Niko Torelli

MAYA TIMBERS

An introduction to sustainable agroforestry in the form of the Maya Forest Garden Cycle. The relevant biological, physical, chemical, mechanical and technological properties of 43 wood species are given, along with their end-use groupings as elements for sustainable, multiple-use forest management. Possible consequences of climate cooling due to the joint effects of the Little Ice Age and Great Dying after Spanish colonisation on forest growth are considered, as is the issue of tonewood for Stradivarius violins.

Essay on mahogany/caoba (*Swietenia spp.*).

GOZDARSKI INŠTITUT SLOVENIJE
SLOVENIAN FORESTRY INSTITUTE

Silva Slovenica

Abstract Maya Timbers

This work presents a description of traditional sustainable agroforestry in the form of the Maya Forest Garden Cycle (MFGC), also called "high performance milpa". This system cycles from the closed forest canopy to a field dominated by annual crops to an orchard garden, and from an orchard garden back to the closed canopy, creating a forest with all essential ecosystem functions.

In the study, the relevant biological, physical, chemical, mechanical and technological properties of 43 wood species were determined in relation to the well-known and all-purpose caoba/ big-leaf mahogany (*Swietenia macrophylla* G. King). By assessing the relevant properties, the respective fields of application and related suitability were predicted, thus making it possible to group species with similar properties with respect to their specific end-uses and technologies (e.g. drying, etc.) – an essential prerequisite for sustainable , multiple-use forest management (MEM), a concept of forest management that combines two or more objectives, not only the production of wood, making possible a sound commercial logging industry without the destruction seen with clear-cutting or selective logging.

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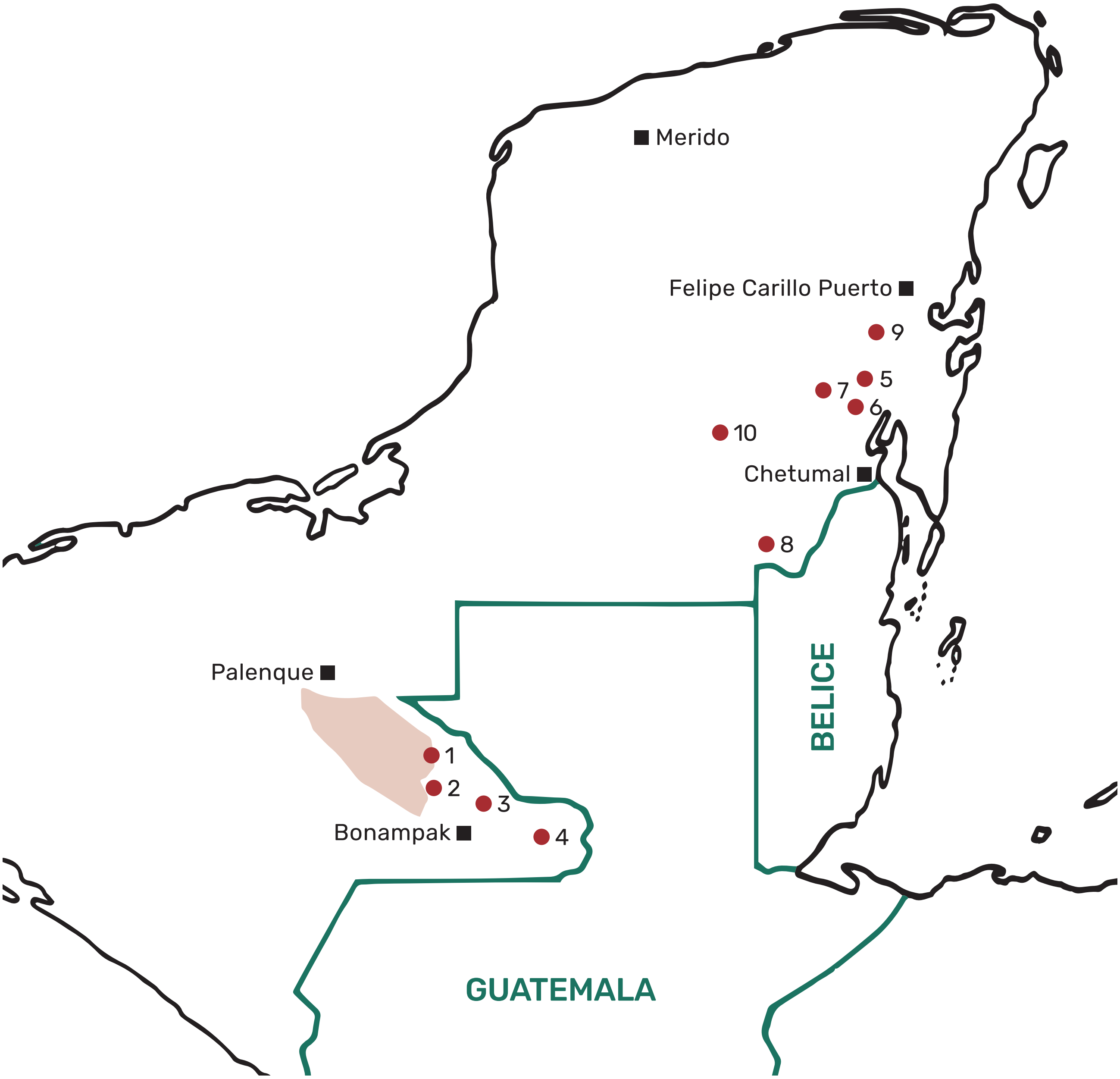


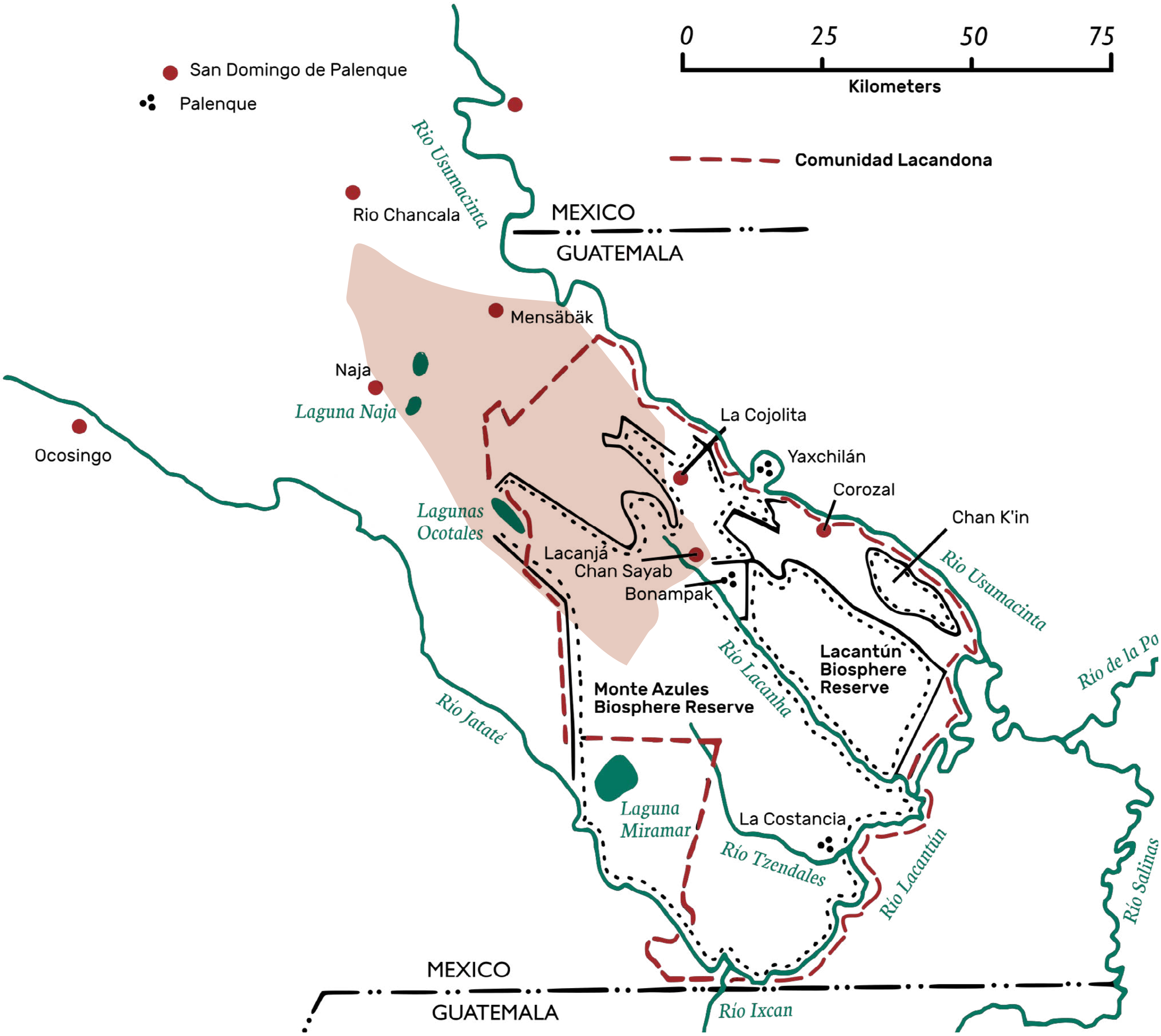
MAP 1: SE Mexico, sampling area and locations of representative plots in Chiapas,Selva Lacandona, SL (selva alta perennifolia): **1.** SL, zone 2; **2.** SL, zone 3; **3.** SL, zone 4; **4.** SL, zone 5 and in Yucatan, Quintana Roo selva alta-mediana subperennifolia): **5.** Ej. Noh-Bec; **6.** Ej. Chacchoben; **7.** Ej. Divorciados; **8.** Ej. Nuevo Guadalajara; **9.** Ej. Petcacab; **10.** Ej. Nvo Becal. See also Tree species composition, density "profiles" and volume percentages (see also Map 2, Chap. 2.2, Tab. 2.2 and Figs. 1-10).

Selva Lacandona – aerial view.

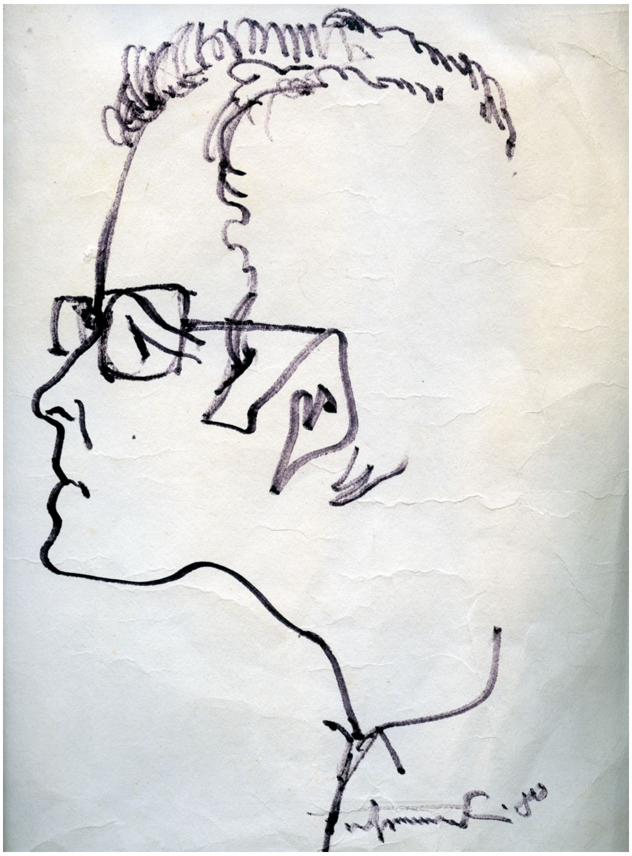
Selva Lacandona (*Selva alta perennifolia*): flowering laurel, onté (*Nectandra ambigens, Lauraceae*) draped with flowering lianas.

Traditional Maya house in Yucatan with a papaya tree in the surrounding house garden.

Maya house with the house garden.



MAP 2: Selva Lacandona, protected areas and sampling area (see Chap. 2.6, Tab. 2.3; Nations 2006:4, 114, 145).



Niko Torelli (1986)

The author with Mexican colleagues (1980).

Introduction

The work covered here was conducted between 30 and 40 years ago in the context of a Mexican-Yugoslav/Slovenian* project entitled *Estudio promocional de 43 especies forestales tropicales mexicanas* (Promotional study of 43 Mexican tropical timber species, 1983), FAO consultant missions and elaboration of the FAO's tropical forestry action plan in conjunction with an international team of experts (1988). The overall goal of our work was the introduction or consolidation of sustainable forest management (SFM) and multiple-use forest management (MFM) as a common and prime forest management objective under SFM.

The Mexicans assigned us the culturally most interesting part of the Maya tropical forest (known as the Selva Maya or Selva Lacandona), an area with extraordinarily rich biodiversity, as our study and wood-sampling area. To begin with they stationed us in Chancalá, a few tens of kilometres south of Palenque, a Maya archaeological site of the Classic Period in the basin of the Usumacinta river, magnificently located in the foothills of the Chiapas highlands, which flourished between AD 600 and 900. During the consultant mission to southern Quintana Roo in connection with the *Plan Piloto Forestal* (PPF), a regional plan for community management of natural forests, where most of the PPF efforts are concentrated on forest-owning *ejidos*, rural cooperatives established after the Mexican revolution, and during preparation of the action programme, we stayed in Chetumal.

I visited Mexico several times during our collaboration, accompanied on occasion by two technical associates. I also visited twice as an FAO consultant or general coordinator of the FAO mission for preparation of the action programme. On the occasion of the 18th World Congress of the International Union of Forestry Research Organisations (IUFRO), which took place in Ljubljana in 1986, a group of our Mexican colleagues spent a month at the Department of Wood Science and Technology (Biotechnical Faculty, University of Ljubljana), where they familiarised themselves with the research and testing methods we employed.

While in the Selva Lacandona we familiarised ourselves – both in the field and on the basis of extensive recent literature – with the Maya rainforest (Selva Maya), its people and their sustainable practice of agroforestry, known as the *milpa* forest garden cycle (MFGC), which is a special aspect or element of sustainable forest management (SFM). MFGC is a form of swidden agriculture which can be characterised as successional agroforestry. Essentially it is a form of horticulture rather than agriculture. It conserves the surrounding rain forest ecosystem while cycling the majority of the land through five successional stages, including a herbaceous stage, two shrub stages and two forest stages (cf. Nations and Nigh 1980; Diemont and Martin 2009, Nigh and Diemont 2013). Sustainable MFGC can be included in the buffer and transition zones surrounding protected areas.

In production forests, the current marketing of timber is typically species oriented and should be complemented by end-use marketing, where names cease to be relevant and the focus is instead on properties. This means that where supplies of a timber are of occasional or sporadic occurrence, they can be marketed for a specific purpose with others that also have the appropriate combination of relevant properties (cf. Brazier 1975).

Our study determined the relevant biological, physical, chemical, mechanical and technological properties of 42 lesser-known wood species and compared them with the generally well-known caoba or big-leaf mahogany (*Swietenia macrophylla* King, Meliaceae). The well-known and commercially important *cedro*, also known as Spanish cedar or Cuban cedar (*Cedrela odorata* L., Meliaceae), and the ceiba, Lac. *yaxche*, sacred to the Maya (*Ceiba pentandra* (L.) Gaertn., Malvaceae) are not included in our study. The species were grouped from the point of view of their wood properties, thus supporting the "end-use marketing" of a substantial part of Maya timbers. (For the species investigated, see Table 4.2)

The species investigated were grouped using 18 relevant properties with regard to 15 potential fields of end-use.

This principle makes it possible to utilise a substantial part of lesser-known or technologically less attractive species that may comprise up to 90% of volume. These species are often treated as weeds and are at present burned or otherwise wasted after logging operations followed by conventional *milpa*, pasture or conversion into food and fast-growing tree plantations.

Such an approach strengthens the economic pillar of SFM and its absolutely necessary balance with the ecological and sociocultural pillars of SFM and multiple-use forest management (MFM) as a common and prime management objective under SFM. SFM also recognises that humans are part of the ecosystem, and that all activities in the forest both affect the ecosystem and depend on it (i.e., an "ecosystem approach" is adopted).

*Slovenia gained its independence from Yugoslavia in June 1991 and is today a member of the European Union.

The end-use grouping of 43 wood species helps to realistically prognosticate the acceptable type and extent of sustainable forest utilisation.

Currently the principles of SFM are at risk from highly selective (often illegal) logging and the abandoning of the sustainable permaculture-based traditional *milpa* (MFGC). The most dangerous factor, however, is uncontrolled and unregulated population pressure, where the ecological footprint of the population exceeds carrying capacity, resulting in the inevitable conversion of forest to (unsustainable) pasture and agriculture, combined with generally negative attitudes towards the existence of the forest and its ecosystem functions/benefits. As a hotspot of biodiversity and anthropological and cultural heritage, the Selva Lacandona, as part of the Maya tropical forest, ought to be preserved.

An essay on the natural and cultural history of caoba (*Swietenia macrophylla*) and West Indian mahogany (*Swietenia mahogani*) has been added as Chapter 8.

We were guided throughout our work by a deep respect for the Maya – the "Greeks of the New World" – and in particular for their sustainable permaculture-based agroforestry: the *milpa* forest garden cycle (MFGC).

The underlying aim of our research was to contribute to SFM/MFM and resource renewability – the fundamental tenet of sustainability using the idea of ecological rotations (cf. Kimmins 1997:504). We constantly kept in mind the protection of the Maya/Lacandon forest and its ecosystem services/benefits while viewing the inhabitants of the forest as a part of this ecosystem and admiring their remarkable sustainable permaculture-based agroforestry (MFGC), founded on exceptionally rich traditional ecological knowledge (TEK). For centuries MFGC, as a special form of SFM that incorporates both the native flora of the environment and introduced plants, preserved the forest (in reality partly modified in a utilitarian sense and adapted to human needs in the forest gardening process) and its essential ecosystem functions and benefits and ensured the survival of the Maya. In addition to MGFC, the Maya used a series of intensive hydraulic production methods readily adaptable to demonstrated changes in the climate, such as raised and channelised fields, *chinampas* ("floating gardens"), surface reservoirs, *chultunes* (reservoirs or storage chambers constructed underground), *cenotes* (natural sinkholes resulting from the collapse of limestone bedrock that exposes groundwater underneath). The Maya were masters at using fire to prepare the fertile anthrosol known as "dark earth" – similar to the *terra preta* of the Amazon.

What drives current global deforestation is the fact that forest production systems cannot generate as much profit as monocultures (rubber, palm oil and "paper" forest plantations, etc.). Unfortunately, market forces replace inefficient production systems with systems that produce more profit – a simple competitive model of survival of the fittest.

The renewable CO_2 neutral woody biomass derived from trees (solid wood, tree trimmings, wood chips, sawdust, bark, and shavings) is used to produce heating, electricity, or other forms of energy. Woody biomass is a sustainable renewable energy source, since new forests can be developed through afforestation and appropriate maintenance. Before it is devalued by physical damage and biological deterioration, we first use the wood for as long as possible as solid wood and later in cascade fashion as various wooden materials. If they are dry enough (at least air dried U = 12-15%) and not too contaminated with adhesives or surface finishing or treatments, we can finally use them with a suitable method and technology as a clean renewable and CO_2 neutral energy source. In view of the sequestration of C or CO_2, the long-term use of wood as a substitute for non-wooden construction materials with much embodied energy is particularly important.

The current production and marketing of timber, which is typically species oriented, should be complemented with marketing for the end use, where the names of tree species cease to be relevant. Where supplies of a timber are of occasional or sporadic occurrence they can be marketed for a purpose with others that also have the appropriate combination of relevant properties. In this way it is possible to better preserve the natural botanical composition of the forest ecosystem, its biological and mechanical strength also contributing ecosystem benefits, as well respect as its importance as part of the world's cultural heritage, along with SFM/MFM/EA.

Due to its indispensable ecosystem benefits as well as its importance as part of the world's cultural heritage, all efforts should be made to protect the Selva Lacandona.

About the Author

Born in Ljubljana on 4 July 1940. Nationality: Slovene

Education and Appointments:

Niko Torelli holds a bachelor's degree in Forestry (1964) and a master's degree in Wood Science and Technology (1974) from the University of Ljubljana.

1979 Receives his PhD in Botany (Tree Physiology) at Humboldt University, Berlin, where he focused on wound-initiated discoloured wood ("red heart") in beech (*Fagus sylvatica* L.)

