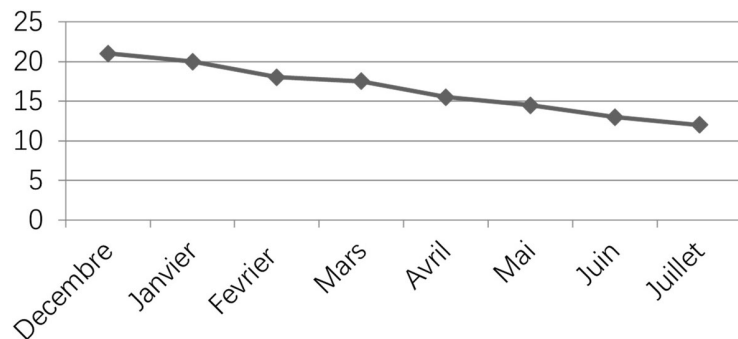
- **From 100% to 30% moisture content:** The wood loses weight but does not deform (cells empty of their free water).
- **From 30% to 0% moisture content:** The wood continues to lose weight but also shrinks progressively this is known as shrinkage (bound water leaves the cell walls), leading to deformations that vary according to the fiber orientation.

Shrinkage occurs only when the impregnation water is released, that is, when moisture content falls below 28%. It is calculated using the following formula:

$$\Delta L = L \times T \times \Delta H\%$$

where; L = the measurement of the wood piece, T = shrinkage coefficient, $\Delta H\%$ = variation in moisture between the beginning and end of drying.

Being a hygroscopic material, wood can adsorb or desorb water depending on the relative humidity of the surrounding air. The **equilibrium moisture content** refers to the level of moisture toward which a wood sample tends when placed under specific conditions of temperature and relative humidity (RH). **Figure 2** illustrates the variation in the moisture content of a six-meter beam under natural drying conditions over time.



Source: Author, 2025.

Figure 2. Illustrates the variation in the moisture content over time. (natural drying)

Since wooden products exhibit distinct objective characteristics, the **hedonic pricing method** can be applied here. This method decomposes the price y of a differentiated product into a set of implicit prices associated with its characteristics x :

The indices I and k correspond respectively to the type of wood I ($I = 1, \dots, L$) and to the characteristic k ($k = 1, \dots, K$). Here, k represents the implicit price of characteristic k , and I is an unobservable factor.

As for the **Herfindahl-Hirschman Index (HHI)** measuring timber market concentration: this index reflects the extent to which a small number of timber enterprises account for a large share of production. It is commonly used as a potential indicator of market power or the intensity of competition among firms. The HHI is computed by summing the squares of the market shares of all firms in the sector:

$$HHI = \sum S_i^2 \quad (i = 1, 2, 3, \dots, n)$$

where S_i shows the market share of firm i , and n the total number of firms. For instance, in a market with two firms, each holding 50% of the market, the HHI equals $0.50^2 + 0.50^2 = 0.25 + 0.25 = 0.50$. The HHI ranges from $1/n$ to 1.

Similarly, the HHI can reach up to 10,000 when percentages are expressed as whole numbers (e.g., 50 instead of 0.50). In that case, the maximum value is $100^2 = 10,000$.

If the HHI approaches $1/n$, the market tends to be competitive; conversely, if it approaches 1, the market tends toward monopoly (Tirole, 2002).

For example, when there are five wood companies in a market, each holding a market share of 20%, the HHI is then equal to: $400 + 400 + 400 + 400 + 400 =$

2,000. The higher the HHI of a given market, the more production is concentrated among a small number of companies. Generally speaking, when the HHI is below 1,000, market concentration is considered low; when it is between 1,000 and 1,800, it is considered medium; and when it is above 1,800, it is considered high.

The **drying gradient (G)** is defined as the ratio between the wood's moisture content and its equilibrium moisture content. It is also referred to as the **drying rate**. Ideally, it should remain below 5.5%. However, practical experience determines which drying gradient a given species can withstand. In drying operations, it represents the ratio between the regulatory moisture and the equilibrium moisture. Since there are seven standard drying tables available for African timbers, at least seven drying gradient tables for African wood species should be established in a comparable manner.

