Guide pratique

Tropical Timber Atlas

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Tropical Timber Atlas

Technological characteristics and uses

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Preface

In the mid 1980s, the International Tropical Timber Organization (ITTO) commissioned the Centre for Tropical Forests (CTFT – CIRAD's former forestry division) to design and develop management software to catalogue the technological characteristics of tropical woods.

The first version of this software was developed using the CTFT's "Tropical Woods" database, a compilation of the results of several decades of research in the field of tropical wood technology. The goal was to provide and make accessible available information about tropical wood species to operators in the wood industry, as well as to help promote and develop the commercialisation and use of tropical wood species, including secondary woods. The tropical wood research team at CTFT-CIRAD made changes to the software later and enriched it in terms of the number of species described and the number of characteristics presented. Towards the mid-1990s, the software was transferred from a DOS to a Windows system and published under the name "Tropix". The tropical wood research team and Bio WooEB unit at CIRAD successively published updated versions of the tool. Version 7.5.1, released in 2015, presents the technological characteristics of 245 species, including 17 temperate species. Today, the software is widely used by wood industry professionals in France and abroad (http://tropix.cirad.fr/).

Between 1986 and 1990, three authoritative works on tropical wood species were published using data from Tropix:

- The Tropical Timber Atlas - Volume 1 - Africa (ATIBT, CTFT), published in French and English in 1986;
- The Tropical Timber Atlas - Volume 2 - Asia-Australia-Oceania (ATIBT, CTFT), published in French and English in 1987;
- The Tropical Timber Atlas - Volume 3 - Latin America (ATIBT, ITTO, CTFT), published in French, English and Spanish in 1990.

These three publications, used on a wide scale by professionals in the tropical wood industry, are out of print. Industry professionals require a guide on tropical species which presents updated data and information suited to their needs.

In this context, now is a good time to highlight the value of the data and information in the 7.5.1. version of Tropix and assemble it in a single volume (in paper and electronic format) entitled "The Tropical Timber Atlas", to replace the three documents on wood species found in Africa, Latin America and Asia/Oceania.

As part of its Trade and Market Transparency programme, the International Tropical Timber Organization agreed to provide financial support for the design and production of this new volume via the project: TMT-SPD010/12 Rev.1 (M), entitled: "Preparation of the publication Tropical Timber Atlas - 1st edition: Technological Characteristics and uses of 273 tropical wood species (and 17 temperate species)".

The Tropical Timber Atlas includes additional information and 55 new species not present in the 7.5.1. version of Tropix, for a total of 300 species. The main technological characteristics and actual or potential uses are presented; the lower heating power values and thermal conductivity of the wood has been added; a new description of the drying schedules is provided based on Cathild Industrie programmes; there are illustrations of every species via two photos of backsawn and quartersawn (or half-quarter sawn), two examples of microphotography (enlarged by 20 and 115) and by a photo of something made using the wood described. The macrophotography shots are enlargements of the surface of the wood. They are taken using a microscope equipped with a camera. They show the surface of the natural wood, which has been sanded and polished beforehand. The × 20 magnification shows a cross section of the plane of the wood, while the × 115 magnification shows the microscopic structure of the wood in greater detail.

This atlas is intended to be a reference tool for all operators in the forestry sector in France and abroad, as well as for research and educational institutions, contractors, architects, builders and, in general, for all professionals who process and use temperate or tropical timber or who plan to do so.

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Contributors to the atlas

The preparation and follow-up of the Tropical Timber Atlas, and later the design, production and publication of this book, would not have been possible without the participation and major involvement of many stakeholders, researchers and operators in the wood sector:

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- Publication teams at Editions Quæ and Laurence Rodriguez at CIRAD-Dist for production.

We wish to express our very sincere thanks to them.

Financial and logistical support

This work is the result of the teamwork of CIRAD staff who, for decades, have studied the characteristics of over 1,200 tropical wood species in their laboratories, carrying out hundreds of thousands of tests. The frequent collection of information in the field has supplemented this data to form a knowledge base which is now available in different forms.