1981 Assistant professor of Wood Science

1978–1988 Split missions to Mexico (total duration around 15 months)

1979–1999 Holder of the Chair of Wood Science and Technology at the Department of Wood Science and Technology, Biotechnical Faculty, University of Ljubljana
1988 General coordinator of the FAO Tropical Forestry Action Programme for Mexico
1990 Professor at the Biotechnical Faculty, Ljubljana
1996–2007 Editor of the monthly scientific journal *Les/Wood*
1999–2008 Director of the Slovenian Forestry Institute

2008 Retired but still active as professor and vice-dean at the autonomous Faculty of Design, Ljubljana

FAO consultant

Member of the Environment Protection Council of the Slovenian Academy of Sciences and Arts

Engaged in research on tropical wood species from equatorial Africa, Guyana (South America) and tropical Mexico as part of several international research projects.

Research interests: secondary changes in trees (heartwood formation, response of trees to mechanical wounding, wound-initiated discoloured wood, ageing and senescence in trees), electrical techniques to measure tree vitality (CER), wood properties and quality, silvicultural practices and wood quality, arboriculture.

In his spare time he enjoys watercolour painting, classical music, cultural history, hiking, biking and skiing.

Selected Honours and Awards:

1986 National Mexican Forestry Award (*Merito Nacional Forestal*)

1998 Honorary doctorate (dr. h.c.) from the Universität für Bodenkultur (BOKU) of Vienna

2004 Ambassador of Science of the Republic of Slovenia.

2020 Professor Emeritus, University of Ljubljana

Acknowledgments (1983, 2018)

On the Mexican side: the *Secretaría de Agricultura y Recursos Hidráulicos – Subsecretaría Forestal* (SARH) and the *Instituto Nacional de Investigaciones Forestales* (INIF), as well as the Mexican timber industry. On the Slovene (Yugoslav) side, the Socialist Republic of Slovenia Institute for International, Scientific, Technical, Educational and Cultural Cooperation (ZAMTES); the Department of Wood Science and Technology (Biotechnical Faculty, University of Ljubljana); the Slovenian timber industry, the Department of Chemistry (Faculty of Natural Sciences and Technology, University of Ljubljana); and the Boris Kidrič Institute of Chemistry.

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On the Slovenian side special appreciation goes to Venčeslav Kavčič of the University of Ljubljana's Faculty of Natural Sciences and Technology for the determination of pH value and to Zvonko Lengar of the Analytical Department at the Boris Kidrič Institute of Chemistry in Ljubljana for the determination of silica content.

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Mr. León Jorge Castaños, politician and forestry expert in his element.

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Lastly, my deep appreciation to my wife Nuška not only for her willing all-round assistance, but also for her support.

Notes on Names

The tree and timber species discussed in this book are known by many names. These can be Spanish names, English names, one of several Maya names or specifically Lacandon names. For the most part I use the generally accepted Spanish common names in the text. Mayan names are written in italics, while Lacandon names are marked "Lac". As regards exact botanical designations, only the scientific/Latin names (usually given in brackets) are authoritative. As an example of the rich terminology, allow me to cite the species *Bursera simaruba* (L.) Sarg.; syn. *Elaphrium simaruba* L. (Simaroubaceae), which is very common in the Maya tropical forests, i.e. throughout the whole of Yucatán and on the Pacific and Gulf of Mexico coasts in the climate area designated **A** (tropical) under the Köppen–Geiger climate classification system. Our working name for it was the Spanish name *palo mulato*, which is widespread in Chiapas and the neighbouring states of Veracruz, Oaxaca, Tabasco, Puebla and Quintana Roo. It is frequently also known as the *Indio desnudo* ("naked Indian"). In Chiapas we encounter Maya names such as *chacáh*, *chaca*, *chacaj* and *chocohuite*, while in Veracruz we find *chacajiota* (cf. Pennington and Sarukhan 1968:234). Cook (2016:284) cites the Lacandon name *chäklah*. Yet these are not all the names. Others include gumbo-limbo, copperwood and turpentine tree, and possibly others as well.

The Maya name for the caoba (*Swietenia macrophylla* King) is written in several different ways: puna, punah, puuna' and puuná. When citing other authors, I have retained the names they use. In the case of ambiguity, I recommend the works of Cook (2016) and Ford and Nigh (2015), although even here there are sometimes specific differences.

Minor ambiguities also exist with regard to the names of settlements. Thus the name of a settlement in the northern community of the Selva Lacandona can be written either as Metzabok (Nations 2006) or as Mensäbäk (Cook 2016). There is also a minimal difference in the way the name of a better-known neighbouring settlement is written: Nají or Nahá (Spanish pronunciation?). For presumably technical reasons, the acute accent is written either as *a'* or as *á* (hence Nahá or Naha'). Sometimes the name appears without any accent at all.

Photographs

With the exception of the photographs of León Jorge Castaños and the scarlet macaw, all photographs are original and were taken between 30 and 40 years ago using a Canon A1 camera.

Acronyms/Abbreviations (see Glossary!)

CITES Convention on International Trade in Endangered Species
COP Conference of Parties to the UNFCCC
CTN close to nature
EA ecosystem approach
EMC (wood) equilibrium moisture content
FG forest garden
FSC Forest Stewardship Council
FSP (wood) fibre saturation point
INIF Instituto Nacional de Investigaciones Forestales, Mexico City
IPCC Intergovernmental Panel on Climate Change
ITTO International Tropical Timber Organisation
IUCN Union for Conservation of Nature and Natural Resources
LIA little ice age
MC milpa cycle
MFM multiple-use forest management
MFGC milpa forest garden cycle
NWFP non-wood forest products
PMP permaculture principles
REDD+ Reducing Emissions from Deforestation and Forest Degradation and enhancing forest carbon stocks
RA retention approach
RIL reduced-impact logging
RRR the three Rs: "Reduce, Reuse, Recycle"
SFI Slovenian Forestry Institute
SFM sustainable forest management
TEK traditional ecological knowledge
UNFCCC United Nations Framework Convention on Climate Change
WWF World Wildlife Fund/World Wide Fund for Nature

PART ONE

A sad "artistic" monument to a forest below Montserrat in Catalonia that was destroyed by fire in 2019.

Humorous addendum to a STOP sign in Ljubljana (2019).

Mit GOtt!
SYLVICVLTVRA OECONOMICA,
Oder
Haußwirthliche Nachricht und Naturmäßige
Anweisung
Zur
Wilden Baum-Zucht,
Nebst
Gründlicher Darstellung/
Wie zuförderst durch Göttliches Benedeyen dem allenthalben und insgemein einreissenden
Grossen Holtz-Mangel/
Vermittelst Säe- Pflantz- und Versetzung vielerhand Bäume zu prospiciren/
Alles zu nothdürfftiger Versorgung des Hauß- Bau- Brau- Berg- und Schmeltz-Wesens/
Worbey zugleich eine gründliche Nachricht von den in Churfl. Sächß. Landen
Gefundenen Turff
Dessen Natürliche Beschaffenheit/ grossen Nutzen/ Gebrauch und nützlichen Verkohlung.
Von
Hannß Carl von Carlowitz/
Königl. Pohl. und Churfl. Sächß. Cammer-Rath und Ober-Berg-Hauptmann.
Mit Königl. Pohl. und Churfürstl. Sächß. allergnädigsten PRIVILEGIO
LEIPZIG/
verlegts Johann Friedrich Braun 1713.

Title page of the famous work *Sylvicultura oeconomica* by Hans Carl von Carlowitz, 1713.

1. Tropical forests between need and greed, their sustainable management, use and abuse

"The Earth provides enough to satisfy every man's needs but not every man's greed."

(Mahatma Gandhi)

Rapid industrialisation of Mexico and uncontrolled population growth over the last few decades have had a substantial impact on the country's environment and left less than 10% of its original tropical rainforests standing. These forests are most threatened by population pressure, illegal logging and subsistence activities, e.g. land clearing for (non-sustainable) agriculture and cattle breeding (*Mexico, Environmental Profile 2006*).

Tropical forests in general are critically endangered. Concern about the role of soil and forests in the global carbon budget and the effects of carbon sequestration have been incorporated into numerous international treaties, but has it all been to no effect? Writing on the *Global Forest Watch* website in 2018, Mikaela Weisse and Liz Goldman report that "last year was the second worst on record for tropical tree cover loss, according to new data from the University of Maryland. In total, the tropics experienced 15.8 million hectares (39.0 million acres) of tree cover loss in 2017 – an area the size of Bangladesh. That's the equivalent of losing 40 football fields of trees every minute for an entire year" (Global Forest Watch, 27 June 2018). Deforestation truly is an urgent issue that should be getting more attention. "We are trying to put out a house fire with a teaspoon," WRI senior fellow Frances Seymour told *The Guardian*. Even more, as a result of deforestation and soil degradation, disease, mechanical wounding, and also ageing and increased respiration, "tropical forests now emit more carbon than they soak up" (Carey 2017). We could say that the fate of tropical forests depends on anything else on the blind greed of the rich, the vaguely defined needs of global "development" and the unjust poverty of the traditional (indigenous, native) people, and also to a large extent on wealthier yet negligent, environmentally unaware, self-satisfied and uncritical consumers of "colonial" goods from the "developed" world. Instead of instead of raising awareness of the importance of forests and their many ecosystem functions/benefits for human survival, and in particular the irreplaceable role of tropical forests in mitigating climate change, we uncritically allow unnecessary defence spending, space exploration, wars (over trade or religion) and the pathological enrichment of influential individuals who, thinking primarily of their own benefits and, influential as they are, frequently deciding on all important matters (see the reports by Oxfam). All this also has an effect on the economic, political, religious and "climate" migration of desperate people to the rich countries of Europe and the USA, which perhaps once upon a time became rich by exploiting their natural riches and labour.

Unfortunately the destruction of forests, particularly tropical forests, continues with unabated force. Under the Brazilian president, Bolsonaro, the inexorable deforestation of the Amazon is continuing with vast fires, including many believed to be deliberately set (recent satellite images show as many as 72,000 outbreaks). "Smoke from the forest fires even brought about a daytime eclipse in São Paulo, the biggest city in the country. The Amazon is seen as the last, fragile buffer against climate change – if the Amazon is lost, then the fight against climate change is as well." (Romain Houeix in *France 24,* 22 August 2019). The problem of the burning of "our common home" (Macron) was addressed for the first time at the G7 summit in Biarritz, France. Despite this, the fires in South America continue to spread. While indigenous peoples practising their more or less sustainable system of shifting cultivation (as they have done for thousands of years) may in fact be responsible for a small proportion of the fires in the Amazon, for the most part they are the result of deliberate burning in order to obtain new agricultural and grazing land. In 2014 the Amazon absorbed in more carbon than it emitted, therefore reducing global warming (Rasmussen 2014). However, recent studies have suggested that due to fires and conversion into various forms of monoculture, some portions of the tropical landscape already may release more carbon than they store. The Amazon rainforest (and other tropical rainforests) is thus most likely now a net contributor to warming of the planet (Welch 2021), while EU observers have said that fires burning for months in Indonesia's rainforests have released more carbon dioxide than fires burning in the Amazon (Nugraha 2019). As if this were not enough, due to the coronavirus pandemic Brazil, India and other tropical lands are facing an unimaginable loss of lives (CNN April 2021). After almost half a million victims, Bolsonaro is now, at the time of writing, being called upon to resign (May 2021).

Even the peat swamp forests of SE Asia, with their extraordinarily rich biodiversity, are disappearing with astonishing rapidity. Harrowing footage of a desperate orangutan trying to fight off a bulldozer destroying its habitat has been widely circulated on the internet. An area of 100,000 square kilometres in eastern Australia is also burning, people are fleeing their homes, and newspapers are publishing moving images of people trying to help koalas suffering from burns. While the main causes of the fires in Australia are drought, heatwaves and winds, an indirect contributory factor has been the negligence of President Scott Morrison, who in the middle of the bushfire crisis, the biggest catastrophe in the country's history, chose to go on holiday to Hawaii and failed to acknowledge his objective responsibility for the damage caused by a bushfire of epic dimensions in SW Australia. The Australian bushfires are half as big again as the Amazon fires. We have already mentioned forest fires in SE Asia and in California, but not long ago (July 2021) we were surprised by extensive fires in the otherwise "cold" Canada and Siberia, where temperatures rose to a record 50 °C! The number of fires in the Mediterranean is also increasing (Fig. 1.1), and we have seen record heat levels in Sicily, up to 48.8 °C in Floridia (13. 8. 2021), the highest temperature ever in Europe.

We are unable to stop wildfires from occuring. Recently (august 2023), wildfires are raging in the Canary (Tenerife), Hawaii (Maui) and Balearic islands and practically in the whole Mediterranean, e.g. in Rhodes, Kras region in Slovenia, Lombardy and Piedmont. Greece battles deadly fires near Athens and on Evia island etc. etc., everywhere forcing tens of thousands of residets and tourists to evacuate. Even more, wildfires and intentional fires emit enormous quantities of CO_2 along with PM_{10} and $PM_{2.5}$ particulate matter, often resulting in the complete destruction of the ecosystems an their services. Wildfires may be followed by devastating floods, e.g. in California and Slovenia. As well as destroying animal and plant life, wildfires and intentional fires emit enormous quantities of CO_2, a greenhouse gas, along with PM_{10} and $PM_{2.5}$ particulate matter.

Today, as people are at last beginning to believe in global warming as a result of the emission of greenhouse gases, in particular CO_2, and when we are recognising the fundamental role of forests and the use of voids in the mitigation of climate change, we can try and estimate the effect of forests on CO_2 absorption and carbon sequestration in the vegetation and forest soils, and CO_2 emissions caused by fires. Trees and their wood store a substantial amount of carbon because of their large volume and the long duration of storage. The largest percentage of sequestered carbon or carbon dioxide is in the wood. The mass of CO_2 equivalents in wood can be calculated from the wood's basic density (ρ_b) – the most popular and easily determinable wood density ($\rho_b = m_o/V_{max}$). Since approximately half of the mass of absolutely dry wood is represented by carbon, we can calculate the quantity of CO_2 equivalents contained by green wood. One cubic metre of green wood contains $\rho_{b/2}$ x [(*Ar* C + 2 x *Ar*O/*Ar* C)] kg of CO_2 equivalents. [A_r is relative atomic mass: A_r C= 12 in A_r O = 16]. In other words *caoba* with a basic density of ρ_b = 420 kg/m³ contains 210 x 3.7 = 777 kg of CO_2 equivalents, while *chicozapote*, which has twice the density, contains 450 x 3.7 = 1,665 kg of CO_2 equivalents. From growing stock (the volume of all living trees in a given area of forest or wooded land that have more than a certain diameter at breast height) and increment, we can estimate the CO_2 absorption and carbon sequestration of the forest, and also the amount of emissions in the event of combustion during fires.

Forest soil contains more carbon than the vegetation above it. When mature, a tropical forest, together with its soil, contains a little over 200 tonnes of carbon per hectare – more than half of this is in the soil, while the remainder is in forest vegetation above this. The carbon content for temperate forests is a little less (ca 150 t/ha), while the figure is much higher for boreal forests (ca 400 t/ha) (based on IPCC reports, Jancovici 2007).

The age of the forest plays an important role in CO_2 sequestration. The world's largest carbon sinks are located in young, regrowing forests (see for example *Karlsruher Institut für Technologie*, KIT 2019). A recent study in *Nature* found that "new rainforests grown on degraded lands, known as secondary forests, are capable of storing up to 11 times more carbon than old growth rainforests" (quoted in McCarthy 2016). In production forests mature trees must be cut down when relatively young, before they reach the age of *pathological rotation*, when the volume added by growth equals that lost to decay, which depends on numerous factors affecting stem decay in the stand, among them tree age, felling wounds, basal scars from fire, skidders and logs, stand density influencing the dimensions of branch stubs, and many others. Deforestation and the biological decomposition of damaged trees that accompanies it are the second largest anthropogenic source of CO_2 to the atmosphere, after fossil fuel combustion (Van der Werf *et al.* 2009).

An increasing number of ways to reduce greenhouse gas emissions are being put forward, all of which have negative aspects as regards our standard of living. This is one of the reasons why we are so hesitant about addressing them. It is an interesting fact that "meat production is responsible for 18% of carbon emissions and 32% of deforestation globally. If everyone on the planet gave up meat for one day each week, it would be equivalent of taking 190 million cars off the road in term of carbon emissions" (Fig. 1.2) (McCarthy 2016). Yet the number of cars continues to grow, and who is going to stop us?

In recent years concern for the fate of (tropical forests) has increased greatly, at least at the verbal level. Even Pope Francis, on his recent visit (September 2019) to poor Madagascar, during which he met the missionary Pedro Opeka (of Slovene descent), expressed concern for the country's devastated forests. At one time Madagascar was admiringly known as "Noah's Ark" because of its extraordinarily rich flora and fauna. Today even the last species of precious ebonies (*Diospyros* spp.) and rosewoods (*Dalbergia* spp.) are being felled (Alexander von Bismarck, Executive Director of the Environmental Investigation Agency, USA).

The role of tropical forests is, of course, not limited to photosynthetic CO_2 absorption, the emission of oxygen and carbon sequestration. There are also other irreplaceable forest ecosystem functions and benefits, such as biodiversity, which includes habitat diversity, plant and animal diversity within the various habitats, and the genetic diversity of individual species (cf. e.g. Kemp 1998:44). The situation in the Amazon is no better in other tropical forests, including the peat swamp forests of SE Asia (Sumatra, Kalimantan), with their extraordinary biodiversity, where the orangutan is dying out along with the forests. Areas cleared by fire are converted into plantations of the oil palm (*Elaesis guineensis*) from West Africa and rubber tree (*Hevea brasiliensis*) from South America, and above all "paper plantations". Non-native species predominate. That's globalisation! This, too, is a slow deforestation, since monocultures, even tree monocultures, are not forests, and the ecosystem functions of the latter are critically reduced.

Monoculture tree plantations are "green deserts", not forests. A plantation is a highly uniform agricultural system that replaces natural ecosystems and their rich biodiversity (Jeremy Mongabay 2008).

> Plantations are monocultures, created from seemingly endless rows of identical trees. They suck the water out of nearby streams and ponds and lower the water table, leaving little or no water for people living near the plantations. They deplete soils, pollute the environment with agrotoxics and eradicate biodiverse local ecosystems. Activists in Brazil call them the *green deserts* because of the way they destroy local people's livelihoods and environments. But what is almost as bad as the plantations themselves is that this sort of plantation is given a green seal of approval by the Forest Stewardship Council. (Lang 2008)

Certification of tree plantations is a sad example of "greenwashing" which tries to misrepresent them as being environmentally friendly while hiding their damaging activities.

The aims of the Paris Agreement (COP21, December 2015) – including reducing greenhouse gas emissions, holding the increase in the global average temperature to well below 2 °C above pre-industrial levels, and pursuing efforts to limit the increase to 1.5 °C – are not being implemented, something that was only sadly confirmed at COP25 in Madrid. However, the European Commission recently unveiled its most ambitious plan to tackle climate change and set out how the 27 EU member states can meet a collective goal to reduce net greenhouse gas emissions by 55% from 1990 levels by 2030 ("Fit for 55"). The EU also aims to be climate-neutral by 2050 – an economy with net-zero greenhouse gas emissions. This objective is at the heart of the European Green Deal and in line with the EU's commitment to global climate action under the Paris Agreement. Wishful thinking or, as the Italians say, "*se non è vero, è ben trovato*"? I followed events in Madrid with interest, because I was eager to see what sort of role would be assigned to forests and the use of wood in mitigating climate change, not least given that trees and forests, with their photosynthesising green leaf area, represent the largest solar collector on Earth. I also expected an emphasis on the importance of the substitution of non-renewable materials containing a lot of embodied energy with CO_2 neutral and renewable wood. The exhaust emissions of the growing number of cars on the road were not addressed sufficiently seriously, either. In my homeland Slovenia, though it is extremely rich in forest (in third place in the European Union in terms of forest cover after Sweden and Finland), there is already one car per hectare of forest, and the number continues to rise.

> The corona crisis will most certainly also have an impact on the sustainable use of natural resources.
>
> According to analysis by the Global Forest Watch, tropical forest loss currently accounts for 8% of the world's annual carbon dioxide emissions. Tropical deforestation now emits more CO_2 than the EU. (Fritts 2018)

My thoughts in this context turn constantly to the MFGC. Forest gardens as part of the *milpa* cycle have long represented an excellent sustainable method of soil use for the production of food and wood and the simultaneous preservation of forest with its numerous ecosystem functions and benefits, including CO_2 absorption and carbon sequestration. The *milpa*, in the estimation of H. Garrison Wilkes, a maize researcher at the University of Massachusetts in Boston, "is one of the most successful human inventions ever created".