The **moisture gradient (G)**, as noted above, arises because wood under given conditions of air temperature and relative humidity does not instantly reach hygroscopic equilibrium. The wood surface is considered to be at equilibrium, while the core requires a longer period to stabilize. The ratio between the core moisture content and the surface moisture content is termed the moisture gradient.

The moisture gradient also provides insight into the internal stresses present in a piece of wood. These stresses are responsible for cracks and other drying defects. The stronger the gradient, the higher the internal stress within the wood, accelerating its deterioration, and vice versa.

$$G = \frac{H\%_{core}}{H\%_{surface}}$$

Today, **mechanical modeling of wood behavior during drying** makes it possible to predict the evolution of stress states within planks. The ultimate goal is to determine optimal drying conditions to improve the quality of dried wood or shorten the drying period without compromising quality. Wood behavior during drying combines several properties—**elasticity, plasticity, viscoelasticity, and mechano-sorption**—all of which are influenced by temperature and moisture content. In what follows, we focus on modeling the **mechano-sorptive behavior** of wood, a phenomenon widely discussed in the literature. Before turning to modeling, it is useful to recall the distinction between these behaviors using a creep-recovery test, which characterizes the viscoelasticity of wood. Under constant stress applied over time to a wood sample, an immediate elastic deformation occurs, followed by a progressive delayed deformation. This delayed deformation plays a decisive role in the relaxation of stresses associated with wood shrinkage. Drying is carried out using **drying tables**, which indicate, for each species and thickness, the air conditions required depending on the wood's moisture content. These tables, derived from empirical knowledge, make it possible to achieve the shortest drying time while preserving the quality of the dried wood according to **Table 2** (Aléon, 2012). Example of a drying **Table 2**: at the end of drying, the core moisture content is higher than that of the surface. This final stage therefore aims to balance the moisture content across the thickness of the wood. Such balancing

also reduces internal stresses. Professionals in the furniture industry defined our Methodological choice for service life calculation for each category of furniture, standard service life.

Table 2. General wood moisture content in the processing industry.

Moisture Content (%)	Wood Condition
>30	Green wood
<30	Pre-dried wood
<20	Wood protected against fungal attack
<18	Dried wood

Source: Aléon, 2012.

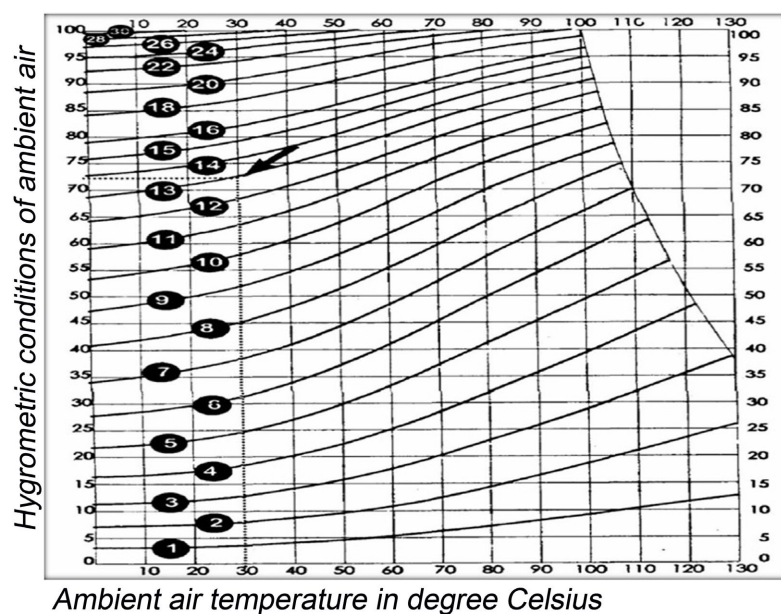


Figure 3. Equilibrium hygroscopic curves of woods.