In addition to its role as a collective memory and repository of information to enrich documents and other material for non-specialists on the quality of tropical timber (technical sheets and guides, atlas, software, etc.), this knowledge base is a tool for studying relationships between different timber properties and different uses for forest products. Today, research and studies carried out by CIRAD's Biomass, Wood, Energy, Bioproducts (BioWooEB) Research Unit continue to enrich this knowledge base on the technological properties and potential uses of a growing number of forest species from tropical regions on four continents.

The publication of this Tropical Timber Atlas was made possible by the financial support of the International Tropical Timber Organization (ITTO). This atlas meets the objectives of the International Tropical Timber Agreement of 2006 (ITTA), in particular by promoting and supporting research and development for more efficient uses of wood and to increase the competitive value of wood-based products compared to other materials. In producer member countries, the agreement encourages increased and more advanced processing of tropical timber from sustainable sources, to stimulate industrialisation in these countries and expand job opportunities.

The atlas also satisfies the priorities and operational activities of the ITTO Action Plan, one of the two main objectives of which is to promote the expansion and diversification of international trade in tropical timber from sustainably managed forests and based on legal operations.

This project is supported by Agropolis Fondation under the reference ID 1600-023 through the « Investissements d'avenir » programme (Labex Agro: ANR-10-LABX-0001-01).

The Association technique internationale des bois (ATIBT) also supported the publication of this atlas both logistically and operationally, in particular by providing the *Nomenclature générale des bois tropicaux*, which was updated in 2016. Support for the updating of this nomenclature was provided by the ITTO, the French Facility for Global Environment (FEEM) and the French Ministry of Agriculture, Agrifood and Forestry (MAAF). It is used to update the Harmonized System of the World Customs Organisation. The European Commission mentions the general Nomenclature of the ATIBT as a reference document for the implementation of the European Union Timber Regulation (EUTR).

Organisations which contributed to the Tropical Timber Atlas

CIRAD

CIRAD (French Agricultural Research Center for International Development) is a French research centre that, in association with countries of the South, tackles international issues of agriculture and development. In partnership with these countries, it generates and disseminates new knowledge to support agricultural development and to inform the debate on the major global issues concerning agriculture, food, and rural territories. CIRAD has a global network of partners and regional offices from which it conducts joint operations with stakeholders in more than 90 countries.

The BioWooEB Research Unit (Biomass, wood, energy, bioproducts) aims to develop different types of timber resources in tropical regions, natural forests, plantations, agroforestry, waste from agriculture, agri-food and wood industries, stems of palm trees, bamboo, cane etc. This valorisation is associated with the development of sustainable and thermally efficient home building materials for tropical and Mediterranean climates, carbon materials (activated charcoal) to process waste waster, and processes for converting biomass into energy in southern countries.

CIRAD, 42 rue Scheffer, 75116 Paris, France
www.cirad.fr

ITTO

The ITTO (International Tropical Timber Organization) is an intergovernmental organisation that promotes the conservation of tropical forest resources and their sustainable management, harvesting and trade. Its 59 members represent about 80% of the world's tropical forests and 90% of the global tropical timber trade. It is primarily concerned with trade and industry, but pays considerable attention to the sustainable management of natural resources. It manages its own programme of projects and other activities, enabling it to quickly test and operationalise its policy work.

International Organizations Center, Yokohama, 220-0012, Japan
www.itto.int

ATIBT

The ATIBT (Association technique internationale des bois tropicaux) represents the growers, forest industry professionals and all those involved in the tropical wood sector who are committed to accompanying the changes needed in the industry. The association was founded in 1951 at the request of the FAO and the Organisation for Economic Co-operation and Development (OECD). ATIBT initiatives are based on three key areas in the tropical wood industry: markets, transformation, and responsible forest management.

ATIBT, Jardin tropical de Paris, 45 bis avenue de la Belle Gabrielle,
94736 Nogent-sur-Marne Cedex, France
www.atibt.org

User guide: general information

Names and Commercial Restrictions (CITES)

Common names for species

The common names are those referenced in the *Nomenclature Générale des Bois Tropicaux* published by the Association Technique Internationale des Boix Tropicaux (ATIBT) in 2016. This reference guide is internationally recognised, particularly in Europe, with the implementation of the European Union Timber Regulation (EUTR).