> Tropical forests contain about 25% of the world's carbon, while other forest regions of the world add another 20% of the world's carbon. In the Amazon basin alone, studies estimate that forests contain 90–140 billion tons of carbon, which could be equivalent to 9–14 decades of human carbon emissions. (*The Global Atlas* 2019)

> Forests absorb almost 40% of all anthropogenic carbon emissions. However, only 15% of global emissions are sequestered by forests. The rest is released back into the atmosphere due to deforestation and forest degradation. To maximize the carbon sequestration potential of forests, the UN launched an initiative called REDD+ (Reducing Emissions from Deforestation and Forest Degradation Programme) in 2007. The programme aims to financially reward developing countries that successfully implement forest conservation, SFM, and reforestation programmes. (McCarthy 2016)

Undamaged old forests ("old-growth forests") ideally represent a balance between CO_2 absorbed and CO_2 emitted. Their carbon pool is full and no longer functions as a carbon sink. Nevertheless, old-growth forests are of inestimable importance for maintaining biodiversity and their numerous ecological and social functions. On the other hand, it should always be borne in mind that the loss of old trees (due to fires in the Amazon and SE Asia) would release huge amounts of already sequestered carbon back into the atmosphere, together with PM (cf. (McCarthy 2016).

Tropical rainforests are the simplest way to keep the climate stable. "They have the dual purpose of storing carbon while also actively pulling it out. Forests are the only machine we have that takes carbon out of the atmosphere" (quoted in Zuckoff 2019). "The numbers suggest that forests, harnessed effectively, could be a powerful climate mitigation tool, but forests have long been overlooked as a climate change solution" (Nancy Harris, Research Manager for GFW, quoted in Fritts 2018). We should also mention that commercial technologies for, among other things, the conversion of CO_2 into methanol (e.g. Huš 2020) already exist and are being developed, although they cannot take the place of photosynthetic CO_2 absorption in terms of quantity. In this context the Orca project, an installation built by Climeworks, seems promising:

> By 2050, humanity will need to pull nearly a billion metric tons of carbon dioxide from the atmosphere every year through direct air capture technology to achieve carbon neutral goals, according to *International Energy Agency recommendations* from earlier this year. The plant in Iceland will be able to capture 4,000 metric tons annually — just a tiny fraction of what will be necessary, but one that Climeworks, the company that built it, says can grow rapidly as efficiency improves and costs decrease 2021. (Birnbaum 2021)

> Forests have four major roles in climate change: they currently contribute about one-sixth of global carbon emissions when cleared, overused or degraded; they react sensitively to a changing climate; when managed sustainably, they produce woodfuels as a benign alternative to fossil fuels; and finally, they have the potential to absorb about one-tenth of global carbon emissions projected for the first half of this century into their biomass, soils and products and store them - in principle in perpetuity. (cf. FAO 9 November 2021)

In production forests, a sustainable CO_2 sink affect is achieved through the planned extraction or production of wood in the process of sustainable forest management (SFM). Trees remain relatively young and sequester more CO_2, while their wood is of significantly higher quality because it is not (yet) biologically and mechanically damaged.

The UK hosted the 26th UN Climate Change Conference of the Parties (COP26) in Glasgow on 31 October – 12 November 2021. The COP26 summit brought parties together to accelerate action towards the goals of the Paris Agreement and the UN Framework Convention on Climate Change, and was perhaps the last chance to achieve that. There was a question what will the 25,000 confirmed guests do, including 120 prime ministers? Unfortunately, the presidents of the countries which produce most CO_2 emissions were not there, including those of China and India, and most of the guests arrived by airplane (a wide-body aircraft on a flight of 4,675 km emits 416 kg of CO_2 per passenger – ICCT CO_2 emissions from commercial aviation).

Photosynthesis is the fundamental life process on Earth. All other forms of life are directly or indirectly dependent on photoautotrophs. All atmospheric oxygen is the product of photosynthesis, which represents practically the only path by which energy enters the biosphere. Even fossil fuels, which today we burn so uncritically, formed through photosynthesis.

"Life exists in the universe only because the carbon atom possesses certain exceptional properties."
James Jeans (1877–1946) *The Mysterious Universe* (1939)

Solar energy, which in the photosynthetically active part of the spectrum is absorbed by pigments in the thylakoid membranes of leaf chloroplasts, is transformed into the energy of chemical bonds. In chemical terms, photosynthesis consists of the splitting of hydrogen from water while releasing oxygen. Hydrogen is transferred from water to carbon dioxide and fixed in the form of a metastable carbon compound. CO_2 only serves as an acceptor for hydrogen. The separation of hydrogen from oxygen is an endergonic reaction that needs the same amount of energy as is released during the formation of water from hydrogen and oxygen. The overall balance of photosynthesis is as follows:

$$6\,CO_2 + 12\,H_2O + \text{solar energy} \rightarrow C_6H_{12}O_6 + 6\,O_2 + 6\,H_2O\ \Delta G^{0'} + 2872\,kJ$$

It is perhaps surprising that the oxygen emitted by a plant during photosynthesis as a "waste" product does not derive from CO_2 but from water, of which only very little is consumed during the process of photosynthesis itself, while a great deal is used to cool the photosynthetic apparatus in the leaves and as a transport medium.

Today, when recipes are in fashion, we might add a recipe for the "preparation" of 1 kg of wood (Frühwald & Wegener 2001, DGfH Deutsche Gesellschaft für Holzforschung, Informationsdients Holz 2001:7):

Photosynthesis: 1.44 kg CO_2 + 0.56 kg H_2O + 18.MJ (solar energy) → 1 kg wood (biomass) + 1 kg O_2 + 18.5 MJ (calorific value)

Burning: 1 kg O_2 + 1 kg wood → 1.44 kg CO_2 +0.56 kg H_2O +18,5 MJ energy

The "waste" oxygen eliminated during photosynthesis is sooner or later used in respiration or in burning/combustion.

Carbon atoms are in constant circulation between living organisms and the environment. The atoms that are "currently" situated in our bodies have already been used countless times in other molecules over the course of the Earth's history. CO_2 that perhaps formed a decade ago during the burning of wood has through photosynthesis and assimilation become part of a crop in a field and, after consumption, part of our bodies, and so on. CO_2 then returns to the atmosphere through the respiration of living organisms or combustion.

An ecological consideration: a single hectare of mature temperate forest absorbs cca.6,4 t CO_2 per year – an amount approxymately equal to the amount produced by driving a mid-sized car with an average fuel efficiency rating of 7,5 litres per 100 km for more than 30 000 kilometres (Jancovici 2007).

Or: the average adult European beech tree with the two–sided leaf area of around 1 000 m^2, ecologically roughly comparable to periodically leafless tall trees in areas with prolonged dry seasons (3 months) in the evergreen seasonal forest (selva alta o mediana) in central Yucatan , absorbs up to 24 kg of CO_2 a year – the quantity emitted by an older car on a 120 km journey. At the same time it produces 11 000 litres of oxygen per day, which corresponds to the daily consumption of 26 people (lungs of Earth?) transpires up to 500 litres of water and produces 12 kg of carbohydrates (Wunderwerk Baum 2019, Torelli 1978). In reality forest consumes allmost all the oxygen it produces. Oxygen is produced by photosynthesis and consumes by decay.

In the wet evergreen forest (selva alta perennifolia) in Selva Lacandona, the absorption of CO_2 and production of oxygen might be higher.

Rosane 2018 and Seymour 2018:

> There's no mystery about the main reason why tropical forests are disappearing. Despite the commitments of hundreds of companies to get deforestation out of their supply chains by 2020, vast areas continue to be cleared for soya, beef, palm oil, paper and other commodities. In the cases of soya and palm oil, global demand is artificially inflated by policies that incentivise using food as a feedstock for biofuels. And irresponsible (illegal) logging continues to set forests on a path that leads to conversion to other land uses by opening up road access and increasing vulnerability to fires.

Yet in the tropical forest the Maya – with no wheeled transport, draft or pack animals or metals – developed a sustainable permaculture called the MFGC and, on its basis, an admirable level of science and culture. Instead of metals, the Maya used obsidian – volcanic glass that can be flaked by percussion or pressure to make fine prismatic blades for cutting tools or projectile points (Muser 1978:118). Their astronomical studies and invention of the concept of zero produced intricate mathematics, a highly accurate calendar, and the ability to determine time to infinity (cf. e.g. Muser 1978:97). Let us recall at this point the groundbreaking discovery by Šprajc using a revolutionary technology LiDAR whic digitally removes the tree canopy from aerial images of the now unpopulated landscapey, revealing the ruins of a sprawling pre-Columbian civilization that was more complex and interconnected than most Maya specialists had supposed. Astronomically oriented sanctuaries and palaces were also built to transfer the celestial order into the Earth's environment. The ancient Mayan calender may originate from 1100 BC, which is many centuries earlier than previously thought (5th century BC.). The results of this analysis were published by the renowed journal Science Adwances). (cf. Križ and Senica 2023). Technically, the Maya were still in the Stone Age at the time of the conquest, but we will never be able to thank them sufficiently for their incredible contributions in the field of food plants. Today these represent as much as five eighths of the agricultural wealth of the USA. They more than doubled Europe's food supply with items such as maize, pineapple, tomatoes, peppers, squash, cacao/chocolate, many beans, avocado, papaya and turkey. Maya ingenuity and patient labour also enriched the world economy with cotton, sisal, tobacco, rubber, numerous spices, cochineal, vanilla, and more. In all this we should not forget the "more remote" South American potato, which saved Europe from hunger but whose diseases caused the "Great Famine" and Irish immigration to America. Between 1845 and 1855, more than 1.5 million adults and children left *Ireland* to seek refuge in America. (cf. e.g. Joel Mokyr in the *Encyclopaedia Britannica*). This exodus may be compared to today's intercontinental emigration from Asia and Africa, for the most part across the Mediterranean to Europe, which is also caused in part by hunger.

The traditional MFGC system of agroforestry used by the Maya depended on the intensive daily work of many hands on tasks such as weeding and the judicious use of fire, producing "black earth", while avoiding negative effects on soil ecology ("high-performance *milpa*"), so ploughs and other tools not even necessary. Hundreds of generations lived and survived peacefully in and with the forest, without destroying it – in a sustainable manner and in balance with nature. At the same time, their system of agroforestry was successfully adaptable to a changing climate, especially drought, which is increasingly accused of being the main cause of the collapse of the Mayan civilisation.

The Maya paradise was a place of peace as well and plenty, where one could rest eternally under the shade of the sacred tree – the *ceiba* or kapok, Lac. *ya'axche*' (*Ceiba pentandra* (L.) Gaertn.).

The Maya lived as part of the forest ecosystem and, long before Europeans, introduced the principle of sustainability and practised a unique form of SFM. While it is true that with their MFGC system they partially altered the botanical composition of the forest for utilitarian purposes, something that may still be observed today, they nevertheless preserved the forest ecosystem and its essential ecosystem functions and benefits, which is of essential importance. Here it should be mentioned that the Maya must have also turned to other intensive food-producing methods. An essential part of the MFGC was the highly sophisticated use of fire, which contributed to nutrient flow and long-term soil fertility in the form of charcoal produced by low-temperature pyrolysis, resulting in long-term carbon sequestration and an increasingly fertile anthrosol ("dark earth"), similar to the *terra preta* of the Amazon (cf. Wilken 1987; Ford and Nigh 2010; Nigh and Diemont 2013). Bruce 1982:

> Classical Maya civilisation probably supported more people in the Lacandon Forest, in an ecologically sounder way, than present use patterns. Recent radar remote sensing research has detected traces of large, ancient, artificially modified and cultivated areas all over the Classic Maya lowland area, of which the Lacandon Forest is a part. It is thought that the Lacandon Indians, who remained relatively isolated until well into the twentieth century, preserved some of the ecological and agricultural skills of their Maya ancestors (TEK).

Highly sophisticated agroforestry involving the preparation of "dark earth" and the sustainable use of the forest links the Maya closely to the Amazonians and, at the same time, additionally explains the density of settlement before the arrival of the Spanish in the two regions. There are of course some important differences as well as similarities. Neither people used metals, while the Amazonians did not use stone at all. Instead, their primary building material was soil (cf. Marshall 2019). Given the proven and surprisingly high density of population in the two regions, both peoples intervened intensively in the forest and transformed it according to their needs for food and materials, although they did not destroy it. We have known this for a long time. In his 1992 paper "The Pristine Myth", the US geographer William Denevan argued that "there is substantial evidence that the Native American landscape of the early sixteenth century was a humanised landscape almost everywhere." Denevan has suggested that the true number of people, even in the "wild and inaccessible" Amazon forest, was some ten million (quoted in Marshall 2019). Indeed, in 1541/42 the Spanish conquistador and explorer Francisco de Orellana reported a surprisingly dense population along the Amazon during his expedition down the length of the river.

The Maya Lowlands was also densely populated at the height of Maya culture, and the Maya population then numbered more than 19 million. Maya cities are believed to have had more than 800 inhabitants per square kilometre, while the population density in rural areas was between 80 and 160 inhabitants per square kilometre (cf. *The Fall of the Maya* 2009; Stromberg 2012). For more information on this (high) population density see Koch *et al.* (2018). The present "pristine" forest in both regions is actually a humanised abandoned "feral" forest with a relatively high proportion of useful trees.

The demographic estimations given in *The Fall of the Maya* (2009) are undoubtedly exaggerated. On the basis of lidar images, the counting of buildings and bearing in mind many other variables, Canuto *et al.* (2018) estimate that the central lowlands were populated by 7 to 11 million people (density 80 – 120 people/km^2) in the late Classic Period (650 – 800 AD). This study is quoted by Koch *et al.* (2019), but they also cite other works, which give even lower figures. On the basis of different procedures, it was also found that in the lidar scanned area of Chactún, where Šprajc *et al.* were active, the population density during the late Classic Period could not have been more than around 63 people/km^2 (Šprajc *et al.* 2021).

Guided by laser images of a remote region of northern Guatemala (La Corona), archaeologists have also discovered the remains of numerous simple dwellings scattered throughout the countryside of a basically dispersed population, now disappeared beneath the dense tropical forest. There were no real town plans (Clynes T.2019, cf. also Coe 1977:110 and Benson 1967:52). What was there in between the scattered dwellings? The answer, I believe, is forest and gardens of different types – kitchen and home gardens and undoubtedly also forest gardens, as an integral part of the *milpa* cycle. The dense feral forest has now covered the abandoned land.

Some more thoughts about the Maya and their forest!

"For people whose mythology describes the whole earth as covered with jungle, to destroy the jungle is to destroy their world,"
(Didier Boremanse about the Selva Maya)

"The Lacandones live in the rainforest, but the rainforest lives in them."
(Manuel Barbosa, director of *Na-bolom,* the "House of the Jaguar", San Cristóbal)

"We are not myths of the past, ruins in the jungle or zoos. We are people and we want to be respected, not to be victims of intolerance and racism."
(Rigoberta Menchú Tum, winner of the 1992 Nobel Peace Prize)

We had the opportunity to see Rigoberta Menchú at the magnificent memorial concert held at the Arena in Verona to mark the tenth anniversary of the death of Luciano Pavarotti, where she came to pay homage to the great singer and friend of the Guatemalan Maya. The *Centro Educativo Pavarotti* (CEP), a junior high school for children aged 12 to 16 located near Lake Atitlán in San Lucas Tolimán, Sololá Department, Guatemala, was founded at her initiative, with the support of the great tenor after whom it is named.

And the very critical words of a great philosopher:
"Es genügt, daβ sie uns zeigen,
Was wir aus ihnen gemacht haben,
Um zu erkennen,
Was wir aus uns gemacht haben."
(Jean-Paul Sartre and Wilfried Westphal, "Die Maya" 1986)
("It is enough that they show us what we have made of them, to see what we have made of ourselves.")

The Maya and the rainforest peoples (e.g. in Amazonia) have long practised and justified in practice the principle of sustainability, which has become a watchword or motto for the survival of humanity in the 21st century, long before Hans Carl von Carlowitz, the official "inventor" of sustainability (or *Nachhaltigkeit* in the German original), and his epoch-making work *Sylvicultura oeconomica* (1713), which at the same time represents the basis of forestry and wood science. The concept of "sustainable" (*nachhaltig*) was not used in a general or broader context, in other words not in the context of forestry and wood science, until 1952, when the Interparliamentary Working Group for a Sustainable Economy of the Federal Assembly of the Federal Republic of Germany adopted the principle that: "Renewable resources must be managed in a close-to-nature (*naturgemäß*) manner in such a way that under the principle of sustainability (*Nachhaltigkeit*), they will also be able to satisfy the needs of future generations of the growing global population." The English expression "sustainability" later became internationally established. "Sustainability" was first discussed at the Paris Biosphere Conference of 1968. In 1969 it was used by the International Union for Conservation of

Nature (IUCN) and it was a key theme of the United Nations Conference on the Human Environment held in Stockholm in 1972, which warned that "what man takes from nature is only on loan". The 1980 World Conservation Strategy defined sustainability as "the modification of the biosphere and the application of human, financial, living and non-living resources to satisfy human needs and improve the quality of human life".

At the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992 (also known as the Earth Summit), it was agreed that "sustainability is an integral part of all natural systems, but with the controlled maintenance of flows of materials or energy through the systems, and that the interruption of these flows or damage to individual components of a system can threaten sustainability" – always with forests in mind. Agenda 21, which is a very bold but frequently unclear document, defines "sustainable development" as the most important global objective. With its conventions and declarations and – extremely important for forest management – the Forest Principles statement, which in Europe has continued with the Ministerial Conferences on the Protection of Forests in Europe (MCPFE), it formally marked out sustainable forest management. It was followed by the historic First Resolution (H1) of the second Ministerial Conference on the Protection of Forests in Europe (MCPFE, Helsinki 1993), which represents the basis of SFM and the modern concept of the "ecosystem approach" (EA), recognising humans as a part of the ecosystem and that human activities both affect the ecosystem and depend on it. Resolution H1 of the MCFPE (Helsinki 1993) also defines, in part on the basis of the Brundtland Report, defines sustainable forest management as the "stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national and global levels, and that does not cause damage to other ecosystems". This is something we wood scientists know and act in accordance with, and it all sounds very "Maya".

Sustainability, and also the principles of permaculture, are the "secret" of the Maya's thousands of years of survival in the forest (cf. e.g. Torelli 2015).

> The original German expression *nachhaltig* means "lasting, stable, strong" and derives from the now archaic but very significant German noun *Nachhalt*, meaning "something put by for bad times" and *Rückhalt* "support, help" (Duden, *Deutsches Universalwörterbuch* 2001). Two German expressions sometimes used as synonyms are *Durchhaltefähigkeit*, "the ability to last" and *Zukunftfähigkeit*, "the ability of the future to survive". As we can see, the MFGC corresponds in full to the definition of "sustainability".

In December 2007 the United Nations General Assembly adopted an intergovernmentally agreed definition of Sustainable Forest Management (SFM) (though not of development, which is in itself problematic): "Sustainable Forest Management as a dynamic and evolving concept aims to maintain and enhance the economic, social and environmental value of all types of forests, for the benefit of present and future generations." Such management provides integrated benefits for everyone: from the survival of local communities to the protection of the biodiversity of ecosystems and, increasingly relevantly, the mitigation of climate change or global warming as a consequence of the emission of greenhouse gases, in particular CO_2.

Ever since then, UN documents (e.g. Rio+20, 2012) have always devoted great attention to "sustainable development". This is supposed to be economically feasible, socially just and environmentally friendly – which given the limited quantity of renewable resources and growing population pressure is neither realistic nor possible!

> On the other hand, the understanding of sustainability and the easy use of the illogical, oxymoronic concept of "sustainable to" or even "sustainable growth" is becoming increasingly broad and unclear (cf. e.g. Ophuls 2011) and, yes, even fashionable, and as a veritable "container" concept. Moreover, if you want to "achieve something" or be considered important, you have to demonstrate your allegiance to sustainability. With the growing popularity of the expression, however, doubts are also growing as to whether this fine-sounding postulated harmony of ecological, social and economic goals is actually feasible at all. Understanding of "sustainability" is left to interests, since in the meantime people have "invented" two different types of sustainability: "weak" and "strong". "Weak" sustainability is advocated by the followers of neoclassical economics. They claim that it is possible to replace natural capital with material capital. We wood scientists, on the other hand, assert the "strong" variant of sustainability through the ecosystem approach and believe that renewable sources should only be used to

the extent to which they are able to regenerate themselves, and that the emission of harmful substances should not exceed the reception capacity of environmental media and ecosystems. Sustainability can only be "strong". This was already something asserted by Hans Carl von Carlowitz, the inventor of "sustainability", when he claimed in his famous work that we should only harvest as much wood as regrows, or, more broadly speaking, that we should only consume as much as we create (without harming nature). The great wood shortage during the Baroque period meant the birth of sustainability and the "golden fiscal rule" that is still relevant today.