The service life depends on the design criteria of the furniture. A service life different from the standard values may be claimed based on performance test results (Salem, 2016). For example, for tables, a minimum standard service life common to all categories has been set at 10 years (Aléon, 2012). Other standard service lives have been defined depending on construction methods: 15 years for mechanically assembled structures; 20 years for glued and/or welded structures (Benoit, 2008). Thus, the drying process can be either **natural** (through storage under ventilated shelter) or **artificial** (in a dryer). It is regularly monitored to achieve an optimal moisture content depending on the species and intended use, whether indoor or outdoor, using equilibrium hygroscopic curves as in Figure 3.

3.4. Data Processing

The dataset was divided from 08 **species** according to Table 3 into two categories

below:

- Secondary data extracted from documentation, exported to Excel, and then transferred into the statistical analysis software. These data were used to determine the quantities and main species exploited in the study area during the survey period.
- Primary data entered in Excel and subsequently transferred to the software. Ultimately, statistical analyses focused on eight principal species.

Table 3. The timber species considered in our study in Mbalmayo.

Species	Scientific Name	Characteristics	Density at 12% Moisture Content	Uses
Mahogany	<i>Khaya ivorensis</i>	Variable color from reddish-brown to light red	570	Cabinetmaking, marquetry, instrument making
Bubinga	<i>Guibourtia tessmannii</i>	Dark wood, occasionally with violet-red streaks	920	Timber for furniture making
Black Ebony	<i>Diospyros crassiflora</i>	Deep black, fine grain, very hard	900	Cabinetmaking, sculpture, instrument making, marquetry
Iroko	<i>Milicia excelsa/Chlorophora excelsa</i>	Yellowish-brown to dark brown with golden reflections	640	Exotic wood, cabinetmaking
Padauk	<i>Pterocarpus soyauxii</i>	Reddish-orange with darker veins; turns dark brown when exposed to light; highly durable	750	Exterior joinery, cladding, furniture
Sapele	<i>Entandrophragma cylindricum</i>	Similar to mahogany in color, finer texture, stable	-	Exterior joinery, plywood, cabinetmaking
Wenge	<i>Millettia laurenta</i>	Two-toned veining, coarse grain	870	Flooring, cabinetmaking, turning, cutlery
Zebrano	<i>Microberlinia</i>	Light yellowish-brown with numerous fine dark veins; zebra-skin appearance	700	Solid parquet flooring, decorative zebra-skin

Source: Author, 2026

From the 43 firms selected in wood transformation industries Tech Wood Industry Database at Mbalmayo and around area Yaounde, We used **purposive sampling** to select 43 firms based on specific criteria: 10 large according to **Table 4**: Sample Numerical Representation of Tropical Drying wood Model and **Table 5**: Sample of Tropical wood corresponding (SEVI SUARL, ECAM PLACAGES SA, JUSTAWE BOIS, BHYGRAPH ENGINEERING, CITY CENTER CONSTRUCTION...), 23 MEDIUM-SIZED FIRMS (NEW GENERATION WOOD SARL, ATELIER DES ARCHITECTES, PROMO CONSTRUCTION, COOP-CA EXTRA BOIS CAM)..., and 10 small (CRELICAM, ETS TALLAK ET FILS BOIS,

CAMEROUN BOIS INDUSTRIE)...all founded after 2000 or reviewed.

Table 4. Sample numerical representation of tropical drying wood model.

Core Moisture Content (%)	Moisture level deep (Humidity)	Wood Hygrometric Stability (%)
40	38.5	80
30	39	75
25	40.5	70
20	46	60
15	47.5	50

Source: William T. et al. (1991), relative drying times of 650 tropical woods estimation by green moisture content, 1991.

Table 5. Sample of tropical wood corresponding.

African Name	International appellation
Azobe	Lophira Alata
Gaiac	Gaiacum Officinale
Zingane	Microberlinia brazzavillensis

Source: William T. et al., 1991. Summary of Drying Tropical woods, Ch. Sales.

- Core Moisture Content (MC_{core}): Moisture level deep within the material (e.g., center of a wood plank, concrete slab).
- Surface Moisture Content (MC_{surface}): Moisture level at the material's exterior.
- Moisture Gradient (MG): The rate of moisture change with distance, calculated as:

$MG = \frac{MC_{core} - MC_{surface}}{Depth_{core} - surface}$ equals the fraction with numerator $MC_{core} - MC_{surface}$ and denominator $Depth_{core} - surface$

$$MG = \frac{MC_{core} - MC_{surface}}{Depth_{core} - surface}$$

Example: In wood, a 10% MC difference between the surface and core (at 2 cm depth) yields an MG of 5%/cm, indicating significant stress potential.