For certain species, the common name, which is the term most referred to, is accompanied by a second, frequently used trade name, indicated by an asterisk. For instance, the following species have been identified with two names: Alan / Alan-Batu*; Anzèm / Nténé*; Balau,Yellow / Bangkirai*; Catucaém / Louro Faia*; Coraçao de negro* / Panacoco; Cryptomeria* / Sugi; Dukali / Amapa*; Fuma / Fromager*; Kurokaï / Breu*; Mango / Machang*; Pashaco / Paricá*; Pinus kesiya* / Kesiya Pine; Pinus merkusii* / Merkusii Pine; Pinus patula* / Patula Pine.

Family and botanical names

Like the common names, the family and botanical names listed are also referenced in the *Nomenclature Générale des Bois Tropicaux* (ATIBT, 2016).

The following abbreviations appear after certain botanical names:

- "spp." (*species pluralis*) and "p.p." (*pro parte*). In botany, the abbreviation "spp." means 'more than one species in the genus'. It can include all species in a given genus, which can be confusing. Different authors use this abbreviation differently, to designate several species within a genus in a non-exhaustive manner, or to designate all species in that genus.
- In this Atlas, the abbreviation "p.p." is used for types of wood which include several – but not every – species within a genus;
- "subgen." (subgenus). In a given genus, several significantly similar species can form a subgenus. In a subgenus, a wood type can cover all species, several species, or simply some of these, as per the conditions mentioned above.

CITES (Washington Convention of 2017)

CITES (the Convention on International in Endangered Species of Wild Fauna and Flora, or 'the Washington Convention') is an international agreement between governments. Its aim is to ensure that international trade in specimens of wild animals and plants does not threaten their survival. Tropical wood is therefore protected by this convention.

Regulated wood species are classified in one of the convention's three appendices:

- Appendix I includes species threatened with extinction. Trade in specimens of these species is permitted only in exceptional circumstances;
- Appendix II includes species not necessarily threatened with extinction, but in which trade must be controlled in order to avoid use incompatible with their survival;
- Appendix III contains species that are protected in at least one country. This country must ask other CITES parties for assistance in controlling the trade. Changes to Appendix III follow a distinct procedure from changes to Appendices I and II, as each party is entitled to make unilateral amendments to it.

The label "no trade restrictions" is applied to species not listed in CITES. For more information, consult the CITES web site: www.cites.org.

Log description

Diameter

The range of mentioned values corresponds to the diameters of the most frequently exploited woods. These values must be weighed against MDCL – minimum-diameter cutting limits – determined by each producer country to ensure acceptable forest sustainability after the rotation period. MDCL values are generally available from the forestry services of these countries.

Thickness of sapwood

The range of mentioned values corresponds to the most frequently encountered thicknesses of sapwood.

Buoyancy

Two classes (floatable and non-floatable woods) were defined according to the average density of green woods (after felling). A third class ('not applicable') was established for species in temperate countries.

Log conservation

Depending on the wood's natural durability, preservation is low (the wood must be treated), moderate (treatment recommended) or good. The concept of preservation only applies to heartwood; sapwood is always considered as non-durable.

Wood description

Colour

Although the colour and appearance of the wood are usually specific to a given species, the colour is not a constant factor from one tree to another or from one piece of wood to another of the same species. It can vary according to different parameters and change over time. Variations in grain gradient (for example, interlocked grain and wavy grain) and moisture content can alter the perception of colour.

Each species is characterised by a reference colour chosen from among 18 predefined colours: white, cream white, pinkish white, light yellow, yellow, orange yellow, light brown, brown, yellow brown, pinkish brown, red brown, dark brown, light red, red, dark red, grey, black and purple.

The description of the wood colour mentioned in the note under "Wood description" emphasises the range of variation found, but does not take into account, for example, the change in the colour of woods exposed to bad weather.

Sapwood

The sapwood can be well-demarcated, poorly demarcated or not demarcated. The rating "n.d." is used in cases where no information is available.