The concept of "sustainable development" (German: *nachhaltige Entwicklung*) is more recent. In its essence, it represents the organisational principle of sustainability. It arose in the context of the general political understanding of the Club of Rome report "Limits to Growth" (1972) and the report of the World Commission on Environment and Development entitled "Our Common Future", also known as the Brundtland Report (1987). The latter defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Sustainable development must take into account social, ecological and economic factors of living and non-living resources and long-term and short-term benefits, and also the faults of alternative actions, as envisaged by the (in many ways problematic) "three-pillar model" (Elkington 1990). The three "pillars" are supposed to mutually reinforce each other, but serious doubts are appearing about the reality of sustainable development. The word "development" sounds very promising, especially for "undeveloped" countries, although it is precisely here that their former colonial masters have utterly subordinated the ecological dimension to the economic "pillar". We should add that no development can be sustainable in the long term. Development also means changes, which require an increase in the consumption of material resources. There is no question that sustainable development should be based on a balance of ecological, economic and social goals, although a fundamental opposition exists between industrial growth and the conservation of natural resources. Not only that, but sustainability on just one continent is not sustainability, while growth in gross domestic product has nothing in common with sustainability.

The expression "sustainable development" is a dangerous fiction which, though it may have been born out of a sincere desire to promote sustainability, has been given a distorted or misleading meaning by economic theories that do not understand or take into account physical reality. In one sense, sustainable and his diplomatic compromise or consensus formula by means of which it is hoped to resolve the frequent goal conflicts between environment and development (economic growth above all in developing countries). Generally speaking, the expression "sustainable development" is extremely ambiguous, if not indeed problematic, since it connects two mutually exclusive concepts and is something of an oxymoron. The widely used expression "sustainable forest development" can easily be substituted with the clearer term "sustainable management" (SFM), which substitutes the German terms *naturnahe/ naturgemäß Waldwirtschaft* ("close-to-nature/ natural forest management"). (Torelli 2015)

During the prodigally luxurious Baroque period, and the even more wasteful Rococo period that followed, the most precious woods were inexorably and unsustainably plundered to make ostentatious furniture, a practice that unfortunately continues illegally today, most harmfully of all in Madagascar.

Somewhat better known is the sad fate of Haiti, which Columbus described as a "paradise on Earth" and from where Europe obtained, after destroying its wonderful tropical forests (and its original inhabitants, the Taino "Indians"), cane sugar and its alcoholic derivative rum (sugarcane was originally brought from SE Asia via Madeira and the Canary Islands). Another notable story is that of the "miraculous" gum from the heartwood of the "lignum vitae" (*Guiacum sanctum*), reputed to be a "miracle" cure for the terrible syphilis epidemic that had broken out in Europe shortly after the return of Columbus's sailors (cf. Torelli 2006). Unfortunately the cure turned out to be mere snake oil, but it contributed decisively to the destruction of this wonderful tree and its remarkable wood.

Certification and chain of custody, which are a *sine qua non* for SFM in the developed world, are unfortunately mere wishful-thinking when it comes to tropical forests. The destruction of tropical forests also continues in "milder" form with the problematic conversion of forest into monocultures, for example of Australian (!) eucalyptus in the Amazon and the West African oil palm in SE Asia (again, that's globalisation), and soya plantations for raising livestock for meat and hides. Many "colonial" imports now thrive on land that was once tropical forest. We go for an (African/American) coffee, or an (American) hot chocolate, or perhaps a cup of (Asian) tea, served of course with healthier tropical brown cane sugar (likewise Asian), and then go to bed at night on a medically recommended mattress made of natural "tropical" latex from the Amazonas rubber tree (*Hevea brasilensis*). (Here we can at least partially exempt shade-grown coffee and cocoa, which are grown under a canopy of trees.) Monoculture bananas from Asia are another thing we cannot live without, and then there are newspapers made of paper from "fast" tree species in the Amazon and SE Asia. We are also eating up the Amazon with hamburgers. With a clear conscience and unintentionally we are thus continuing with the destruction of the last tropical forests. The story of the extraction of latex from the white rubber vine *Landolphia owariensis*, a woody vine known as *eta* that grows in the Congo, is too horrific to repeat it here, but it is typical of European greed. Now that the Amazon is burning, I advise everyone to give up their tasty hamburgers made with the beef of cattle that may have been fed with Amazonian soya.

Moreover, climate change in the form of global warming is most frequently mentioned in connection with the destruction of tropical forests. Despite the promising climate resolutions – the implementation of which is likely to be postponed – tropical forests are unfortunately continuing to disappear at an inexorable rate. At the same time, transport using biofuels, above all palm oil, is being promoted as environmentally harmless. We are using more paper every day, and since the elimination of plastic bags are sure to use even more of it, and in any case the amount we use is unacceptable. Every third tree that is felled is used for the manufacture of paper. Clearly the pressure on tropical forests will continue to grow until…

At the Earth Summit in Rio in 1992 it was unanimously agreed that "sustainability is an integral part of all natural systems, but with the controlled maintenance of flows of materials or energy through the systems, and that the interruption of these flows or damage to individual components of a system can threaten sustainability" (cf. e.g. Kemp 1998: 389). Agenda 21, which is a very bold but frequently unclear document, defines "sustainable development" (!) as the most important global objective. With its conventions and declarations and – extremely important for forest management – the Forest Principles statement, which in Europe has continued with the Ministerial Conferences on the Protection of Forests in Europe (MCPFE), it paved the way for SFM.

As we already know, the "invention" of the principle of "sustainability" some 300 years ago (in the context of forestry and wood science) also gave rise to the increasingly relevant but difficult to implement "fiscal rule", also known as the "golden fiscal rule", under which a balanced budget must always be ensured and the government (i.e. the state) is prevented from borrowing beyond its capacity to repay. Simply put: outgoings must always be less than revenues into the state coffers. To put it another way: we can only spend what we earn, with a little something put aside against hard times. Sustainability is effectively an "invention" of forestry and wood science, and has for three centuries represented the guiding principle of forest management (cf. Torelli 2015).

At this point it is worth respectfully remembering the American statesman Benjamin Franklin (1706–90), who lived at the time that the principle of sustainability was beginning to gain ground, and who supposedly said:

"Happiness is spending less than you earn."

There is no need to explain the concept of sustainability to the Maya, however, since for centuries, if not millennia, they have lived in and from the tropical forest, for which reason they have also conserved it. Their TEK, which we are today discovering and increasingly admiring, and which is the basis of their sustainable permaculture-based agroforestry in the MGFC system (cf. Nations and Nigh 1980), is their great message to future generations and, unquestionably, a significant part of the solution when it comes to the survival of such forests.

Present-day science frequently attempts to attribute the "mysterious" collapse of Maya civilisation above all to the stresses of deforestation and drought and the increased need for food due to overpopulation/population stress, the resulting over-farming and warfare. In most cases the collapse of a civilisation is usually a syndrome consisting of multiple harmful factors (see below), and yet the Maya, and in particular the Lacandon, still live in their forest. Their absolutely sustainable agroforestry (MFGC), developed on the basis of extraordinary TEK obtained over the course of centuries and comparable to today's ecological engineering, is still alive and well. In contrast to the disastrous, non-sustainable, intensive monocultures of the new homesteaders in the Maya tropical forest, the traditional "eternal" MFGC of the Lacandones is proven to be sustainable. It is a practice that allowed the Maya to keep the use of primary forest to a minimum! It is about time that we, too, learned some of this (cf. Nations 1980). Unfortunately the sustainable management of the Maya based on the traditional MFGC is beginning to be forgotten. According to a reliable estimate (Nations and Nigh 1980), just 20% of the Lacandones were still living in the traditional way in 1980.

Not only that, but the Maya, and certain other inhabitants of tropical forests, may also be considered the originators of *permaculture*, a form of agriculture in which a plot of land is maintained in cultivation and constantly in production by relying on renewable resources and a self-sustaining ecosystem. Permaculture represents an ethical system of planning that is suitable for the production of food, the use of land and the construction of dwellings. It combines ecology, landscape, organic farming, architecture and agroforestry. Central to the identity of these people, who have successfully and sustainably practised it for millennia, is their intimate connection to the forest lands they have lived in, worshipped and protected for generations.

Sustainable forest management and permaculture are linked by concepts such as ecology, ecosystem, permanence (permaculture!), sustainability and the forest garden, all with the idea and purpose of surviving harmlessly and sustainably in nature or the forest. A revolving cycle lasting thousands of years, the MFGC represents the sustainable coexistence of the Maya and their forest.

The word "sustainability", if it is even necessary, is today gaining an increasing number of meanings or synonyms: self-sufficiency, balance, stability, harmlessness, thrift, ecosystemicity, socially responsible management, honesty, altruism and the responsible treatment of nature. "Sustainability" formulated in this way therefore certainly does not mean strict immutability, but also implies adaptation, which is maintained precisely through change (cf. Torelli 2015):

> Today we know that stable systems have mechanisms that maintain balance and in this way level out fluctuations in the environment.
>
> Wood scientists, who try to take an ecosystem approach to forest management (close-to-nature management), are well aware what "sustainable" means. A forest (like every ecosystem) is a community of mutually dependent organisms – flora, fauna, human beings and the physical environment – that inhabit it. Individual organisms "cooperate" with each other and the environment in numerous ways that are facilitated by the flow of materials and energy. This includes, for example, the *symbiosis* representing a close and long-term biological interaction between two different biological organisms, be it be mutualism, commensalism or parasitism (*Symbiosis* 2019), or *mycorrhiza*, a close physical association between a fungus and the roots of a plant, something extremely important for the tropical forest (cf. Strasburger 2008:1088), and so on. Relationships are dynamic and routinely respond to changes without changing the basic characteristics of ecosystems. In contrast to the destructive and forcibly imposed liberal capitalist social system, the forest ecosystem is the best preserved part of nature and, with its numerous ecosystem functions, is indispensable for human survival. There is a dynamic balance in the forest between birth and death or between growth and biological decay. After felling, humans can "borrow" wood for a shorter or longer period and then return it harmlessly to the great "eternal" carbon cycle, either via biological decay or through controlled incineration with energy recovery.
>
> Even in trees themselves, there is a balance of structures and functions (homeostasis). The size of the photosynthetic area (i.e. the leaves) is in functional equilibrium with the system of active fine roots and the living cells of the sapwood. If a storm damages part of the treetop, a new equilibrium is established that sees a reduction in the size of the root system and sapwood, and vice versa. A tree is also an excellent example of thriftiness: before leaf abscission, useful substances return (!) to the body of the plant, where they are used again. The secret of the "eternal" youth of woody perennials lies in their annual renewal of vital tissues, i.e. the leaf area with the photosynthetic apparatus, active fine roots and the wood tissues that are visible in cross section and radial section as growth rings. Only in this way can a tree reach the venerable age of 5,000 years and more, like the bristlecone pine (*Pinus longaeva*) respectfully known as Methuselah in the White Mountains of California. Since the leaf area of trees no longer increases after the tree reaches a certain age, older tissues consequently die off in a programmed

> manner and are transformed into the heartwood of the trunk and branches and dead outer bark (rhytidom), in this way enabling the formation of new tissues and seeding, and thus survival and "eternal" youth. Like human society...

"There's nothing that keeps its youth, so far as I know, but a tree and truth."
(Oliver Wendell Holmes Sr., American physician, poet, and polymath)

Von Carlowitz, the "inventor" of sustainability, and Bill Mollison and David Holmgren, the "fathers" of permaculture, could have learned everything from the Maya and perhaps the peoples of the Amazon, who lived sustainably and survived in their forests for millennia until they were reached by the much-vaunted (and unrestrainedly non-sustainable) civilisation and technology of the "developed" Europeans. If you are brave enough, you might perhaps read Gert von Paczensky's excellent book *Weiße Herrschaft. Eine Geschichte des Kolonialismus* (1979) (Torelli 2015).

And then there is this: incredibly, hundreds and perhaps even thousands of years before Charles Goodyear, the Maya discovered the vulcanisation process that made commercial rubber viable. Two MIT researchers have found that ancient rubber for ritual balls was made from latex of the *hule*, wild rubber, *kiikc,* Lac., *k'ik'* (*Castilla elastica*) by mixing it with the juice of a perennial, herbaceous liana, Lac. *hach hut'kih* (*Ipomoea alba*, a species of morning glory/moon vine), a process which preceded Goodyear's vulcanisation by several millennia. The Maya are consequently the first polymer scientists! Once again we can only bow to them in wonder...

The rampant destruction of tropical forests began more than half a millennium ago with the search for a shorter route to Asia, when the Genoese navigator Christopher Columbus (Italian: Cristoforo Colombo; Spanish: Cristóbal Colón), attempting to find a "western" sea passage to the East Indies on behalf of the Spanish crown (for which reason he was also known as "Iberia's pilot"), unexpectedly encountered (without realising it) a hitherto unknown continent, that was later named "America" and, on his fourth voyage (1502), a magnificent mahogany canoe, 25 metres long and three metres wide, bearing elegantly dressed Maya traders and passengers who used cocoa beans as currency.

It would be unfair to describe Columbus simply as an ambitious and greedy conqueror and forget about his admiration for the forest and trees. Las Casas quotes an extract from Columbus's journal of this third voyage that shows how Columbus was entranced by the beauty of the Haitian forests: "The green of the trees is so intense that it is no longer green. The trees were here so luxuriant that their leaves ceased being green and became almost black" (quoted in Todorov 1982:33–37, cf. Niess 1991:119). By contrast the conquistadors, the ruthless professional soldiers who followed Columbus, were only interested in gold, and in their lust for this they caused the greatest genocide in human history (cf. Todorov 1982). As the famous conquistador Hernán Cortés admitted frankly: "We Spaniards suffer an affliction of the heart that can only be cured by gold."

1.1. Americas' depopulation after 1492 :

LIA, Maunder Minimum and Great Dying and their influence on the development of forests and xylogenesis as well as the possible effects on the growth of "Stradivari spruce wood" and hypothetical development of Classical and Romantic music in Europe

In the context of climate change, only now are we gaining more accurate estimates of the dimensions of the genocide that followed the arrival of white Europeans in the Americas. Stannard (1994) estimates that some 100 million natives died either directly in unequal battles or as a result of the diseases the Europeans brought with them: "The European and white American destruction of the native peoples of the Americas – the "Great Dying" – was the most massive act of genocide in the history of the world."

The decreases in the human population due to the "Great Dying" after the colonisation of the Americas after 1492 and the Black Death in Europe (1347–1351), resulting in the deaths of an estimated 75–200 million people, have been proposed as among the main causes of the "Little Ice Age" (LIA; 1300–1850), others being cyclical lows in solar radiation, heightened volcanic activity, changes in ocean circulation, variations in the Earth's orbit and axial tilt (orbital forcing), as well as inherent variability in the global climate.

The Maya and other conquered peoples paid dearly for their gold, and even more dearly for what they did not have (Yucatán), and therefore had to work even harder in their fields.

Today scientists are assessing the "climatic" aspect of the terrible genocide in the Americas:

> By multiplying the population that died in each region (regional depopulation rate), cross-multiplied by the corresponding regional estimates of *per capita* land use, we estimate that 54.5 million people died and a median area of 55.8 million hectares of anthropogenic land use was abandoned and recovered to forest or other natural vegetation. It is estimated that 55 million indigenous people died following the European conquest of the Americas beginning in 1492. The abandonment resulted in increased CO_2 absorption and a consequent lowering of surface air temperatures in the two centuries prior to the Industrial Revolution. Reduced atmospheric CO_2 levels led to a decline in radiative forcing that may then have contributed to the coldest part of the LIA. (Koch *et al.* 2019)

> Abandoned fields and woodlands, once carefully cultivated, must have been overrun by wild plants that would have drawn huge amounts of carbon dioxide out of the atmosphere. Perhaps that was the cause of a sixteenth-century drop in atmospheric carbon dioxide, which scientists had earlier uncovered by sampling ancient bubbles in polar ice sheets. By weakening the greenhouse effect, the drop might have exacerbated cooling already under way during the *Grindelwald Fluctuation* (1570–1620) […] We cannot firmly establish that depopulation in the Americas cooled the Earth. The co-authors never claim, for example, that depopulation caused the LIA, as some headlines announced, nor even the Grindelwald Fluctuation. At most, it worsened cooling already under way during that especially frigid stretch of the Little Ice Age. (Degroot 2019)

Besides the Grindelwald Fluctuation, the other three particularly cold periods in the LIA were the Spörer Minimum (1460–1550), the Maunder Minimum (1645–1715), and the Dalton Minimum (1790–1830).

Interestingly enough, according to the fifth IPCC report (AR5 2014), the influence of the sun on our climate since pre-industrial times, in terms of radiative forcing, is very small compared to the effect of greenhouse gases, which is evidence of the importance of CO_2 emissions with regard to global temperature. Thus alongside the “prolonged sunspot minimum”, a reduced concentration of CO_2 or its increased photosynthetic absorption may have had an important or even decisive influence on stronger global cooling in the middle part of the LIA.

This invites reflection. In the abandoned areas the leaf area would have increased, and with it CO_2 absorption, which in a young, growing forest is particularly high. This really may have caused the temperature to fall by 0.6 °C in the late 16th and early 17th centuries (cf. also Senica 2019).

> Estimates of the magnitude of cooling during Maunder Minimum range from 1-2 °C (Shindell *et al*. 2001) compared to the 0.5 °C – 1.5 °C range for the LIA overall (Rind, Overpeck 1993). (Burckle and Grissino-Mayer 2003)

On the other hand it is doubtful that a fall in global temperature by just half a degree could really have caused such a change. Even the expression “Little Ice Age” seems excessive and not entirely appropriate for this assumed fall in global temperature!

It is difficult for me to imagine that the tragic decrease in the human population, alongside proven cyclical lows and solar radiation (“Maunder Minimum”, which endured from approximately 1645 until 1715), could be one of the significant causes of the global fall in temperature.

The Black Death, also known as the Great Plague (1347–1351) might have had even worse effects. It is estimated to have killed 30 to 60% of Europe’s population. Dendrochronological evidence of such effects, however, would require extremely old trees (700 years old), of which, however, there are almost none left today, with the exception of the wood contained in old buildings.

When thinking about the collapse of the Maya, I cannot help thinking about the present COVID-19 pandemic. Alongside the general cooling of the economy, the loss of life and jobs and the uncertain destiny of globalisation, including long-distance tourism, we expect a strong reduction in air and car transport and thus reduced CO_2 emissions, and consequently some cooling. The collapse of the Maya population could also have been caused by an unknown virus, at least as a significant contributing factor. This is indicated by the surprisingly synchronous last dates on stone monuments.

Here I must once again mention the disintegration of the Mayan civilisation connected with the death or out-migration of 90 to 99% of Classic-era Maya people between 700 and 900. “In the population vacuum, the vegetation of the Maya tropical forest gradually regenerated” (cf. Nations 2006:259).

1.2 Attempt at a musical interpretation of the climate cooling – the violin and piano

At this point I will quote an interesting article by US researchers which made me think about a musical interpretation of the global lowering of the planet's temperature.

Burckle and Grissino-Mayer (2003) hypothesised that the longer winters and cooler summers produced wood that had slower, more even growth – desirable properties for producing higher-quality sounding boards. During period of reduced solar activity the relatively low temperatures caused trees to lay down wood with narrow annual rings, creating wood with a high modulus of elasticity (MOE) and low density. During Stradivari's later decades, he used spruce wood that had grown mostly during the Maunder Minimum. These lower temperatures, combined with the environmental setting (i.e., topography, elevation, and soil conditions) of the forest stands from where the spruce wood was obtained, produced unique properties and a superior sound quality. This combination of climate and environmental properties has not occurred since Stradivari's "Golden" period. (1700-1720/25). During this period Stradivari created violins whose sound boxes are unmatched even today.

Violin makers know that reduced growth is not enough to produce the best tonal wood for violins. Only very old (300 years), perfectly upright spruces with short crowns and a long series of narrow rings at the tree base are suitable, of course without juvenile and compression wood and sapwood, which has a higher EMC than the (spruce's) colourless heartwood. The tonewood of "golden" Stradivarius violins began to grow before the year 1500, i.e. at the end of the Spörer Minimum. For physiological reasons, growth rings are narrowest in the lower part of the trunk, compared to the width of growth rings below the crown. The same annual increment layer can be at least twice as wide further up the tree, near the crown, than at a greater distance on the base due to the provision of assimilates. This is also the reason for full-woodedness i.e. the formation of cylindrical trunks (German: Vollholzigkeit) in stands of "violin" trees with short crowns. In a dense stand the lower branches are "pruned" faster than the upper ones due to the lack of light. Although the trunk is younger at the top, the wider rings mean it is not significantly narrower than at the base of the tree where the trunk is older.