Measure/Simulate: Obtain MC values at different depths (surface, intermediate, core) at specific times (t) during drying.

Correlate with Quality:

- High MG (e.g., >5%/cm in wood): Often leads to tensile stresses exceeding material strength, causing surface checking or cracking.
- Low MG (e.g., 0.5%/cm): Suggests slower, more uniform drying, reducing defects.

Support with Models: Use numerical simulations (Finite Element, Finite Differ-

ence) to solve coupled heat/mass transfer equations, predicting moisture profiles and validating against measurements (like X-ray CT) for process optimization.

Example Application (Wood Drying)

- Initial State (Green Wood): $MC_{core} = 80\%$, $MC_{surface} = 80\%$, $MG = 0\%/cm$.
- During Aggressive Drying: $MC_{core} = 22\%$, $MC_{surface} = 10\%$ (at 2 cm depth).
- Calculation:

$MG = 22\% - 10\% \text{ 2 cm} = 5.5\%/cm$ cap M cap G equals the fraction with numerator 22 % minus 10 % and denominator 2 c m end-fraction equals 10%/cm

$$MG = 22\% - 10\% \text{ 2 cm} = 5.5\%/cm$$

Wood scientists emphasize that tropical timbers differ greatly; high-density species might dry differently than low-density ones, affecting properties and moisture-related issues like shrinkage (which starts below the ~30% Fiber Saturation Point).

4. Results

a) Findings from the survey conducted by IUT-Bois students in Mbalmayo.

The survey results indicate that, in most cases, commercial and financial considerations largely determine drying practices. Business owners often choose artificial drying for large-scale projects in order to quickly meet client demands and to increase stock turnover rates. For smaller products, however, most operators skip any form of drying altogether, proceeding with processing without prior assessment of moisture content. This practice has a direct impact on the lifespan of the finished products. The same survey, conducted among artisans in the wood processing sector, revealed that generally, out of 100 artisans, more than 95% disregard the initial moisture content of the timber. This is particularly true in the Centre, South, and East regions of Cameroon. Consequently, they fail to account for both the expected lifespan of the finished product and the environmental conditions in which it will be used. These two parameters directly influence the durability of the items produced, leading to lower longevity than what is normally expected for their designated service class.

Furthermore, the estimation of the value of standing timber and its subsequent transformation emerges as an important area requiring further research, both for national forestry services and for timber processors. This would enable them to establish appropriate pricing and ensure fair market value for timber and its derived products. At present, there is a clear disconnect between timber production, which spans long cycles, and timber supply to the market, which depends on harvesting and transformation decisions. Without precise reference to production costs, sellers must rely on other factors, such as market demand, last year's prices, or current trading conditions by species and product category, to determine the reservation value of their goods.

b) Analysis of timber sales data: Using detailed database of timber and wood

product sales, our study highlights the importance of heterogeneity in influencing both the probability of sale and the price of timber. We demonstrate that grouping timber by species is necessary to more accurately estimate the implicit prices of product characteristics. In fact, the hedonic price equation varies depending on whether products are homogeneous or mixed. Our in-depth analysis of timber species underscores the crucial role of interspecies heterogeneity in sales outcomes: several characteristics significantly influence both sale probability and pricing. This provides valuable insights into how to optimally compose product assortments. Three key results are noteworthy:

1) The **mode of sale** (auction vs. negotiated sale) does not alter the implicit price of characteristics. However, negotiated sales generally result in lower prices compared to auctioned lots. This suggests that prohibiting post-auction negotiated sales of unsold lots could increase bidder competitiveness and restore sellers' negotiating power.

2) Despite the **random order of presentation** of timber lots at sales, prices tend to increase as the auction progresses. This finding aligns with auction theory but contrasts with the frequently observed downward trend in sequential auctions.