Texture

The texture of a wood corresponds to the visual impression given by the size and the arrangement of the vessels. Three classes of texture are defined: fine, medium and coarse.

Grain and interlocked grain

The grain of the wood is the general alignment of the fibres in relation to the log. The interlocked grain is due to an alternate incline (in relation to the trunk axis) of the successive layers of the wood that form during tree growth.

Physical and mechanical properties

The values of the physical and mechanical properties (mean values) are computed from tests conducted at CIRAD laboratories or obtained from international literature. They must be used with caution due to the highly variable nature of wood properties. This variability is well-known by people working in the wood industry. It depends on numerous external or internal factors: the age of the trees, the position of the wood inside the trunk, wood maturity, and growth conditions (including soil type, rainfall and climate).

Density

The density or relative density of a solid is the ratio of its mass per unit volume over the mass per unit volume of water (pure water at 4 °C at atmospheric pressure, i.e. 1,000 kg/m^3). It has no unit.

Indicated density is determined on wood at 12% moisture content. This basic technological characteristic is the first to be determined when qualifying wood. This property is more or less closely related to the wood's main physical and mechanical properties and with certain working characteristics.

Monnin hardness

Monnin hardness (determined on wood at 12% moisture content) is an important property to know when the wood is used for flooring (parquets, decking) or any end-use where the wood will be subject to impacts or punching. It has no unit.

Hardness classification:

- H ≤ 1.5: very soft;
- 1.5 ≤ H ≤ 3: soft;
- 3 ≤ H ≤ 6: medium;
- 6 ≤ H ≤ 9: hard;
- H ≤ 9: very hard;

The method of measurement of Monnin hardness is defined by the French NF B 51-013 standard (1985).

Janka hardness is another characteristic, measured in several countries, using another method. Sallenave (1971) suggests the following ratio between Monnin hardness and Janka hardness:

Janka hardness (in pounds) = 300 × Monnin hardness.

Fibre saturation point (FSP, in %)

In green wood, part of the water fills, more or less completely, the cellular and intercellular empty spaces. The draining of this free water occurs without wood shrinkage. Once free water has completely disappeared, the wood only contains bound water impregnating the cell walls. When this bound water evaporates during drying, shrinkage occurs and provokes wood warping.

The fibre saturation point (FSP) corresponds to the moisture content of wood saturated with bound water. Below this threshold, the wood starts to shrink during drying. The FSP usually varies between 20 and 40% according to species, but most often, it is around 30%.

Fibre saturation point classification:

- FSP ≤ 25%: low;
- 25% ≤ FSP ≤ 35%: medium;
- FSP ≥ 35%: high.

Coefficient of volumetric shrinkage (Vs, in % by %)

When a piece of wood dries below its fibre saturation point (FSP), its volume decreases. If it reabsorbs moisture, its volume increases up to the FSP. Above that, the volume no longer varies. In order to quantify these volume variations, the coefficient of volumetric shrinkage is used (called Vs) and corresponds to the volumetric shrinkage of a piece of wood when its moisture content has a variation of 1%.

Classification for the coefficient of volumetric shrinkage:

- Vs ≤ 0.35: small shrinkage;
- 0.35 ≤ Vs ≤ 0.55: medium shrinkage;
- Vs ≤ 0.55: large shrinkage.

Total tangential shrinkage (Ts) (in %) and total radial shrinkage (Rs)

Until the fibre saturation point, the wood does not shrink during drying. Once below this threshold, however, it is subject to dimensional variations when its moisture content varies. Shrinkage under the FSP occurs in the wood's three directions: longitudinal, tangential and radial.

Longitudinal shrinkage is very small compared to the two others, about some tenths of a percent, but it can notably influence the dimensional variations of long wood pieces. Few data are available on this characteristic which is quite difficult to measure in the laboratory.

Total tangential and total radial shrinkages are usually determined to qualify the behaviour of wood during drying or more generally during moisture variations.

Total tangential shrinkage classification (Ts):

- Ts ≤ 6.5%: small shrinkage;
- 6.5% ≤ Ts ≤ 10%: medium shrinkage;
- Ts ≥ 10%: large shrinkage.