"Violin" tonewood of the finest category has an optimal growth ring width of 1–2 mm. In one of the best preserved Stradivarius violins, known as the "Messiah" (cf. Grissino-Mayer *et al.* 2004), the rings are between 1.25 mm (year 1582) and 1.863 mm wide (year 1589) and with a proportion of denser latewood of between 21% and 25% and a density in absolutely dry state ρ_0 of between 360 and 420 kgm^{-3} (cf. also Trendelenburg 1939, from Trendelenburg and Mayer-Wegelin 1955:420). Such wood combines great strength and stiffness (MOE) with relatively low density. The MOE is positively correlated with the density. The decisive factors for acoustic properties are high sound velocity in the axial direction, generally lower density and a high MOE. All these properties are found in mountain spruce, which thrives in conditions of a short vegetation period, for the most part in less fertile leached soils, which are the main reason for the more modest growth increments, i.e. narrower, slow-grown, close-grained growth rings, and uniform growth.

The conclusion may be a very dramatic one – "Reduced solar activity in the 17th century may be the reason for the perfect sound of Stradivarius violins"! (D Whitehouse 17 December 2003 in the BBC NEWS world edition).

Of course, the proven drop in temperatures may be just one of the factors responsible for the creation of superior tonewood for violins!

As a rule, in normal wood a low density and high elastic modulus tend to be mutually exclusive in conifers.

It is s also true that in the wood with extremely narrow growth rings (below 1 mm), which is not used for violin tops, the latewood proportion is very low (cf. Kollmann and Cote 1986:307,306; Holzlexikon 2003:1134).

> Normally in the softwoods, however, increasing rate of growth results in an increased percentage of low-density earlywood and consequently both density and strength decrease as ring width increases. Exceptionally, it is found that very narrow ring also have very low density. This is characteristic of softwoods from the very northern latitudes where latewood development is restricted by the short summer period. (Dinwoodie 2000:165)

And even that's not all. In the course of the ordinary storage of tonewood in the Venetian Lagoon, the alleged unreduced MOE of the pit membranes of bordered pits decayed as a result of infections and the cell walls of the tracheids were somewhat eroded. The people of Cremona could of course not know this, but it actually increased the "tonality" or tonal permeability of the wood.

Also interesting are the findings by J. Nagyvary, an American of Hungarian origin (as explained in Torelli 2005c).

After the unsuccessful anti-communist student riots, he fled to Switzerland in 1956, where he studied chemistry under the Nobel prize-winner Paul Karrer. At the same time he studied the violin and not just on any old violin but Einstein's violin. He discovered that the violins from Cremona were never attacked by woodworms due to the insecticidal action of borax, which was in general use at the time. Chemists know that borax effectively links up polymers. No other substance could have made the wood harder and its sound more brilliant! As the climate in northern Italy is very humid, the luthiers of Cremona used various sugars and gum from fruit trees to combat decay. It is also thought that they used a very fine crystal powder to fill cavities in the wood and prevent woodworm. They are said to have used quartz and Venetian glass. They would mix the quartz dust and fruit gum, and rub the mixture into the outer surface of the cover, which then became very hard and brittle. This should at least theoretically have helped make a lighter sound. Other fillers, e.g. shellac or animal adhesives can help create a brighter sound, but cause unpleasant crackling at higher frequencies. Stradivari's violins have a bright sound and are not "noisy", because their coating is brittle and disintegrates into infinite pieces. The vibrations at "noisy" frequencies are highly muted. This results in a cleaner sound.

Hwan-Ching Tai, a professor of chemistry at National Taiwan University, found evidence of chemical treatments containing aluminium, calcium, copper and other elements — a practice lost to later generations of violin makers.

Another possibly decisive factor was the slow release of growth stresses in the wood during the usually lengthy storage, particularly above cesspits, which give off ammonia that has a proven effect on the plastification of wood. This is a technique that even Stradivari supposedly used.

Nagyvary assumes that Stradivari did not use wood that had been dried directly, but is supposed to have been stored in water for a long period of time beforehand. Aqueous solutions can penetrate much deeper into saturated wood. In the course of his 25-year violin-making career, he studied the effects of different chemicals on sound. He used different fruit gums and animal proteins, including egg-white, as well as many soluble salts and insoluble crystals. In the end he used chitin from the shells of crustaceans. The sound thus achieved was brilliant, but at the same time "noisy". He notes critically that Stradivari most definitely did not do this (Choi 2002). Nagyvary also mentions the traditional method for releasing growth stresses. To achieve this, the wood had to be stored above a manure pit! Ammoniac and the high relative air humidity enable the plastification of wood, as well as many other chemical reactions such as ester hydrolysis in wood, the elimination of lignin and the growth of mould. Such wood does not crack. Nowadays, we can do this in a container in an ammoniac atmosphere. The process lasts a few weeks and is supposed to reduce the "noise", while the wood acquires a golden colour due to the oxidation of lignin.

Some people soak the wood in boiling water. In this process, the internal tensions are broken down and the volatile and soluble components removed. The most important ones are pectic acids and polyoses. A moderate elimination of these hygroscopic substances lowers the hygroscopicity of wood and equilibrium humidity, while at the same time increasing its stiffness, i.e. the modulus of elasticity. Stiffness is very important as without it the wood cannot withstand the pressure of the strings under the bridge. The stiffness of the wood can be increased by adding bone dust or chitin to boiling water. A similar effect, but without high temperatures, can be achieved by using microbes to modify fresh wood. This was achieved inadvertently in the 17th and 18th centuries when wood was stored in water. In Italy, this was the case in the Venetian Lagoon where wood for the *Arsenale* shipyard was kept. Such wood was colonised by bacteria and fungi. The pit membranes of border pits decayed, and the cell walls were partially eroded, while the mechanical strength remained practically unchanged. The permeability of wood was thus increased by up to 50 times. When dried directly in the open air, the pits simply close (aspiration). Nagyvary is convinced that microbes played an important role in the production of violins. Unfortunately, it is very hard to acquire the wood of violins made by important masters. Nevertheless, Nagyvary succeeded in acquiring six spruce samples of violins made by Stradivari, Guarneri, Guadagnini and Ruggeri, and studied them with a raster microscope. All of them contained the remains of fungi and some of them even had traces of bacteria, and thus the wood of old violins was more permeable than the wood of modern violins. The violins from Cremona also had traces of clay and calcium carbonate – from having been stored in water or having undergone further treatment (cf. Torelli 2005c).

Recently the Swiss bioengineers Swarze Francis, Spicher and Fink (2008) found that by treating the wood used in a violin with special fungi (*Physisporinus vitreus* and *Xylaria longipes*) it be-

In the end the MFGC creates valuable woodlands with managed succession.

Violin trees on the Pokljuka and Jelovica plateaux (photo: Matjaž Čater).

comes lower in density and higher in elasticity. This has a direct influence on the violin's acoustic properties, and brings it closer to the instruments built by Antonio Stradivari. (cf. Wise 2012)

A similar pathological effect could also have the storage of spruce tone wood in the Venetian Lagoon! According to Schwase the speed of sound increases with the stiffness and decreases with the density.. All wood decay fungi reduce density and the speed of sound. However a few members of the Xylariaceae (Ascomicetes) reduce wood density without altering the speed of sound. Schleske explained that a high ratio of speed of sound to density in material quality is a characteristic feature of superior tone wood and has the most significant impact on the acoustic properties of a violin.

And very important:due to the global warming it is becoming increasingly difficult to find superior tone wood even in high altitudes. (cf. Harris 2012.)

Sensationalist headlines appeared in the literature based on such findings, indicating that not only was modest and uniform growth important, but also slight biological decay: “Superior wood for violins – wood decay fungi as a substitute for cold climate” (Swarze Francis WMR., M. Spicher and S. Fink in *New Phytologist* 2008, 179:1095-1104); “Fungus-treated violin outdoes Stradivarius” (Empa, 14 September 2009 in *Science Daily*; “Solved: the mystery of why Stradivarius violins are best” (Connor S., 23 October 2011 in *The Independent*); “Treatment with fungi makes a modern violin sound like a Stradivarius” (Delbrück M., 8 September 2012 in *Science Daily*); “How to make a modern violin sound like a strad: just add fungus” (Wise B., 12 September 2012 on the WQXR blog), and “Fungi treatment produces Stradivarius-worthy sounds” (Boness L., 10 September 2012 in *Innovation, News, Science*), among many other reports.

Evidently reduced and homogenised growth due to a drop in temperatures does not suffice for the creation of “Cremona wood”! In this context the dendroclimatic findings of Burckle and Grissino-Mayer (2003) become less sensational, and above all insufficient for explaining the creation of primary tonewood for violins.

Stradivari and the other *cremonesi* (from the city of Cremona on the River Po) obtained high-quality mountain spruce from the present-day *Parco Naturale Paneveggio* in the eastern part of Trentino (the autonomous province of Trento). Located in the northern part of the *Parco* is the *Foresta dei Violini* – the forest of violins – where old, slow-growing and full-wooded spruces up to 40 metres tall with short crowns, of a form known as *Abeti di risonanza*, can be found in an area covering 2,700 hectares. The spruces there are supposed to grow uniformly and have particularly narrow growth rings, and exceptional acoustic properties. The old Italian luthiers also selected wood by the sound or tone made when a log fell off the end of the steep and rapid timber chute. They called these logs *cantori*, or singers! The famous Tyrolean luthier Jacob Steiner also selected “his” wood by its sound. He would only choose logs that gave off a characteristic high, long-resounding sound as they slid down the chute (Feuerstein 1935 quoted in Schmidt-Vogt 1996:178). Luthiers also selected trunks with drying tops, which had drier but still healthy wood. Slowly dying trees secrete a lot of resin, with the result that the wood contains less of it (Feuerstein 1935 quoted in Schmidt-Vogt 1996:179). I am convinced that such spruce trees still grow, however, due to the poorer state of forests, especially after the Industrial Revolution, they must be rarer.

High in the mountains, above 1000 m, for example on the Jelovica plateau in Slovenia, old spruces produce precious tonewood (known in German as *Tonholz*, *Klangholz* and *Resonanzholz*) with the “prescribed” narrow growth rings (1–2 mm). Here and there in Slovenia tonewood of the finest quality is produced. It has been used by the top Slovene luthiers Vilim Demšar and his father Blaž Demšar, and is now used by their grandson/great-grandson, who is also a woodworker and luthier.

Viva in silvis – fui dura occisa securi; dum vixi tacui – mortua dulce cano

“I lived in the forest; I was felled by a hard axe; as long as I lived I did not say a word, but in death I sing sweetly.”
(Inscription in an old violin, cf. Armin Lutz 1972)

In other words we could hypothetically (oh, the horror!) at least partially blame the genocide in the Americas, Grindelwald Fluctuation and Maunder Minimum for the fall in global temperature that is believed to have led to the more modest and uniform growth increment in the resonant spruce needed for the tops of the famous Amati, Stradivarius and Guarneri violins. As a wood scientist, however, I do not believe that such a small fall in global temperature, whether for astronomical reasons or as a result of genocide, would have significantly slowed growth and increment. But this could mean that without such genocide there would have been no slower growth of the “cool” mountain spruces, no famous luthiers such as Amati, Stradivari and Guarneri, and consequently no great composers and performers. This would mean (my current selection) no Vivaldi's *Le Quattro Stagioni*, no Paganini's *Moto Perpetuo*, *Campanella* and *Carnevale di Venrezia*, no Sarasate's *Zapateado*, *Zigeunerweisen* and *Jota Aragonesa*, no exciting development of the orchestra. By 1700 it was widely accepted that the core of any orchestral group was the string family (cf. Kendall 2000:266). The Classical orchestra (1750-1830), with principal composers Mozart (1756-91), Beethoven (1770-1827) and Haydn (1732-1809), has a wooden core consisting of the string instruments with eight first and seven second violins, as well as four violas, three cellos and three double basses, and the Romantic orchestra (1830-1910) with the chief composers Wagner (1813-83), Berlioz (1803-69) and Mahler (1860-1911) has even more: 21 first violins, 20 second violins, 18 violas, eight first cellos, seven second cellos and 10 double basses, followed by the modern symphony orchestra as we know it today. The strings were joined by the – again wooden – woodwind instruments: piccolos, flutes, oboes cor anglais, clarinets, bass clarinets, bassoons and harps. What a lot of valuable wood! In order to become acquainted with the leading role of the strings in the orchestra, I propose we listen to the polonaise from the opera *Eugene Onegin* by Tchaikovsky (1879) performed by the famous Berlin Philharmonic Orchestra, founded in 1882, conducted by the charismatic Claudio Abbado. Then we should listen to Liszt's brilliant transcription of the opera (1880).

It is perfectly logical that the finest music of the Classical and Romantic eras has been and continues to be performed on valuable Cremona violins.

"Orchestral music is one of the glories of the world."
(Georg Solti)

Even more, for acoustic and aesthetic reasons, all the best-known concert halls and recording studios around the world are panelled in wood, and always have a wooden floor. Here I should make particular mention of the famous Grange de Meslay in France, an enormous medieval barn with a perfectly preserved wooden framework, the discovery of the great Russian pianist Sviatoslav Richter. It represents an ideal auditorium for solo and chamber music.

Moreover, without the "cooling" the Dutch Renaissance artist Pieter Bruegel (1525–1569) would not have been able to paint his famous winter scenes.

1.2.1 Why wood, and mountain spruce in particular?

The wood (or secondary xylem as it is known scientifically) of dicotyledons and conifers is the derivate of the centripetal division of vascular cambium with wonderful acoustic properties. The velocity of sound in dry wood parallel to the grain is about the same as in steel and most other metals. However, since the density of wood is much lower, it has low sound wave resistance and high damping of sound radiation.

> Two acoustic properties related to sound velocity are the sound wave resistance, which is the product of velocity and density ($\upsilon\rho$), and the damping of sound radiation, which is determined essentially by the ratio of velocity to density (υ/ρ). The sound wave resistance is important in sound propagation and the reflection of sound at media boundaries, whereas damping of sound radiation determines the energy loss from a vibrating body to surrounding media by radiation.
>
> The damping capacity of vibrating wood results from energy dissipation through internal friction. A measure of damping capacity is logarithmic decrement δ, which is defined as he natural logarithm of the ratio of two successive decaying wave amplitudes (A_i and A_{i+1}) for a body set in harmonic motion and allowed to vibrating freely: $\delta = \ln (A_i / A_{i+1})$. The values of logarithmic decrement are affected by moisture content, temperature, grain direction and frequency of vibration (Dunlop 1980, Pentoney 1955).
>
> Low sound wave resistance facilitates resonance, and high damping of sound radiation combined with low damping capacity means that less of sound energy is consumed in internal friction and more is emitted as sound radiation to the surroundings – precisely what is desired of sounding boards in musical instruments.
>
> Density does not significantly affect the velocity, but the ratio of medium's elastic modulus E to its density ρ is important; for the case of rods, the velocity of sound υ can be shown to be given by $\upsilon = (E/\rho)^{1/2}$ (Smith in Schniewind 1989:4,5).

For the functions of soundboards, the physical properties most desirable are, generally, lightness, high elasticity, speed of propagation of vibration, length of duration of sound, and bigness of sound. These properties are related to physical quantities, namely specific gravity Υ (relative density d), Young's modulus E, sound velocity υ which is proportional to $(E\rho^{-1})^{0.5}$ (where ρ is density), internal friction Q^{-1} which is proportional to internal loss of energy, and sound radiation damping *v* which is proportional to $\upsilon\rho^{-1}$. Consequently, it can be summarized that wood having low ϒ, high $E\Upsilon^{-1}$ and low Q^{-1} is suitable for soundboards. Characteristically, spruce has higher $E\Upsilon^{-1}$, lower Q^{-1} and higher $\upsilon\rho^{-1}$ than wood of other species in the L-direction. Furthermore, it has been found that wood for higher graded instruments has higher $E\Upsilon^{-1}$ and lower Q^{-1} (Ono in Schniewind 1989:251).

The density of conifers typically increases as the width of the annual growth rings gets smaller, and vice versa. The reason for this is that the proportion of denser latewood as a rule increases as the rings get narrower cf. Kollmann and Côté 1968:177; Trendelenburg and Mayer-Wegelin 1955: 420). It is important that the density of the wood does not affect the velocity of sound. Spruce tonewood for violas should have a ring width of 2–3 mm and tonewood for double basses a ring width of approximately 3 mm, while the soundboards of pianos can have even greater widths (4 mm). As growth rings get wider, the proportion of latewood is generally smaller. As we have already said, however, the proportion of denser latewood can, in extremely narrow spruce growth rings, be even lower, in contrast to this rule (cf. *Holzleksikon* 2010:1134). As a general rule, there should not be more than 20–25% of latewood in tonewood (cf. Kollmann and Côté: 1968 176-9, Smith 1989:4-8, *Tonholz*, Holzlexikon 2010:1227). Still, the essence of "Stradivari's" violin wood is not only in its very narrow growth rings and their uniformity over a longer period of time, as there are also particularities. Tonewood must not contain any structural anomalies such as core juvenile wood with an exceptionally high microfibril angle, reaction compression wood in leaning stems with a higher lignin content, resin streaks and pockets and no sapwood due to the higher EMC, of course without any grain deviations, let alone decay and knots.

The Japanese, who are among the finest makers of stringed instruments and piano soundboards, use their own Glehn's spruce (*Picea glehnii*), called *Akaezomatsu* in Japanese. The Americans use their own Sitka spruce (*Picea sitchensis*). There must be something about spruce (cf. Torelli 2005 c).

I should emphasise once again that the link between Stradivari and the Little Ice Age and, in particular, with genocide, is greatly exaggerated, if it even exists at all, and above all romanticised, which merely further increases the mystery surrounding these unique instruments, not to mention their already astronomical prices (sometimes several million euros!). The cooler conditions in the years between 1645 and 1715 slowed the trees' growth, "causing the wood to grow evenly and produce low density and a high modulus of elasticity – both of these qualities essential for a good violin tonewoold." (Bonnes 2012).

We should mention in passing that the backs of top-quality violins are made from the wood of the sycamore maple (*Acer pseudoplatanus*), with the highly decorative "fiddleback" figure in the radial section, while bows are made from precious Pernambuco wood or brazilwood (*Guilandina echinata*) and fingerboards from black ebony (*Diospyros* sp.).

Even so, I believe that it is not only about the wood. Other undoubtedly significant factors include the craftsmanship involved in making the instrument, the mould, the preparation of the wood and perhaps even the slight biological decay that occurred during the lengthy storage of logs, usually in the Venetian Lagoon, when the decomposition or de-aspiration of the margo of bordered pit membranes increased the "sonority" of the wood and thinned the cell walls. This did not significantly reduce the strength of the wood, although the density of the wood is supposed to have decreased a little.

We can now at least try to define the phenomenon of the "mysterious" "Stradivari" wood: narrow-ringed or close-grained mountain spruce wood, slowly and uniformly growing in short vegetative periods high up in the mountains, on infertile leached soil, further "cooled" by the LIA, the Maunder Minimum and the post-Columbian genocide, and slightly biologically damaged while strength (the E-modulus) remains practically unreduced, and chemically modified as a result of having been kept in water. Only adult wood can be considered, without the juvenile wood, crown and sapwood, and of course without reaction compression wood and knots. It must have distinctly homogenously distributed density and be optimal in terms of stiffness and sound-damping characteristics. There are also many well-known and "mysterious" additives such as the red discharge or "dragon's-blood resin" of the dragon tree (*Dracaena draco,* Agavaceae) from the Canary Islands, which Stradivari is said to have added to varnish (Torelli 2005c).

We strongly emphasise that stringed instruments, particularly the violin, have had a decisive influence on the development of music. After hearing the first concert of the "devil's violinist", Paganini in Paris (1831), Franz Liszt resolved to become the Paganini of the piano. Deeply moved by his revolutionary virtuosity on the violin, he developed a piano style whose beauty, brilliance and tonal luxury far surpassed all previous perceptions of piano music and which younger composers had to accept (Harden in Neunzig *ed.* 1995:312). In aiming to transfer some of Paganini's fantastic violin effects to the piano Liszt wrote a fantasia on his *La campanella* (it. "The little bell") is the nickname given to the third of Franz Liszt's six grandes etudes de Paganini, S.141 (1851). It is in the key of

Giuseppe Tartini (Antonio Dal Zotto 1896), an Italian born in Piran/Pirano (now part of Slovenia), Baroque violin virtuoso, composer of the famous Devil's Trill/it. Il trillo del diavolo). He bows elegantly to the public, dressed in extravagant Baroque clothing, with a violin made in the Amati workshop in Bologna (this is definitely not the famous, Nicolò Amati or Nicolao Amati, Master Luthier from Cremona). But it could be a Stradivarius or Strad Lipinski Stradivarius, as the virtuoso was the first reputed owner of this fine violin. In his right hand he is holding a bow made from pernambuco wood or perhaps snakewood, which he technically perfected himself.