3) **Heterogeneous timber lots** sell at lower prices, a result consistent with findings by Boltz, Carter and Jacobson (2002). As in their study, our results can be used to estimate the opportunity cost of biodiversity in wood products. Indeed, policies promoting biodiversity by encouraging mixed forests may negatively impact the value of timber, as mixed lots reduce market value by introducing heterogeneity.

c) Market concentration (Herfindahl-Hirschman Index). In the case of Mbal-mayo, our surveys reveal that the **Herfindahl-Hirschman Index (HHI)** is high, indicating that wood product manufacturing is concentrated among a small number of enterprises. Consequently, the financial evaluation of products depends directly on estimated quantities and qualities, rather than on published price lists, which are typically based on broader market evolutions.

Sellers therefore tend to rely on their own cost estimates as the basis for setting acceptable final prices, without necessarily factoring in the lifespan of the product—a parameter that itself depends on the initial moisture content of the processed wood. For this reason, establishing a **scaling tariff system** (based on volume calculations using geometric assumptions, wood species, expected lifespan, and initial moisture content) would be essential.

Such tariffs would only be valid for specific species within defined geographical zones, determined through sampling. Furthermore, due to the **hysteresis phenomenon** in wood moisture sorption, differences in desorption and adsorption rates complicate drying behavior and ultimately affect product durability see **Table 6: Survey Results on Timber Drying Practices in Mbal-mayo**.

The surveys carried out by UIT-Wood students across nearly one hundred enterprises yielded the following results:

Table 6. Survey results on timber drying practices in Mbalmayo.

Number of Companies Surveyed	Average Large Articles Sold per Month (Lot 1)	Average Small Articles Sold per Month (Lot 2)	Quantity of Lot 1 Sold	Quantity of Lot 2 Sold	Drying Method Used
22	45	123	40	118	Vertical drying
13	23	76	17	66	With “tasso” (traditional method)
07	03	48	02	45	Without “tasso”
28	56	233	48	223	Natural drying
25	125	330	110	315	No preference
05	750	3,500	722	3,425	Artificial drying (hot air)
Total = 100	1,002	4,310	932	4,280	-----

Source: Author, 2026.

5. Discussion

Based on the above table and adopting an empirical approach, we can extract relevant information that explains the pricing of Lots 1 and 2 by integrating **heterogeneity** as the principal parameter. Furthermore, the consideration of **unsold products** represents a fundamental and original element for our forthcoming econometric work. We propose to study the impact of inter- and intra-lot heterogeneity of timber and processed wood products not only on selling prices but also on the probability of whether a given lot or wood-based article will be sold.

In the Congo Basin, for instance, the central issue regarding timber sales has generally revolved around price comparisons and auction systems (ITTO, 2013). However, this subject remains less relevant in Central Africa, where most sales occur through direct negotiations rather than formal auctions. Our analysis is therefore more closely aligned with studies such as those of Prescott and Puttock (Prescott & Puttock 1990), who proposed a price function to forecast timber lot prices in Ontario, Canada. Their model is simpler than our procedure since their data did not account for unsold timber. From a scientific standpoint, the results regarding wood moisture content show that in wooden house constructions and timber-frame buildings, the moisture level must be below 18%. In roofing timbers, it should not exceed 22%. In traditional frameworks and trusses, acceptable moisture ranges from 15% to 22%, while for exterior joinery; it should be between 15% and 18%. In glued laminated timber, moisture should be $\leq 13\%$, in visible interior frameworks between 10% and 13%, and for interior joinery and parquet flooring between 8% and 12%. The National Forestry Development Agency (ANAFOR), which oversees standards in Cameroon, should establish technical specifications regarding wood materials. Despite such measures, if wooden materials are ex-

posed to water during construction, they must be dried to a hygrometry level of 18% or lower before integration into assemblies. Indoor timber generally ranges between 8% and 12% moisture, while outdoor or structural timber ranges between 13% and 22% moisture content.