Total radial shrinkage classification (Rs):

- Rs ≤ 3.8%: small shrinkage;
- 3.8 % ≤ Rs ≤ 6.5%: medium shrinkage;
- Rs ≥ 6.5%: large shrinkage.

Ts/Rs ratio

The "Total tangential shrinkage" over "Total radial shrinkage" ratio gives an indication of the deformation suffered by a piece of wood subjected to humidity variations.

This parameter is of particular importance for non-directional cuts (half-quartered cuts). A Ts/Rs ratio tending towards a value greater than or equal to 2 indicates that a species is susceptible to deformation. The more this value tends towards 1, the more stable the wood, whatever the type of cut.

Thermal conductivity

The thermal conductivity λ (watt per metre and per Kelvin: W/m · K) of a substance is its ability to conduct heat. The more insulating a substance is, the lower the λ.

The λ values specified in this atlas for each wood species are the result of a campaign to measure a broad sample of tropical and temperate woods of a wide range of densities. However this sample does not cover all the species included in the atlas.

Measurements were made in the thermal physics lab of the Heterogeneous Materials Study Group (GEMH) at the European Ceramics Centre in Limoges, France) using the hot disk method regulated by the NF EN ISO 22007-2 standard (October 2015). This measurement campaign revealed that thermal conductivity (λ) is correlated with wood density (D) (Figure 1).

Thermal conductivity λ in relation to density D is therefore expressed in the following equation: $\lambda = 0{,}289\ D + 0{,}030$.

The λ values specified in this atlas were determined using this model, based on the average density of each wood species.

Heating value

The heating value (or calorific value) of a substance is defined as the amount of heat released by its combustion. It is usually measured in kilojoules per kilogram (kJ/kg) or joules per gram (J/g), sometimes in calories per gram (cal/g) or kilocalories per kilogram (kcal/kg). Two types of heating value can be defined:

- The higher heating value (HHV) is the amount of heat released by combustion, at constant volume, of 1 kg of an anhydrous substance. Water produced during combustion is condensed, while the heat released by water condensation (latent heat of vaporisation) is recovered;

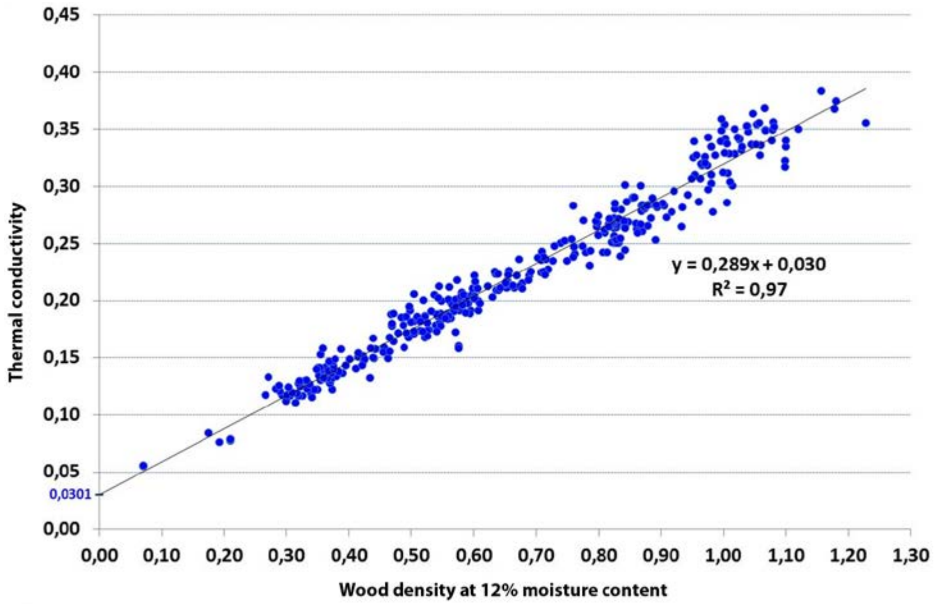

Figure 1. Thermal conductivity in relation to wood density (determined at 12% moisture content).