Franz Liszt playing a piano built by Ludwig Bösendorfer (unknown author, from Max Wade-Matthews 2004:227).

Charcoal drawing of Paganini by Jean Auguste Dominique Ingres, c. 1819.

G-sharp minor. At this time Liszt also met Frédéric Chopin, whose poetical style of music exerted a profound influence on him.

The violin had undergone its most dramatic improvements two hundred years before the piano did, and it was a mature instrument by that time. As Paganini himself remarked: "What wonderful things might be done with the piano if its technical possibilities were developed as those of the violin!".

And thus, if the great Liszt had not met Paganini, he would not have vowed to achieve the same virtuosity as a pianist, something that also had a decisive influence on the development of the piano, the second most important classical instrument (Max Wade-Matthews 2004:80), which also had a decisive influence on the development of the piano and music in general in the 19th century.

"The piano, the most perfect of all musical instruments: its invention was to music what the invention of printing was to poetry."
(George Bernard Shaw)

The pianoforte was invented around 1709 by Barolomeo Cristofori (1655-1731), a harpsichord builder and keeper of the royal musical instruments in Florence. During the late 18th century and with the development of the fortepiano (and then the increasing use of the piano in the 19th century), the harpsichord gradually faded from the musical scene.

The early Cristofori pianos, which looked and sounded like contemporary harpsichords (it. clavicembalo, ger. cembalo*)* had range of four octaves, half that of a modern "grand".

Christofori developed the pianoforte which would lead to the ultimate development of the concert grand piano. Not all composers were privileged to have the pianoforte at their fingertips, let alone the grand piano with all of its improvements. Therefore, each composer's musical style can be correlated to the piano's development during each time period (Sica 2008, from abstract). (Cummings 1997:495):

> The instrument on which J.C. Bach, "London Bach", son of Johann Sebastian Bach, who in 1768 had his first solo concerto on piano, sounded very different from a modern piano. Indeed, Beethoven and Mozart would not recognize their music now, as the "modern" piano sound did not begin to appear until 1850. The strings of early 19th century pianos were still quite light and thin and at much lower tension than today's models, in which the strings are so rigid and tense that they behave more like bars. This thinness gave the instruments more harmonic overtones than a modern piano, a characteristic that gives early pianos an "out-of-tune" tone quality, reminiscent of ragtime pianos of the 1920s. To increase the volume of sound, makers increased the thickness of the strings. This meant that the tension also had to be increased to maintain them at the same pitch...Added tension in the strings meant that the frame had to be reinforced. (Max Wade-Matthews 2004:229)
>
> The hammer action was improved by very gradual processes, and English makers contributed the invention of the iron frame replacing the dimensionally unstable wooden frame. The iron frame was capable of supporting a much greater tension of strings, resulting in a more powerful tone.

Otherwise, just as with the violin, the quality of a piano is determined by the quality of wood and how it is treated.

The first iron frame for a grand piano was made in Boston in 1843 by Jonas Chickering. In the 1860s, Steinway's cast iron frames were first seen in Europe, and almost all makers followed suit. Unfortunately, Mozart, Bach, Vivaldi, Beethoven, Paganini, Schubert, Schumann, and Mendelssohn did not live to see the wonderful grand piano, not even Chopin did, but Liszt, Wagner, Verdi, Brahms, Puccini and Tchaikovsky did. However, most of them did hear the great Paganini and knew or were friends with Franz Liszt, who treated them to virtuoso paraphrases and transcriptions of his most beautiful works. The wonderful Romantic period was beginning...

By the beginning of the 20th century the modern piano had definitively appeared, with cross-stringing and iron frames, and steel strings. (Randell 2003:658)

So after the fall in temperature during the LIA and further drops in temperature due to the Maunder Minimum, and (perhaps) the tragic anthropogenic cooling of the Great Dying, which caused an additional shortening of the vegetative period high up in the mountains, as well as the desired homogenisation of growth, followed by the supreme skills of the master luthiers of Cremona, along with Paganini and Liszt, who wanted a perfect "grand piano", I will soon conclude this very brief history of wood in relation to violins and pianos.

"Music, the greatest good that mortals
Know,
And all of heaven we have below."
(Joseph Addison in Song for St Cecilia's Day, 1694)

To finish, let us try a Steinway Grand Piano, a large, wing-shape piano, in which the plane of strings is horizontal, "the gold standard of musical instruments, representing 170 years of dedication to craftmanship and uncompromised expression.". We can have Liszt play a Bösendorfer, veneer with the precious Wawona Burl or Redwood burr from California redwood (*Sequoia sempervirens*), and he can play us on of his many virtuose paraphrases and transcriptions.

Alternatively, his contemporary »incarnation«, the unbeatable player of Liszt's music, György Cziffra, can perhaps play for us, on Steinway Grand Piano, one of the most-well-known and also one of the hardest pieces for piano, the »Paraphrase de Concert sur le Rigoletto« (*Bella Figlia Dell' Amore*) with fantastic, almost harp-like cadenzas. Personally, I would love to also hear the extremely difficult concert etude with the strange name of *Gnomenreigen* (fairly-tale beings) , The Grand Galop Chromatique, Rhapsodie Espanol, Mephisto Waltz No.1 and the mighty Sonata in B Minor – an "encore", reserved only for the best pianists, not forgetting "the most beatiful piano piece", Chopin-Ballade No.3 in the interpretation of Vladimir Horowitz, defined for many years the ultimate standard of the virtuoso.

The basic material of pianos is wood. One part in particular is the sound board, always made of spruce. The soundboard is a “board” that transmits vibrations, while at the same time it is in a certain sense, a board that *stops* vibrations. What makes the spruce family, especially Alaskan Sitka spruce *(Picea sitchensis*), European spruce, Glehn's spruce or jap. Akaezomatsu (*Picea glehnii*), so highly valued as soundboard materials is that spruce has the property of absorbing the higher overtones more effectively. It thus transmits only the sounds that we perceive as round and mellow in a rich fashion.

The best instruments are veneered in costly exotic woods: mahogany or caoba (*Swietenia mahagoni* and S. *macrophylla*, Meliaceae), rosewood (*Dalbergia* spp., Leguminosae, Papilionatae), macassar ebony (*Diospyros celebica,* Ebenaceae), (*Peltogyne venosa,* Caesalpiniaceae) and their decorative and even more expensive figures or textures: esp. various tree burrs: “Amboyna” (*Pterocarpus indicus*, Leguminosae, Paspilionatae), “Madrone” (*Arbutus menziesii*, Ericaceae), “Wavona” (*Sequoia sempervirens*), and “Thuya” (*Tetaclinis articulata syn*. *Callitris quadrivalvis*, Cupressaceae), etc. What would we do without wood? Today's music certainly wouldn't be the same. Most of the listed woods and many other rare decorative woods have been placed on the CITES *Appendices* and controlled by the IUCN *Red Lists*. Today we can only use reliably certified wood that comes from sustainable managed forests (SFM). Some domestic decorative woods are also useful, such as the European walnut burr *(Juglans regia),* European elm burr *(Ulmus procera)* and figured European sycamore *(Acer pseudoplatanus*) for with the already mentioned and necessary “fiddleback” figure.

In this context I cannot help thinking sadly about the devastated forests of Haiti and Madagascar, but also happily of Cremona and its famous square, dominated by the mighty *torazzo* and which is surrounded by violin-making workshops. Far away in the distance there are Alpine forests where tonewood grows… All the scents and smells of wonderful music getting ready to be played… Beautiful…

After all this we can conclude that life without music would be a mistake.

Without music, life would be a mistake.
(Friedrich Nietzsche, Götzendämmerung, 1889)

Very pertinent at this point is also Elgar’s idea, which links music with forests, trees and wood.

The trees are singing my music - or have I sung theirs.
(Edward Elgar)

A Stradivarius violin “combines the best in fine engineering, visual artistry and sound quality” (cf. Richardson1995:42). Even more, since wood is biological material, it is subject to environmental, and genetic factors that influence its formation.

1.2.2. Famous violins from Cremona – owners and players (cf. Torelli 2005 c)

What is certain is that without wooden stringed instruments, there would be no beautiful “wooden” music at all. The instruments made by the likes of Stradivari and Guarneri continue to stir the imagination today, and also to interest science, which continues to place new theories about the formation and processing of the mysterious spruce tonewood alongside the theories of reduced forest increment during the so-called Little Ice Age, further reduction by the Maunder Minimum and above all the Great Dying. The "Devil's Fiddler" Paganini owned several Stradivarius instruments, but his favourite violin was a Guarneri (*Bartolomeo Giuseppe Guarneri, del Gesù)* known as *Il cannone* because of its remarkable tonal qualities. (All Strads, and the most valuable violins in general, have their own history and sometimes very meaningful names!)

We should end the list, of course, by mentioning the virtuoso musicians who play, or played, this music on the unsurpassable instruments from Cremona (c.f. various sources Torelli 2005c).

Before that we should mention that no material has ever reached the value of the spruce wood forming the bellies of Stradivarius and Guarneri violins. There are no more valued (and many times counterfeited) labels than (in the Latinised form fashionable at the time) *Antonius Stradivarius Cremonensis Faciebat Anno* – (followed by the year, either printed or handwritten) and *Joseph Guarnerius fecit † Cremone anno* (year) IHS. The cross and the IHS monogram earned the famous luthier the nickname *del Gesù* (IHS has several meanings: *ΙΗΣους* – *Jesus Hominum Salvator* – Jesus Saviour of men, *In Hoc Signo* [*vinces*] – In this sign [thou shalt conquer, Emperor Constantine] or *In Hac Salus* [salvation] – in this (cross) is salvation.

The famous violins from Cremona are named – like for example the famous trees – after their makers, owners or unusual events and circumstances they have been associated with. I will list some famous violins and their owners or users below. The question of current ownership is a little more difficult to answer, as such violins may be owned by musical foundations, banks or wealthy individuals who generously lend them to outstanding violinists like patrons, but they can also end up in bank vaults just like other valuable investments, without being of any benefit to music, and sometimes the owners are even unknown. But the lucky owners must pay very high sums for insurance, which most musicians can not afford.

These instruments from Cremona began to attain astronomic prices at the end of the 18th century. In the 1920s prices in London already reached between 25,000 and 50,000 dollars, and at the end of the 1960s even as much as 100,000 dollars. The amazing enthusiasm for classical music in Japan also caused the prices of Cremona-made instruments to skyrocket. In 1971, one of the best Stradivariuses, *Lady Blunt* (1721), was sold to an unknown banker from Singapore for the record price of 200,000 dollars. The famous violin bears the initials *P.S.*, which means that it was owned by Stradivari's son Paolo. It lay forgotten for 100 years in an attic in Spain. Then Vuillaume succeeded in locating it and sold it to Lady Anne Isabella Noel, the granddaughter of Lord Byron, known as Lady Anne Blunt. It was bought in a Sotheby's auction for an unknown buyer by *Hill & Sons.* The buyer was later identified as a banker from Singapore.

Cathédrale (1707) was bought in 1984 for 1,456,000 DM. It is now owned by Peter Mandell, patron of the *Stradivari Society*, which lent it to Tamaki Kawakubo. In 1986 it was played by the charismatic Nigel Kennedy. In 1985 Stradivari's *Jules Falk* (1723) also went for more than one million DM at Sotheby's. Its current user (owner?) is Viktoria Mullova. R. Loh from Singapore acquired three Stradivariuses, while the collector C.N. Sin from Hong Kong has bought more than twenty Stradivariuses and Guarneris! The famous Stradivarius *Soil* (1714) (named after Monsieur Soil, 1902), was bought by the man who is perhaps today's violinist, Itzhak Perlman, from the great Yehudi Menuhin (1916-1990) for the "bargain price" of 1,250,000 dollars. A wealthy plastic goods manufacturer from Taiwan founded the Chi Mei Culture Foundation, which purchases French paintings, Chinese antiques and Italian musical instruments. In a short space of time the museum acquired five Stradivariuses and two Guarneris, paying between 1,700,000 and 2,700,000 dollars for each of them. A few years ago the Nippon Music Foundation bought the Stradivariuses from *Paganini's quartet* (the violins *Dessaint* 1692 and *Paganini* 1724, the viola *Paganini* 1731 and the cello *Paganini* 1736) from Washington's Corcoran Gallery of Art for 15 million dollars, as well as the Stradivarius violins *Jupiter* 1722 (played by Viotti) and Heifetz's *Dolphin* (1714), and the Stradivarius cello *De Munck ex Feuermann* (1730) and Stern's famous Guarneri *Ysaÿe,* each one costing between four and five million dollars! (Bein in Fushi 2005). I keep listening to the Stern's infinitely beautiful recording of one of Mendelssohn's *Songs without Words* (*On Wings of Song*) adapted for orchestra and violin solo!

Some orchestra's also possess instruments from Cremona: the *Chicago Symphony Orchestra* has two Stradivarius violins, the *Los Angeles Philharmonic Orchestra* has a Stradivarius violin and a cello, while the largest number belong to the famous Berlin Philharmoniker. Individual owners such as the virtuoso Anne-Sophie Mutter (born in 1963), Karajan's great discovery, currently owns two "golden" Strads: *Lord Dunn-Raven* (1710) and *Emiliani* (1703)!

This year the Strad *The Lady Tennant* (1699) was sold for 2,032,000 US dollars (EUR 1,621,000). The *Royal Academy of Music* in London has just acquired the Stradivarius *Viotti*. Price: 3.5 million pounds sterling! This was the favourite Stradivarius of the great violinist Giovanni Battista Viotti (1755-1824), a gift to him from Catherine the Great. However, Viotti had a number of Stradivariuses, and it was in fact he who consolidated their reputation while Niccòlo Paganini was responsible for making the Guarneris famous. It is interesting that until the end of the 18th century violins made by Nicòla Amati and Jakob Steiner were valued just as much, or even more. A letter has been preserved in which Mozart's father recommends that his son, Amadeus, buys a violin made by Steiner or Amati, and by no means a Stradivarius (!): "...the Stradivarius sounds squeaky" (René Morel, top connoisseur and "Strad" dealer).

We can only guess how much the *Alard* would cost (1715), purportedly the best Stradivarius in use (Wade-Matthews 2004) and currently considered stolen.

Stradivari's "golden" *Red Diamond* (1732), which disintegrated in the sea during a storm and was rescued and reassembled, fetched EUR 6 million, with this incident actually increasing its price significantly.

Some very famous instruments are not available for sale, such as the already mentioned Stradivarius *Messiah* (1716), which is located in the *Ashmolean Museum of Art and Archaeology* in Oxford). This was Stradivari's favourite violin, from which he was never separated. The *Salabue* was also named after the collector Count Cozio di Salabue. The instrument was then bought by the famous collector Luigi Tarisio and hidden until his death. When people heard about the hidden violin they doubted its existence. Delphin Alard, the son-in-law of the famous French luthier Vuillaume once exclaimed: "Your instrument is like the Messiah... people wait for him but he never appears". This is how the famous violin got its name. It was bought by Vuillaume following Tarisio's death. He opened it, replaced the bass bar and repaired the fingerboard range. It was later acquired by the English family Hill, which was known for its luthiers and collectors. The violin underwent a few more changes and was valued at 10,000,000 pounds sterling (that's right, yes!). Finally, it was donated by the Hill family to the museum in Oxford.

Paganini's favourite violin – the Guarneri *Cannone*, which is kept by the Town Hall in Genoa (*Palazzo Municipale Tursi*) – is evidently of inestimable value, and can only be played by the winner of the international Paganini Competition (*Paganiniana*). Before that not even the unforgettable Jasha Heifetz (1901-1987) nor Itzhak Perlman (born in 1945) were allowed to play it. The *Cannone* is cared for by a team of three luthiers, and once a month it is "warmed up" by its "personal trainer" who thereby keeps it in "top playing form". Paganini (1782-1840) made a significant contribution to the art of violin playing. Some of the effects he played most often included flageolet tones, double trills, pizzicato played with the fingers on the left hand while simultaneously playing cantilena with the bow. Paganini used to say: "I'm not handsome but when women hear me play, they creep up to my feet".

But which violins are truly the best: Amati's, Guarneri's or the most famous Stradivariuses? Only the following joke gives a reliable answer to this question:

Three violin manufacturers have all done business for years on the same block in the small town of Cremona, Italy, under the protection of the mighty Torazzo, reputedly the highest bell tower in Italy. After years of peaceful co-existence, the Amati shop decided to put a sign in the window saying: "We make the best violins in Italy". The Guarneri shop soon followed suit, and put a sign in their window proclaiming: "We make the best violins in the world". Finally, the Stradivarius family put a sign out at their shop saying: "We make the best violins on the block" (Lüder from Wikipedia).

Are these violins really so much better and worth so much more? Difficult question. I admit that this has greatly intrigued me for a long time, and I always wondered what violins famous violinists play. Who can recognise them? The best violinists of course, and a small number of experts. There are around 10 to 12 respected international dealers, including those who cooperate with the auction houses *Sotheby's* and *Christie's*. There are quite a number of LPs and CDs featuring recordings of famous violins. There is a recital called *Glory of Cremona* (1963), on a CD issued by *The Strad*. The original mono LP was issued by *Decca* with the designation AXA 4521. Ruggiero Ricci plays 15 famous violins including the Stradivarius' *Ernst* (1709), *Joachim* (1714), *Monasterio* (1719), *Madrileno* (1720), *Rode* (1733), *ex Vieuxtemps* (1939) and the Guarneri *Plowden* (1735), and Ricci said that he would choose the latter out of all the violins.

We can also hear them on the recordings of contemporary virtuosos. Those who play valuable Strads and Guarneris and are alive today are widely known. Here are some names of famous contemporary violin virtuosos: Itzak Perlman (Strad *Soil* 1714), Anne-Sophie Mutter (Strad *Lord Dunn-Raven* 1710 and Strad *Emiliani* 1703), Gil Shaham (Strad *Countess Polignac* 1699: Countess Polignac was the patron of art in the court of the "Sun King" Louis XIV), Nigel Kennedy (Strad *Cathédrale* 1707 and Guarneri *Lafont* 1735), and Kyoko Takezawa Strad *Hammer* 1707 and Strad *Ruby* 1708 – both violins lent by the *Stradivari Society*, Chicago).

Perhaps you are interested which instruments were played by famous, top violinists who are no longer with us? Joseph Joachim (1831-1907): *Joachim, Morgan* 1708 and nine others, only Strads, including the already mentioned *Alard*; Pablo de Sarasate (1844-1908), composer of *Gypsy Airs*: Strad *Boissier* 1713, Strad *ex Sarasate* 1724 and Guarneri *David* 1742; Fritz Kreisler (1875-1962): Strad *Hubermann, ex Kreisler* 1733 and Guarneri *ex Kreisler* 1733; Nathan Milstein (1904-1992): Strad *ex Goldmann*, 1716; Isaak Stern (1920-

2001): Guarneri; *Isaÿe* 1740; Zino Francescatti (1860-1942): Strad *Har*t 1727, David Ojstrah (1908-1974): Strad *Marsick* 1705 and eight other Strads; Jascha Heifetz (1901-1987): Guarneri; David 1742, Strad Dolphin, Strad Heifetz-Piel 1731 and Yehudi Menuhin (1916-1999): Guarneri *Lord Wilton* 1742, Strad *Prince Khevenhüller* 1733 and the already mentioned Strad *Soil* 1714.

Let us conclude with the greatest, Niccòlo Paganini (1782-1840). Despite owning a number of Strads, his favourite violin was a Guarneri, which he called *Cannone* because of its exceptional loudness.

I like visiting Piran, especially in the winter low season, when I drink cappuccino in the peaceful Tartini Square, between the musician's monument and the house where he was born. From the west, the direction of Venice, I can subconsciously hear Vivaldi's *Four Seasons*. The famous "Winter" of course, the Allegro first movement, described by Vivaldi himself as: "a dreadful storm – running and foot stamping because of the cold – winds – chattering of teeth." Played by the matchless Anne-Sophie Mutter on one of her two Strads. There are also 12 violins, four violas, three cellos, a double bass (all from Cremona), and a harpsichord. As usual, when I hear this beautiful music my thoughts cannot help wandering over the Atlantic, to the Great Dying, which also affected the Maya and perhaps even contributed to the preservation of their forest.

I should mention in passing that no other material can match the value of the mountain spruce used for the bellies of precious Cremona violins (F. Kollmann).