If timber is installed either too dry or too humid, it will swell or shrink until reaching its equilibrium moisture content. Large-section timbers may also warp when not installed at the proper equilibrium level. This underlines the importance of controlling moisture content, since even dry wood can reabsorb humidity. Water penetrates surfaces parallel to the grain very slowly, but it enters much more easily through the ends. Hence, it is preferable to protect the extremities of wood pieces. Submerged timber absorbs water regardless of the surface exposed, posing a particular threat to product longevity. To address these problems, protective measures must be adopted: drying shelters to keep timber safe during construction, ventilated workshops to encourage drying, and structural designs that limit direct exposure to rainfall and environmental humidity.

Comparative research conducted in Saint-Laurent, Canada on the potential use of timber in construction systems, emphasized the need to maintain moisture content within specific ranges. According to their final report, to achieve target final moisture content with minimal variation, the average diameter shrinkage due to drying should not exceed 1.6%, regardless of the method employed. This is remarkably low compared to the 6% - 8% shrinkage typically observed in sawn timber.

A study case from 2024 (Thapa et al., 2024): Wood and Fiber Science article shows tropical hardwoods' resistance depends heavily on kiln conditions, indicating species-specific drying curves.

Another case Study (González-Melo et al., 2025): Research from Agitprop connects wood specific gravity (WSG) to nutrient content, demonstrating intrinsic differences between species that influence how they interact with moisture.

The concept of moisture content influencing wood properties is strong, but a fixed 5.5% gradient is likely too simplistic; expect variability based on wood density, anatomical structure, and thickness, requiring species-specific guidelines.

The Herfindahl-Hirschman Index (HHI) measures market concentration by summing the squares of individual firm market shares (as percentages), indicating higher values for less competitive **Table 7: HHI wood Market in Mbalmayo**, more concentrated markets (e.g. of 43 wood transformation industries in Mbalmayo areas: 10 + 23 + 10 often seen as concentrated). To clarify, if firms A, B, C have shares of 23%, 54%, 23%, the HHI is $(23^2 + 54^2 + 23^2) = 529 + 2916 + 529 = 3,974$, showing a highly concentrated market, An HHI of 3,974 indicates a highly concentrated market, calculated by summing the squares of individual firm market shares close to the target, showing few dominant firms like one 54% and the other 23% share.

Table 7. HHI wood market in Mbalmayo.

Firm	Wood market Share/Mbalmayo Areas	Square of wood market Share /Mbalmayo Area
A	23	529
B	54	2,916
C	23	529
A, B, C	HHI	3,974

Source: Author, 2026.

6. Conclusion

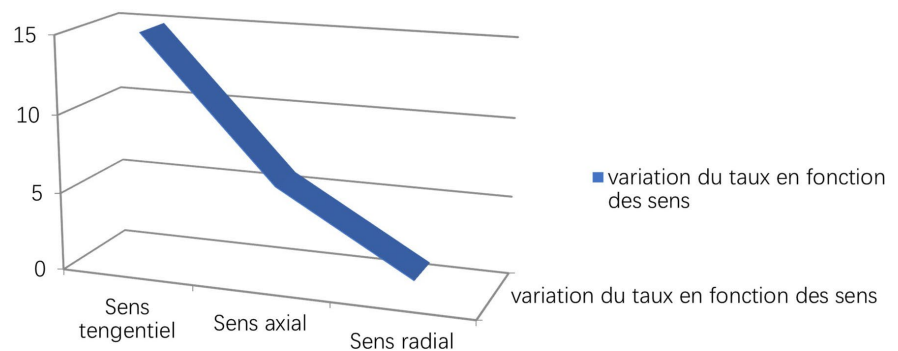
Given the weak dynamics of timber drying in the city of Mbalmayo—one of the epicenters of wood processing in Cameroon—the drying process plays a decisive role in determining the service life of timber products. Positioned midway between the forest and industry, the timber processing and sawmilling sectors hold a strategic role within the wood value chain. The variability of wood properties, particularly physical and mechanical characteristics, is especially marked in tropical timbers due to the diversity of species and growth conditions. As outlined earlier, moisture content is central to this variability, and is directly linked to the drying gradient—the ratio between the wood's moisture and its equilibrium moisture content, also known as the drying rate. This gradient should remain below 5.5%. Since seven reference drying tables exist for African timbers, equivalent references for African wood drying gradients must also be established. It is important to recall that, under temperature and relative humidity conditions, timber does not immediately reach hygroscopic equilibrium: while the surface of the wood may stabilize quickly, the core requires more time. The ratio between core and surface moisture, known as the moisture gradient, reveals the internal stresses present within a wooden piece. These stresses are the primary cause of cracks and other drying defects. The stronger gradient represents the greater tension within the wood. The faster deterioration of the product or conversely is slower when the gradient is reduced. This study thus contributes to the pilot project to be implemented by the University Institute of Wood Technology (IUT-Bois) of the University of Yaoundé I in Mbalmayo, Cameroon, which seeks to further research in timber construction and related applications.