- The lower heating value (LHV) is the amount of heat released by combustion, at constant pressure, in open air, of 1 kg of an anhydrous substance. Water produced during combustion is not condensed. Therefore, energy produced by condensation is not recovered.

LHV is the value most commonly used when calculating combustion. It is measured in kJ/kg of anhydrous wood.

HHV is defined in an experimental (lab) setting using an object called a "bomb calorimeter".

For wood, the lower heating value (LHV, in kJ/kg) is subtracted from the higher heating value (HHV) using the following equation:

- Anhydrous LHV = Anhydrous HHV – (212.2 × H)

where H is the hydrogen content (expressed in % by weight) of a given biomass model regulated by the "Solid biofuels - Determination of calorific value" NF EN 14918 standard (March 2010).

The LHV specified in this atlas were determined using HHV values measured in a laboratory at CIRAD. Hydrogen H content is not determined during the experiment. Therefore, an average H content of 5.85 % was used for the calculation (experience shows that the H value is nearly identical from one species to another).

Crushing strength (in MPa)

This resistance (called C_{12}) is determined on wood at 12% moisture content, according to the procedure stipulated in NF B 51-007 standard (September 1985). It corresponds to the load to be applied parallel to the grain to achieve rupture of a standardized sample.

Crushing strength classification:

- C12 ≤ 45 MPa: low resistance;
- 45 MPa ≤ C12 ≤ 75 MPa: moderate resistance;
- C12 ≥ 75 MPa: high resistance.

Static bending strength (in MPa)

The static bending strength (called B_{12}) is determined on wood at 12% moisture content, according to the procedure stipulated in standard B 51-008 (November 1987). It corresponds to the load to be applied to the middle of a standardized sample placed between two supports to achieve rupture.

Static bending strength classification:

- F12 ≤ 75 MPa: low resistance;
- 75 MPa ≤ F12 ≤ 125 MPa: moderate resistance;
- F12 ≥ 125 MPa: high resistance.

Longitudinal modulus of elasticity (in MPa)

Longitudinal modulus of elasticity (E_L) is determined on woods at 12% moisture content and is a very important property for structural end-uses where pieces of wood usually support static bending forces in their largest direction, parallel to the fibres. This property characterises the relationship between load and deflection. It is an indicator of wood stiffness.

Longitudinal modulus of elasticity classification:

- EL ≤ 12,500 MPa: low modulus;
- 12,500 MPa ≤ EL ≤ 18,500 MPa: medium modulus;
- EL ≥ 18,500 MPa: high modulus.

Natural durability and treatability

Except special note concerning sapwood, durability characteristics refer to the heartwood of mature woods. Sapwood is always considered as non-durable towards biological wood decaying agents. A wood whose in-service moisture content is less than around 20% is not prone to fungal attack. Temperatures below around 5°C prevent any fungal propagation. The same applies for woods under water or placed at high temperatures (around 60°C), that are never attacked by decay, whatever their natural durability.

Resistance to decay

Resistance towards decay is determined on standardized samples in the presence of fungal strains, under controlled ambient conditions. These tests last several months.

The NF EN 350 standard, under review when this atlas was published, defines the classes of natural durability towards wood-decaying fungi:

- Highly durable woods: DC1 (durability class 1, called "class 1";
- Durable woods: DC2, called "class 2";
- Moderately durable woods: DC3, called "class 3";
- Poorly durable woods: DC4, called "class 4";
- Non-durable woods: DC5, called "class 5";

Resistance to dry wood insects (Lyctus, furniture beetle, death watch beetle)

Most commercialised tropical woods are not attacked by dry wood insects, provided that they do not contain sapwood. When the sapwood is not very demarcated, it is advisable to treat the wood against dry wood insects. Some tropical species are completely attacked in every part of the wood and require special attention when dry. Sawn woods or end-products are attacked only when they contain some sapwood and sufficient starch content.

Based on the NF EN 350 standard, a species is classified as sensitive (DC class S, called "class S") if it is attacked during laboratory tests. Otherwise, it is considered as durable (DC class D, called "class D").

Resistance to termites

Resistance to termites is determined in the same manner as for decay. Standardised samples are placed with termites. The intensity of termite attack, and consequently the natural resistance of