1.3 Towards the SFM – preserving forest ecosystem services

There is no doubt that we need the forests. The question now, however, is how to preserve them. Protected areas safeguarded by buffer and transition zones where the traditional sustainable, permaculture-based *milpa* cycle with forest gardens (MFGC) should also be practised, along with SFM/MFM/RA, RIL, reforestation and afforestation in production forests. It is also necessary to support forest management with an experienced forestry service, REDD+ and accredited forest management certification and chain of custody certification. The inclusion of the local population in the sense of the ecosystem approach (EA) is essential as well, as is the global implementation of the *Paris Agreement* on Climate Change – the legally binding international treaty on climate change adopted by 196 Parties at *COP21* in Paris, on 12 December 2015, which the world is, unfortunately, tackling very hesitantly.

Whether or not people admit it, forests, particularly tropical forests, remain an important part of the climate change mitigation solution. Epic fires of vast dimensions are an extremely serious warning that humanity should on no account overlook. Today our attention is already being drawn to the abuse of nature and the destruction of forests by the younger generation (e.g. Greta Thunberg), who have – as we like to say – only lent the forest to us, and have by no means permitted its destruction. Opening the Amazon Synod (6–27 October 2019), Pope Francis joined the entire world in expressing concern over the recent Amazon fires. (*Quo usque tandem*...). Do such calls help at all?

St Augustine's famous witticism, which we can understand as meaning "just a little longer", is still valid more than 2,000 years later:

> ***Da mihi castitatem et continentiam, sed noli modo.***
> "Give me chastity and continency, but do not give it yet."
> *(Confessions*, bk VIII,ch.7)

Unfortunately the post-Columbian destruction of tropical forests continues today, and is even intensifying. Objectively, we are all more or less to blame for it: the overpopulation of the hungry and innocent in "developing countries", and the rest of us, more fortunate, in the temperate zone, who are incapable of imagining life without tropical raw materials (rubber, paper, palm oil) and other "colonial" goods. And yet...

"Destroying rainforest for economic gain is like burning a Renaissance painting to cook a meal."
(Edward O. Wilson , "the father of sociobiology"
and "the father of biodiversity")

Here it should be mentioned that concerns about the exploitation of tropical forests have occasionally led to boycotts of tropical timber in the developed world, in the hope that reduced consumer demand for tropical timber would slow the destruction of the rainforest, but

> "...boycotts did lower demand for tropical timber, but they also lowered the value of tropical forests for timber production. This in turn discouraged investment in managing the resource and, in some cases, may have encouraged more rapid conversion of forest land to other uses as plan-

> tation agriculture, thus accelerating rather than discouraging deforestation.” (Hunter 1999:627)

Our work has been primarily oriented towards the support of the SFM/MFM/EA/RA of the less degraded “secondary” production forest. Secondary forest can be created in a number of ways, from degraded forest recovering from selective logging, to areas cleared by slash-and-burn agriculture that have been reclaimed by forest. Generally, secondary forest is characterised (depending on its level of degradation) by a less developed canopy structure, smaller trees and less diversity. The very last remnants of primary forest, which refers to untouched, pristine, “virgin” forest that exists in its original condition, should be strictly preserved by establishing various types of protected areas.

By determining the relevant properties for individual uses, we estimated the useful value of numerous tree/wood species and compared them to the wood of the *caoba* or big-leaf mahogany (*Swietenia macrophylla*), well known to the Mexicans. With a wider selection of useful species, grouped from the point of view of end use (“end-use grouping”; Bazier 1979) or technologies (seasoning/drying), we attempted to contribute to: (a) the necessary balancing of the economic, ecological and sociocultural pillars of SFM/MEM, (b) abandoning the (often illegal) highly selective harvesting of a few “preciosas”, mainly *caoba* (*Swietenia macrophylla*) and *cedro* (*Cedrela odorata*), and (c) preventing further damaging intrusion into the last preserved forests.

Brazier (1982:337) stresses that in end-use marketing “names cease to be relevant and, where supplies of a timber are of occasional or sporadic occurrence, they can be marketed for a purpose with others that also have the appropriate combination of (relevant) properties”. This principle makes it possible to utilise a substantial part of “lesser-known species” that may comprise up to 90% of volume. These species are often treated as weeds and are at present burned or otherwise wasted after logging operations, agricultural conversion projects (including shifting cultivation) and conversion of the natural forest into plantations.

For “weed” species it is also necessary to seek out other, perhaps already forgotten non-wood forest product (NWFP) uses alongside wood use.

If I may be allowed to quote here the American essayist, lecturer and poet Ralph Waldo Emerson in *Fortune of the Republic*, with a line that is particularly apt with regard to the botanically remarkably heterogeneous tropical forest ecosystem:

"What is a weed? A plant whose virtues have not been discovered."

Such an approach implies the “translation” of end-use requirements to measurable or estimable wood properties (cf. Noack 1979). To develop this idea, we investigated the relevant biological, physical, mechanical and technological properties of 42 wood species and the well-known *caoba* for comparison, in this way attempting to promote end-use marketing that would cover the costs and realisation of SFM.

Even if selective felling does take place, it is important to remember how many trees will be lost due to transportation and related infrastructure – such as building roads in the forests. The influence of road building on immigration should also be taken into account.

Fortunately, Mexico established eight protected areas between 1978 and 1998 in the Selva Lacandona area, among them the most valuable *Reserva de la Biosfera Montes Azules*, surrounded by buffer and transition zones.

The aim of our research into 43 wood species from the Selva Lacandona was to support economically more feasible *end-use marketing* of a substantial part of lesser known and often technologically less desirable wood species, and in this way preserving the highly delicate balance with the ecological and sociocultural “pillars” of the SFM/MFM through the ecosystem approach, while also practising various protection principles such as reduced-impact logging and the retention method.

To do this, the biological, physical, chemical, mechanical and technological properties and uses of 43 wood species in the Selva Lacandona were determined. Based on measurable or estimable wood properties, all woods investigated were placed into groups with other woods with comparable end uses or similar technological properties (e.g. drying).

For the easier assessment of these species, their properties were compared with the those of the *caoba* (*Swietenia macrophylla*). The species investigated are grouped using 18 relevant properties with regard to 15 potential fields of end use.

When marketing for a specific use, names cease to be relevant and, where supplies of a timber are of occasional or sporadic occurrence and of “lower” value, they can be marketed for a purpose with others that also have the appropriate combination of (relevant) properties, resulting in end-use marketing.

In production forests, we nevertheless propose SFM/MFM with

EA and RA, combined with the traditional sustainable MFGC with PMP. Although these cause some modification and homogenisation of the botanical composition of the forest, it can still continue to provide essential forest functions, services and benefits, including carbon sequestration and climate change mitigation, which are increasingly relevant and of global importance. It is encouraging that in the case of the Maya, the directed (and accelerated) restoration of forest in the MC system takes place in a manner that is quite similar to the same process in nature, and at the same time enables sustainable and moderate wood production!

In largely undisturbed primary forests the establishment of various protected areas with strictly prohibited or limited forest use, surrounded by buffer and transition zones, is of critical importance.

Eguiluz-Piedra (2003) describes the intolerable current practice as follows:

> … illegal logging for firewood and charcoal, illegal logging for industrial wood products, past land clearing government programs, legal and illegal land clearing for farming and animal grazing, forest fires and pest attacks, lack of ecological and forest education of the owners, poor supervision of forest management plans, selective logging (always cutting down the best trees), corruption of authorities in the process of wood supply and lack of supervision by private owners who fear of being kidnapped.

Some hope is raised by the implementation of the United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation (UN REDD+), which might foster conservation, sustainable management of forests and enhancement of forest carbon stocks, if introduced carefully and taking into account all economic and sociological aspects, population pressure, etc. The programme aims to financially reward developing countries that successfully implement forest conservation, SFM and reforestation programmes.

> If you ask people who work on biodiversity how to conserve tropical forests, they will say "protected areas", but if you ask people who work on climate the same question, they will say "carbon payments" (REDD+). We found this divergence of approaches curious, since it is the same forests providing both services. There are very good reasons to conserve tropical forest biodiversity using park/protected areas and tropical carbon using payments. (Jonah Busch, quoted in Kalaugher 2013)

In the Selva Lacandona, too, UN REDD+ has raised hopes and expectations, although it is not proceeding without problems, as demonstrated by the resistance to its implementation in Chiapas in 2012 (*People's Forum Against REDD+ in Chiapas, Mexico* 2012). REDD+ policies, meanwhile, are "often designed with little consideration for where they will be put in place" (quoted in Kalaugher 2013). On the part of "developed" CO_2 emitters, the programme might even uncritically increase their emissions and the warming of the atmosphere. So while the programme does have its good sides, it also has, unfortunately, negative or unpredictable consequences for the people affected by REDD+ projects (cf. Lang 2010 and Dhiaulhaq 2011; Hess 2014). Not only that, but we continue to use the unjust terminology of "undeveloped", meaning "poor" and "developed", meaning "rich", where in many cases the latter became rich through their use of tropical natural riches.

In younger forests, CO_2 absorption in the process of photosynthesis is greater than CO_2 emissions because of the respiration of tree tissues and decomposing organisms, and thus these represent a CO_2 sink, while older trees become CO_2 emitters over time. Their carbon pool is "full" and no longer functions as a sink. However, older forests are of critical importance for the maintenance of biodiversity and numerous ecological and social functions. Relatively younger, healthy forests ideally represent a balance between CO_2 absorbed and CO_2 emitted, and that is also when their biologically undamaged wood is at its most valuable. A sustainable sink effect can only be achieved through the planned, biologically balanced extraction or production of wood in the context of SFM.

Regarding the blame for excessive CO_2 emissions, I wish to strike a critical note. Delegates at enormous climate conferences with thousands of participants always talk about the importance of forests for the mitigation of climate change, and about the harmful release of CO_2 and PM in the case of wild and deliberately set fires, which are globally estimated to be responsible for a fifth of all CO_2 emissions. They also airily set deadlines for the implementation of truly important resolutions at some specified date that is carefully set some years into the future. Unfortunately, in doing so they forget about their own conference-related CO_2 emissions on long intercontinental flights. The Cancún Climate Change Conference (2010) on the edge of the Maya forest saw almost 12,000 participants, including 5,200 government officials, 5,400 representatives of UN bodies and agencies, intergovernmental organisations and non-governmental organisations and 1,270 accredited members of the media!

To put it more clearly, climate conferences (COPs) are usually organised in very remote destinations (e.g. Durban, Nairobi, Bali, Cancún). By way of comparison: according to data from Lufthansa, every passenger on a return flight from Frankfurt to New York and back to Frankfurt, which is as a rule only part of the journey of the majority of passengers, taking into account the Radiative Forcing Index or RFI, emits approximately 4,000 kg of CO_2, or approximately the same CO_2 equivalents as contained in around five cubic metres of green *caoba* or the average annual increment per hectare of both temperate and tropical forest.

It is always useful to remember the binding definition of SFM developed at the second MCPFE and contained in resolution H 1 (Helsinki 1993), as adopted by the UN Food and Agriculture Organization (FAO), which is unavoidable if we wish to preserve forest, ensure its sustainable management and maintain its ecosystem services/functions:

> **The stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems.**

"Sustainable tropical forest management needs to be financially supportable from revenue earned from sales of forest products, primarily from log harvesting. It is the commercial operation of a forest management unit which is the driving force for the generation of revenue from which all forest conservation and development activities should be funded" (FAO Guidelines), i.e. "protection through use" (cf. Tappesser 2014).

"The modern approach to conservation includes not only preservation and protection, but also the planning and management of resources to allow both use and continuity of supply. It may also involve attempts to return mismanaged resources to their former state" (Kemp 1998:80).

Barbier *et al.* (1994) concluded that "in order for sustainable timber management to be viable, it must yield net returns that are greater than those derived from competing uses, such as conversion for frontier agriculture."

All this sounds very good, but the realisation of sustainability and an ecological future, given all the pressures on forests, is an extremely demanding challenge and in many places barely possible.

We should always remember that almost every lauded human development has been the result of the use, or rather the destruction, of natural resources. In the case of the forest this is all too evident. In his provocative call for a new ecological politics, William Ophuls starts from a radical premise: "sustainability is impossible". He warns us that "we are headed for a post-industrial future that, however technologically sophisticated, will resemble the pre-industrial past in many important respects." He believes that the "technological man" of the 21st century has liberated himself from all moral restraints but not from natural constraints. We will be obliged to renounce continual material growth and instead devise a way of living in a long-term harmonious balance with nature, since it is not true, as politics falsely asserts, that man can tame or subordinate nature through science (*Plato's Revenge: Politics in the Age of Ecology*, 2011, MIT Press, cf. also Maselj 2018).

Another very bad sign for humanity and, of course, for tropical forests in particular, is that in 2018 Earth Overshoot Day (EOD), previously known as Ecological Debt Day (EDD), landed on 1 August! EOD marks the date when humanity has exhausted nature's budget for the year. For the rest of the year, we are maintaining our ecological deficit by drawing down local resource stocks and accumulating CO_2 in the atmosphere. We are operating in overshoot...

We must thus do everything possible to preserve the last primary and less degraded production forests. Through consistent SFM, some of them could be transferred to or included in various forms of protected areas, or at least incorporated in surrounding buffer and transition zones. It should be noted here that more or less sustainably managed forests were (in the past) generally focused on timber, while other forest values were often compromised. Forestry has now increasingly refocused on ecosystem management (Jensen and Bourgeron 1994; Kaufmann 1994; Overboy 1992, quoted in Kimmins 1996:499).

It is also necessary, where possible, to maintain traditional sustainable MFGC, while with less degraded *secondary* forests it is necessary, after their clear spatial demarcation, to begin managing them consistently according to SFM/MEF principles, including RIL and EA/RA, on which there is increasing emphasis, avoiding the traditional and unregulated highly selective (high-grading) logging of only a few technologically and decoratively high-value woods, which often ends in irreversible forest degradation, deforestation and conversion to pasture land.

"The aim of RIL is to preserve as much 'ecological integrity' as possible of the logged stand, including protecting already established seedlings, saplings and subadults of commercial species that, in theory, would form the next crop of trees. RIL has proved effective the world over in reducing collateral damage to the residual stand by 20–50%" (reviewed by Putz *et al.* 2008, quoted in Zimmerman and Kormos 2012). Gustafsson *et al.* (2012) define the retention approach (RA) as "an approach to forest management based on the long-term retention of structures and organisms, such as live and dead trees and small areas of intact forests, at the time of harvest."

> Low-intensity selective and selection logging systems (cf. *Selection Cutting* 2018), especially those based on diameter limits, may be often attractive to foresters and conservationists because they maintain a high degree of forest cover while theoretically providing a sustainable flow of harvestable wood. However, as currently practised, low-intensity selective and selection harvesting requires human intrusion into large areas of undisturbed forest, gradually resulting in the commercial elimination of the most highly-valued species, and often neither provides conditions appropriate for regeneration nor protects biological diversity. Instead of evaluating the success or failure of harvests by their selectivity or temporary maintenance of canopy cover, it would be more appropriate to evaluate the success of harvesting based on measurable standards of sustainability. In many cases, more intensive forest harvesting of more wood species on a smaller land base may increase the profitability of forest operations, provide better regeneration, maintain stumpage value, and protect biodiversity by reducing or preventing the rate of intrusion into primary forest. (Fredericksen 1998)

> The current (often unregulated and also illegal) logging in the tropics follows the same economic model as is evident in most of the world's ocean fisheries: the most-valuable species are selectively harvested first, and when they are depleted, the next-most-valuable set is taken, until the forests are mined completely of their timber and the land becomes worth more for agriculture or ranching than for forestry (Asner *et al.* 2006; Karsenty and Gourlet-Fleury 2006; Laporte *et al.* 2007; Hall 2008; Schulze *et al.* 2008). The pursuit of high-value species for export markets drives the expansion into previously unlogged and remote areas (Kammesheidt *et al*. 2001; Laporte *et al*. 2007; Hall 2008; Schulze *et al*. 2008b; Asner *et al.* 2009; Bryan *et al.* 2010). With an abundant timber supply from usually illegal and conventionally unmanaged logging, there is no incentive for management or conservation. (quoted in Nawir and Rumboko 2007)

The story repeats itself. The timber trade defends itself by saying that "selective" logging ensures that the forest regrows naturally and in time, once again ready for their "safe" logging practices (WWF). In most cases, however, this is untrue due to the nature of rainforests and of logging practices.

This practice might often be the beginning of the classic three-stage process of deforestation. Logging roads are followed by landless families who clear the forest and move inexorably farther into shrinking forest, as cattle ranches follow in their wake, turning the exposed, thin soils into mediocre pasture lands (Nations 2006:144).

I should once again emphasise that EA and RA are a reliable way of making decisions in order to manage forestry activities sustainably. EA recognises that humans are part of the ecosystem and that all activities in the forest both affect the ecosystem and depend on it. RA accepts that during harvest important structures and organisms are intentionally retained on site for the long term, i.e. a sufficiently large portion of the original stand is left unlogged to maintain the continuity of structural and compositional diversity.

Here it should be mentioned once again that several communities Maya (still) have enormously rich "traditional ecological knowledge" (TEK), that we are slowly discovering and marvelling at (cf. Martin *et al.* 2010) – including the preparation of "dark earth", which is comparable to the Amazonian *terra preta*, supporting the sustainable successional agriculture and agroforestry acquired over centuries of practising absolutely sustainable MFGC. EA is something perfectly obvious to the Maya, as is RA, which is based on their belief that the forest must be maintained. This was the purpose, after all, of their "forest" and "home" gardens, particularly because these were able to play the role of nurseries and, in this way, serve the renewal or restoration of the forest after long droughts or fires (cf. Nigh and Diemont 2013). Living in the forest, the Maya

One burn establishes the open field gap and initiates the milpa cycle; fire-stimulated forest regeneration.

Careful and elaborate burning initiates the milpa cycle.

evolved a highly managed landscape – known as "high-performance *milpa*" – a sophisticated, intensive form of agroforestry which has shaped and conserved forest ecosystems and which has been the axis of the sustainable Maya forest garden resource management system (Wilken 1971; Nations and Nigh 1980; Ford and Nigh 2009; Ford and Nigh 2010:184; Ford and Nigh 2010:52-64; Ford and Nigh 2015:41-76). The system corresponds surprisingly well to modern, progressive "ecological engineering" principles integrating human society with its natural environment for the benefit of both" (Mitsch 1996; Mitch and Jorgensen 2004; Nations and Nigh, 1980; Diemont and Martin 2009:256). As for wood, it should be noted that in the last stage of the MFGC it is possible to harvest the trees for personal use or sell them, when they again clear, burn and plant the field. It is, however, necessary to distinguish between the modest wood production in the MFGC system and wood production in sustainably managed production forests.

In a certified SFM system it is necessary, for economic and ecological reasons, to exploit multiple tree species under the end-user grouping principle (Brazier 1979), alongside a vertically and horizontally integrated (small and medium) woodworking industry. This was the underlying idea of our work.

It is almost inconceivable that the high culture of the "Greeks of the New World", with their enviable knowledge of mathematics, the concept of zero, astronomy, a calendar system, the use of compact written language and ritual ball games, should have lasted for more than 100 generations and survived in the tropical forest without the wheel, metals, draft or pack animals, practically in the Stone Age – without destroying it. I have always wondered how the Maya managed to fell thicker trees. Prior to the supposed adoption of copper axes in the post-Classic period they used obsidian cutting tools, while thicker trees were simply ringed and left to die (cf. Coe 1966:161). Interestingly, they deliberately preserved some nitrogen-fixing trees, while other thicker unburned trunks did not significantly hinder the process of planting with a stick either. Today we know that unburned partially charred trunks had an important function in the creation of "dark earth" (cf. Nigh and Demont 2013).

Although with their sustainable system of MFGC (Ford and Nigh 2015), the Maya did somewhat adapt the forest to their needs in the botanical sense, they nevertheless preserved it with all its essential functions and benefits. It should at any rate be noted that the Maya forest is partially anthropogenic, with a markedly increased proportion of native species (e.g. chicozapote, breadnut, avocado, cacao) and the introduction of useful alien species after the conquest (e.g. orange trees, bananas, sugar cane, coffee, etc.). Generally speaking, the Maya took a utilitarian view of the forest and were happy to adopt the useful alien species which the cosmopolitan Spaniards brought with them.

The MFGC "entails a rotation of annual crops with a series of managed and enriched intermediate stages culminating in the reestablishment of the forest on the once-cultivated parcel" (Ford and Nigh 2010:184). "In a traditional milpa, from the first year farmers take measures that ensure the regeneration of forest vegetation" (Ford and Nigh 2015:49).