It should also be emphasized that shrinkage varies depending on fiber orientation. For instance, when drying wood from 30% to 0% moisture, the following shrinkages are observed: axial (grain direction): 0.1%, radial (across the log's diameter): 5%, and tangential (along growth rings): 11%. In practice, this explains why door panels made from overly humid wood may remain stable along the grain but shrink across their width, sometimes even leaving grooves during drying.

This phenomenon is explained by the fact that wood surfaces reach fiber saturation earlier than the core, creating a moisture gradient across the thickness of

the plank. This induces non-uniform shrinkage between the surface and the center, generating internal stresses that can cause surface checks and internal cracking. Shrinkage, therefore, is an orthotropic property.

Each species is characterized by three shrinkage coefficients expressing dimensional variations per 1% change in moisture content along the three directions: α_L (longitudinal), α_T (tangential), and α_R (radial) as demonstrated in **Figure 4** below: Humidity variation according to the senses. While axial shrinkage is negligible, tangential shrinkage is most significant ($\alpha_T > \alpha_R \gg \alpha_L$). In some species, radial and tangential shrinkage are nearly identical, making them less prone to drying deformations. Shrinkage coefficients for many species were quantified by Guitard (Guitard, 1987).



Source Author, 2026.

Figure 4. Humidity variation according to the senses.

Finally, wood's orthotropy—its directional dependence of mechanical and physical properties—must be taken into account during drying. Being an anisotropic material, wood exhibits different behaviors depending on radial, axial, or tangential orientations. Uneven shrinkage may deform pieces or cause cracks. Thus, moisture content ($H\%$)—the quantitative measure of water present in timber relative to its oven-dry weight—remains the most critical factor for determining product stability and lifespan (Interreg POCTEFA 2014-2020).

$$H\% = \frac{(Mh - Ma) * 100}{Ma}$$

Ultimately, it is essential to ensure that the moisture content of timber is adjusted to values compatible with its intended destination and usage conditions. While air-dried timber stabilizes naturally at 25% - 30% relative humidity, only artificial drying can lower it below 14%, which is necessary for indoor and structural applications.

Lifespan estimates from moisture gradients often use models linking moisture content/diffusion to material degradation, like Wood Moisture Limit (WML) principles or Fick's Laws, estimating time for moisture to reach decay-causing levels (e.g., >20% for wood), using formulas like Fick's Laws & Wood Diffusion.

Fick's First Law: Describes steady-state moisture flux

$$J = \frac{-DC}{dj}$$

equals negative cap D the fraction with numerator d cap C and denominator d x end-fraction,

$$J = \frac{-dC}{dx}$$

- Fick's Second Law: Accounts for changes in moisture content over time (non-steady state), crucial for modeling drying and moisture uptake in wood, often represented by a partial differential equation.
- Wood Specifics: In wood, the diffusion coefficient varies with moisture content (increasing exponentially with MC), temperature, and the wood's anatomical direction, as bound water moves through cell walls.

Diffusion can be described as the random movement of particles through space, usually due to a concentration gradient. Diffusion is a spontaneous process and is a result of the random thermal motions between two particles. The diffusion coefficient D can be solved for with Fick's laws of diffusion, which are broken up into Fick's First Law of Diffusion.

Equation indicates that if the flux and the change in the concentration over time are known, then the diffusion coefficient can be calculated. The negative sign indicates that the concentration gradient is negative. The first law can only be applied to systems in which the conditions remain the same. Fick's second law is more applicable to physical science and other systems that are changing. This second law is applied to systems in which the condition are not steady, or the solution in not equal throughout.

Fick's Second Law of Diffusion represents the rate of change of concentration in a certain area and represents the changes that the change in concentration can take; this would not be a smooth curve. This term accounts for a varying concentration in the system.

Diffusion can be thought of as a series of random steps that the particle takes as it moves from where it started. These steps can either lead the particle away from where it started, or lead back to where it started. This means that the overall path that a particle takes can look like line overlapping itself multiple times. A third way to calculate the diffusion concentration is through the Fick's law:

$$J = -D\nabla$$

Fick's law describes the evolution of a dilute tracer substance in a background. The left-hand side is the flux of this substance while the right-hand side is a multiple of the gradient of the density of this tracer substance. The coefficient D is called the diffusion constant and depends on the system at hand. The law is a phenomenological one and can be used, if combined with some other basic equations, to derive a mathematical framework for diffusion an important equation.

The diffusion coefficient is useful because it can tell you something about the system. Different substances have different diffusion coefficients, so knowing this

can give you an idea of the substance. Ions at room temperature usually have a diffusion coefficient of 0.6×10^{-9} to 2×10^{-9} m²/s, and biological molecules fall in the range 10^{-11} to 10^{-10} m²/s. The diffusion coefficient changes as the properties of the system change. For example, at higher temperatures, the diffusion coefficient is greater because the molecules have more thermal motion. The diffusion coefficient is also related to the viscosity of the solution. The diffusion coefficient, the lower the viscosity. Because the rate of diffusion depends on the temperature of the system, the Arrhenius equation can be applied. Applying this equation gives the dependence of the diffusion coefficient on the viscosity can be modelled by the Stokes-Einstein relation demonstrates the dependence of viscosity on temperature.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Parameters and Indices Calculated in the Study

- Weighing a sample of wood in both wet and oven-dry conditions (core and surface);
- Calculation of the wood moisture content;
- Calculation of the drying gradient;
- Analysis of the Herfindahl-Hirschman Index (HHI) measuring the concentration of the timber market;
- Application of Wassily Leontief's input-output table for the timber sector in the city of Mbalmayo.

Appendix

Law No. 94/01 of 20 January 1994 on the forestry, wildlife, and fisheries regime in Cameroon stipulates in Article 23 ([Law No.94/01, Cameroon 1994](#)) that the management of a permanent forest is defined as its implementation on the basis of predetermined objectives and a plan, involving a series of activities and investments aimed at the sustainable protection of forest products and services. This must be done without undermining the intrinsic value of the forest, without compromising its future productivity, and without causing undesirable effects on the physical and social environment.

Accordingly, the reference framework of best practices established by the Cameroonian Forestry Code constitutes the guiding document that sets forth general principles for enterprises and other manufacturers of wooden objects wishing to engage in such activities, providing them with a common foundation. This framework outlines a series of indicators that enable comparisons among wood-based products belonging to the same category, which are examined in this article.

The guide also aims to explain and disseminate certain concepts and requirements of the reference framework relating to selected wood products, thereby allowing all stakeholders to understand the rationale behind the choices made and to contribute to the elaboration of a future framework for wood-based products in Cameroon.

In this regard, a broader reflection on the wood sector in Cameroon is undertaken. It should be noted that this pilot project will be carried out by the University Institute of Wood Technology in Mbalmayo (IUT-Bois), University of Yaoundé I, with the objective of furthering studies on wooden constructions and other related applications.

This analysis thus represents an exploratory approach intended to ensure that indicators are calculated in a consistent manner. The moisture content of processed timber, a central element of this study, should therefore assist in estimating the lifespan of wooden objects according to their uses and living environments. Consequently, as part of this analytical framework, we will specify the calculation methods and the Life Cycle Assessment (LCA) of wood based on its reference moisture content during the manufacture of associated objects, as well as the influence of the surrounding environment on the finished product. Our evaluation

will make it possible to identify the full range of potential impacts of wood-based products on the environment, including those related to their potential treatment. Such evaluations are internationally regulated by ISO 14040 and ISO 14044 standards, which nonetheless allow for certain methodological choices to remain open.