They succeeded in doing this in the context of a traditional agroecological system of management that today we would call "ecological engineering" (cf. Mitsch and Jorgensen 1989; Diemont and Martin 2009:256; Martin *et al.* 2010). It should be repeatedly stressed that the traditional *milpa* is not a maize monoculture. While maize is visually dominant, it is interplanted with beans, squash and more than 90 other Mesoamerican and "post-conquest" useful plants. Moreover, the multi-cropped maize field is just one stage of a recurring cycle" (Ford and Nigh 2015:47).

At present, forest management relies (in the best case) on government-mandated cutting cycles, minimum felling diameters, per-unit-area harvest intensities and seed-tree retention. In the given circumstances, the system is not a bad one and it is partially sustainable, in that it attempts to take into account the biology of growth, the rejuvenation and ageing of individual tree species, the social/cenotic status of trees, the appearance of juvenile and reaction/tension wood and the biology of wood quality.

The damaging practice of highly selective logging is repeatedly mentioned in the essay "Mahogany – a natural and cultural history of the famous wood". We should always, however, emphasise the destructive harmfulness of unregulated and negligent illegal logging and increasingly unmanageable population pressure.

A further contribution to the lack of clarity regarding forest management comes from the different understandings of the extremely broad definition of SFM developed by the Ministerial Conference on the Protection of Forests in Europe and adopted by the FAO.

Instead of the required balanced holistic approach, with operations to maintain the full complement of forest integrity, understanding of the SFM is frequently reduced to sustained yield management. It is therefore generally focused on timber, or possibly on CO_2 absorption, while other forest values are often compromised.

Kimmins (1997) states that “fine words, good intentions and warm feelings about the sustainability of forest ecosystems” do not suffice, and offers some reasons:

> (1) Lack of a generally accepted definition of the SFM; (2) lack of an adequate understanding about forest ecosystems by politicians who pass laws and the forest policy makers who establish regulations about how to manage forests; (3) lack of an adequate ecological classification of forested landscapes and (4) lack of ability to predict the long-term ecological consequences of alternative ways of managing a particular forest ecosystem…

Here should be stressed that SFM and the ecosystem approach express similar goals and ambitions for forest management focusing on balancing the environmental, sociocultural and economic objectives of management in line with the original definition of SFM.

But as Kimmins (1987:318) warns: “Much of traditional economics is concerned with expanding economics, with growth, and with maximising short-term returns on investment. In this context, economics and ecology are dancing to different tunes.”

The multiple value of forests has long been appreciated and used by forest-dependent peoples in the tropics (e.g. the Lacandones). The goal of multiple-use forest management (MFM) is stated in the laws of many countries in much the same way as the guiding principles of SFM became firmly established in laws following the Earth Summit in Rio in 1992. “MEM represents a common and prime management objective under the SFM paradigm … It is a concept of forest management that combines two or more objectives, not only the production of wood…” (Sabogal *et al.* 2013).

Today the focus is mainly on the terrible consequences of climate change and the decisive role of forests in climate change mitigation. After a series of annual United Nations Climate Change Conferences held within the context of the United Nations Framework Convention on Climate Change (UNFCCC), awareness is growing of the key importance of forest for mitigating climate change or global warming. The 2010 United Nations Climate Change Conference was held in “nearby” Cancún, Mexico. “Now is the time to take global action to protect the forests”, said UN Secretary General Ban Ki-Moon in Cancún. Soon there will be no more time. Of course, however, mitigating CO_2 absorption is not the only essential ecosystem function of forests. Others include soil protection and formation, erosion control, nutrients cycling, biodiversity, protection, water regulation and supply, disturbance regulation, and others we have yet to encounter.

2. Selva Maya, Selva Lacandona and its inhabitants

2.1 First encounter with the Selva

Forty years ago my long-cherished dream of visiting Mexico came true at last. The main person I can thank for this is the great German naturalist, world traveller and my role model, Alexander von Humboldt, also known as "El Descubridor Científico De América", or as is written below his statue in front of "my" Humboldt University in Berlin "Al segundo descubridor de Cuba". Having seen almost the whole world he said: "If I could call only one small part of this world paradise, then it would have to be Mexico". The great Venezuelan revolutionary General Simón Bolívar (1783-1830) commented that "Baron Humboldt did more for the Americas than all the conquistadores" (quoted in Tudge 2005:18). Moreover, the famous Prussian, naturalist, founder of biogeography and respected world traveller made an important contribution to spreading the idea of sustainability around the world.

In Mexico at last! On our first visit, we were greeted on the road from the airport to Villa Hermosa in Tabasco, in the direction of Palenque and Chiapas (which required a little more than two hours), by a solitary, mighty ceiba (*Ceiba pentandra* (L.) Gaertn.), which the Lacandon Maya (also called the Lacandon or Lacandones) call *yaxche'*, "the first", and also the "green" tree. It is a symbol of life and the centre of the world. When a person is born, he climbs up its roots onto the Earth, and after he dies he climbs up its branches into the heavens.

The ceiba is my old acquaintance from the African rainforest (!), where we called it *fromager*. It is also an example of extreme long-distance seed dispersal, via wind or marine currents, which creates taxonomic similarities in the plant communities of Africa and the Neotropics (cf. Dick *et al.* 2007), although it most likely originated in South America. After this first "rainforest" greeting, we were even more excited and prepared ourselves for the incomparable experience that was awaiting us.

We entered this mysterious country through its most beautiful and most famous entrance – **Palenque**, the capital of the Maya city state that reached its apogee in the 7th century. The Palenque ruins date mostly mostly from 4th to 9th centuries (Classic Period). They are architecturally distinguished by the *Palace* and *Temples of the Sun, Cross, Foliated Cross*, and *Inscriptions*, the latter with the famous tomb of Lord Shield-Pacal (AD 615-83). After its decline, Palenque was absorbed into the tropical forest – the *selva*. Its buildings and temples have now been excavated and restored as an archaeological site which regularly attracts thousands of visitors. Many consider the site to be the most graceful and beautiful of Mayan cities.

> The late Sylvanus Morley considered Palenque to be the most beautiful of all the Maya centres, albeit in comparison with a giant like Tikal it is of no great size. The setting is incomparable: Palenque lies at the foot of a chain of low hills covered with tall rainforest, just above the green flood plain of the Usumacinta. (Coe 1977:119)

What we see nowadays in Palenque is only a small part of the incredible complex of chambers, terraces, staircases, temples, palaces and other structures that graced Palenque in its heyday in the 7th century AD.

In 1987 UNESCO recognised Palenque as a World Heritage Site and in 1993 it was declared an Archaeological Monument by the Mexican Federal Government, so as to be protected under the Federal Law on Archaeological, Artistic and Historic Monuments and Sites.

Alongside the *Palace/El Palacio,* the most famous building is undoubtedly the *Temple of the Inscriptions/Templo de las Inscriptiones* with Pacal's sarcophagus lid, which is made out of a single stone. It is a priceless piece of Mayan art and one of the most important archaeological finds of all time.

Pacal's tomb has been the subject of ancient astronaut hypotheses since its appearance in Erich von Däniken's 1968 best-seller, *Chariots of the Gods?* Von Däniken reproduced a drawing of the sarcophagus lid, incorrectly labelling it as being from Copán and comparing Pacal's pose to that of Project Mercury astronauts in the 1960s. Von Däniken interprets drawings underneath him as rockets, and offers it as possible evidence of an extra-terrestrial influence on the ancient Maya.

The Sacred Tomb found inside the pyramid of the *Temple of the Inscriptions*. The intricate sarcophagus of the jade-dressed ruler is perhaps the greatest archaeological find in the western hemisphere, comparable to that of the discovery of the Tomb of Tutankhamun in Egypt.

Ceiba/kapok, cotton tree, floss silk, Lac. *yaxche*' (*Ceiba pentandra*, Malvaceae). Depending on the pronunciation of the Maya name it can mean "green tree", "first tree", or "great tree" (Bruce 1975:249, quoted in Cook 2016:273).

Stepped edge of the *Temple of the Inscriptions/Templo de las Inscripciones* with the *selva alta* in the background, a superb example of Classic Period Mayan architecture. The structure was specifically built as the funerary monument for Pacal the Great.

Palenque, *the Palace*: the corbeled arch seen in the hallway, called a "false arch" because it lacks a keystone; it is built up from the walls, each successive stone jutting out over the one below, eventually topped by a flat stone.

Pacal's sarcophagus also features carvings of avocado, cacao, mamey, nance and guayaba trees, which all grow in traditional forest gardens and forests today (cf., for example, Ford and Nigh 2015:150), and are also proof of the amazing way Lacandon survival is connected with forests, something that was further confirmed for me by the excellent, already mentioned, co-authored paper by Nations and Nigh "The evolutionary potential of Lacandon Maya sustained-yield tropical forest agriculture" (1980). These authors were the first to describe in detail the Lacandones' intensive agricultural method. For these researchers, the Lacandon system answered the question of how the ancient, lowland Maya managed to feed several million people on crops produced from thin forest topsoil (cf. Cook 2016:37).

In reality, the relief shows the *World Tree*, the ceiba tree, which the Maya believed had its roots in the underworld, trunk on the earthly plane, and branches high in paradise, and Pacal's relationship to it in death. The king is depicted either at the moment of his death falling, from the earthly plane down into Xibalba (i.e. the underworld), or at the moment of his resurrection from the same, climbing up the World Tree toward paradise. There are carvings on the top and sides of the sarcophagus.

This is where I first met the Lacandon Maya from the community in Nahá, a very conservative community located in the Selva Lacandona, dressed in the traditional *xikul*, a white tunic made of two panels sewn up the sides. In the past it was made of hand-woven cotton, but today it is made of commercial, bleached cotton (cf. Cook, 2016:83). Today, the Lacandones only produce bows and arrows for tourists, and the sale of these is the main source of income for the community in Naha', and is the principal activity for 90% of the families (cf. Cook 2016:73,74). Soon after our arrival we saw the first "real" Lacandon in the forest.

The Lacandon with their exotic "Maya" look and the pyramids in the background, stir the imagination of countless tourists, although we must note that they are not the direct descendants of those who built these structures (see Chapter 2.3). The bows are mainly made from a wood called chico zapote*, hach ya, hach ya*, Lac. *chäk ya' ,hach ya', ya'* (*Manilkara zapota* (L.) P. Royen, Sapotaceae) or also from Lac. *säk ya' (Chrysophyllum mexicanum* Brandegee ex Standl.*,* Sapotaceae*)* or from *guaité,* Lac. *subul* (*Dipholis* sp.*,* Sapotaceae*),* and in the past certainly also from the famous palo santo, "lignum vitae", Lac. *hach chulul* (*Guaiacum sanctum* L., Zygophyllaceae), whose heartwood exudate was once the last hope of a cure for the terrible syphilis epidemic which spread through Europe after Christopher Columbus' return (cf. Torelli 2006a). "Lignum vitae" does not grow in Selva Lacandona, or at least not now. It was probably imported from northern Yucatan, central Chiapas or the Pacific coast (forest type: *Selva baja caducifolia*). The same name was perhaps also used to designate the guayacán tree type (*Tabebuia guayacan* (Seem.) S. Grose, Bignoniaceae), which also has a very dense and hard wood. We also studied the wood of the chico zapote and the guaité in our research.

Arrows are predominantly made of the hollow flower stalks of Lac. *'ooh* (*Gynerium sagittarum* (Aubl.) P. Beauv., Poaceae – the Latin name of the species name!). There are four kinds of arrows, each made to kill specific game. Most are fitted with a *chuste* ""foreshaft" , made of Lac. *säk ya' (Chrysophyllum mexicanum*, cedro, Lac. *k'uche'* (äh) (*Cedrela odor*ata L., syn. *C.mexicana*, Meliaceae), palo de tinta, palo de campeche, logwood, dye wood, Lac*. ek'*. (*Haematoxylon campechianum* L., Fabaceae) and mahogany, caoba, Lac. *puuna (äh*) (*Swietenia macrophylla* King*,* Meliaceae). The *tok'* (arrowhead) is made either of flint or obsidian (cf. Cook 2016:74). We also carried out a study on mahogany.

I bought a bow during my first visit and it now adorns my collection of tropical bows, which includes two Pigmy crossbows made from a wood that has an exceptionally high modulus of rupture and elastic modulus. Only after years of friendship with the Pygmies did they tell us what type of wood they use to make the bows for their crossbows (*Xylopia hypolampsa* Mildbr. & Diels, Annonaceae). We carried out a special study on this wood in Ljubljana. It is characterised by a high density, like the wood of both "our" types, and an exceptionally homogenous anatomical structure.

We were also excited because we had stepped into the land of the great revolutionary Emiliano Zapata, a hero of the Mexican Revolution (1910-1917). In 1910 Zapata took up arms against the Porfirio Diaz government with the famous cry "Tierra y Libertad", and his name was pronounced in the time of Tito's Yugoslavia with admiration and much sympathy. We all knew his famous statement (1910) "It is better to die on your feet, than to live on your knees", which was erroneously ascribed to Spanish revolutionary Dolores Ibárruri ("La Pasionaria"). To this day, Zapata is (to most Mexicans) the hero of the agrarian movement.

We also remembered the statement: "Poor Mexico, so far from God and so close to the United States" (Porfirio Diaz).

Fig. 2.5 Our first meeting with a Lacandon at work in the forest near the village of Naja, wearing a white cotton *xikul*.

Older Lacandon from Naja' in his traditional hand spun cotton, *xikul* with artificially crossed eyes or a squint, created by hanging a small, light object, perhaps a little ball of resin, from the hair between the eyes, thus forcing the infant to bring the pupils together (cf. Mendez 1986:27).

Maya boy – our Mexican friends provided top security for us.

Yucatan girl.

Lacandon boy selling imitations of the famous bows.

Our Mayan associate with a typically round head, broad face with protruding cheekbones, although some of the highland groups, such as the Tzeltals and the Tzotzils, have elongated heads.

Also connected with Selva Lacandona is the name of the mysterious B. Traven, author of *The Treasure of the Sierra Madre* and six "jungle novels", including *The Rebellion of the Hanged* (once translated into Slovene), in which he described the hard lives of mahogany loggers. I mention him because he may have been of Slovenian origin (see the essay on mahogany, Chapter 7!).

Among the numerous buildings in Palenque there are two charming temples, with the Selva in the background, which stir the imagination even further.

From Palenque we took the highway for 25 km to Rio Chancala, where we settled down in the "Casa grande". After so many years, I still cherish grateful memories of our friendly landlady Carmela. On the way to Chancala we could observe the sorry sight of the remains of what had once been a forest. It is this very road that evidently had the most devastating impact on the Selva Lacandona between 1951 and 1973, not the activities of the indigenous people (1980), with 20% of the Lacandones still practicing their traditional farming methods – the milpa forest garden cycle or MFGC. Since then, the traditional milpas has declined. Today, traditional farmers are progressively reducing the number of species they cultivate, while the younger generation has shifted to monocropping maize (conventional milpa). Even more, the spread of colonization and an increase in forest reserves forces the Lacandones to rotate their existing milpas more often (cf. Cook, 2016:42,). (Nations 2006: 260)

> This modern wave of deforestation is driven by overconsumption of natural resources … The current rate of forest destruction in the Maya tropical forest surpasses 800 square kilometres per year (Nations, Bray and Wilson 1998). In at least half the years, dry weather conditions, forest fragmentation, and burning for pastures and agriculture produce forests fires that inadvertently burn thousands of additional hectares of natural forest. While the ancient Maya cleared the forest for food production und fuelwood, the modern iteration of deforestation is goaded along by logging (mainly non-sustainable highly selective felling of coba and cedro), oil exploration, road construction, colonization, slash and burn agriculture (conventional milpa), export crops production, and cattle ranching.

We later also went to the Selva from Tuxtla Guitérrez, the capital of Chiapas, taking a small plane to Rio Chancalá or Palenque, and numerous times also with a 4x4 via the wonderful San Cristóbal de las Casas, to Ocosingo and from there on a good road past Agua Azul, the most beautiful waterfalls in Mexico on the Río Tulijá and the 35 m Misol Ha waterfall, to Palenque or via Monte Libano to the village of Nahá with its beautiful laguna. With a bit of luck you can see crocodiles here. This is where the legendary Chan K'in Viejo, *t'o'ohil* lived, the spiritual leader and preserver of Lacandon tradition. He died in 1996, apparently aged 100. From Nahá we travelled via Tumbo, Limonar and El Diamante to Río Chancalá – our base.

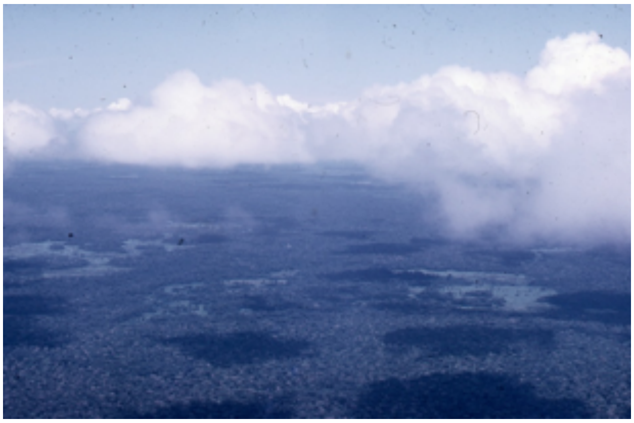
On numerous occasions we had to take the crammed buses, which are the cheapest form of transport and are called *guajoloteros* ("turkey buses"). Despite already being overfull, there was always room for turkey sellers laden with these large birds. With the obligatory *Virgen de Guadalupe* statue watching over the driver's seat, we sped safely along the winding roads. The curtains waved happily out of the open windows. Someone had written on the back of the dust-covered bus: *mejor morir que llegar tarde* – "It is better to die than arrive late". Everything went smoothly, as we were under "Morenita's" protection.

We reached Chetumal via a long, straight road from Escárcega, a small city in the Mexican state of Campeche. The land here is rocky and semiarid (*Selva alta o mediana subperennifolia*) and is poor for agriculture. Here are e.g. Río Bec, a late Classic Period site that lends its name to a distinctive regional style of temple architecture; Becán, a rare fortified Classic Mayan site near Xpuhil, another Classic Mayan site with a temple in the Río Bec style, Chicanná and Kohunlich, near Chetumal, an Early Classic site whose pyramid has large stucco god masks flanking its stairway (Fig. 33) (cf. Muser 1978).

Palenque, *Temple of the Sun/Templo del Sol* with the roof comb.

Palenque, *Temple of the Cross/Templo de la Cruz*, also topped with an impressive roof comb.

Partly deforested and fragmented Selva Lacandona south of the Rio Chancala due to the selective logging followed by the conventional milpa and ending with the pasture and cattle breeding, and possibly some permanent agriculture.



2.2 The forest

CONAFOR (2010) and FAO (2010) estimated the total forest area of Mexico at 64.8 million hectares, of which 31.4 million hectares are in the tropics. The tropical region includes rainforests, which originally covered about 6% of the country. Tropical forests are found on slopes along the Gulf of Mexico and the Pacific Ocean, on the Isthmus of Tehuantepec and in southern Yucatan in the states of Campeche, Chiapas. Oaxaca, Quintana Roo, Tabasco and Veracruz. The average annual rainfall in these forests is above 2000 mm and the temperature is always higher than 18 °C, with little variation (usually staying between 23 °C and 25 °C) (cf. *Forests of Mexico* 2018, Pennington and Surukhan 1968:1-46).

According to the canopy height, the tropical forests can be divided into three major types: high forests (*selva alta*), with a canopy height of 30 m and above, medium forests (*selva mediana*) with a canopy height of 15-30 m, and low forests (*selva baja*) with a height of 4-15 m (Miranda and Hernández 1963; Pennington and Sarukhán 1968).

The diverse vegetation formations make the Lacandon forest the richest ecosystem north of the Amazon (De la Maza 1997). Breedlove (1973, 1981) reports that in Chiapas true tropical rainforest occurs only in a few locations in the flat valleys of the upper drainage of the Usumacinta River, and is surrounded by more common forest types (quoted in Cook 2016:14-18):

1. ***Lower Montane Rainforest*** which corresponds to *Bosque Tropical Perennifolio*, in part (Rzedowski 1978) and *Selva Alta Perennifolia*, in part (Miranda and Hernández 1963; Gómez Pompa 1965; Pennington and Sarukhán 1968; Flores *et al.* 1971). In tropical regions, *Lower Montane Forest* refers to the rainforest on mountain slopes that are distinctly different from the *Lowland Rainforest* that covers the plains, flatlands, and low hills. Generally, this forest formation can be considered an intermediate zone between the *Montane Cloud Forest* located at much higher altitudes, generally above the persistent cloud zone, and the tall *Evergreen Rainforest* of the lowlands. This formation covers most of the Selva Lacandona from 350 to 1100 m and displays the greatest diversity of vegetation (Pennington and Sarukhan 1968:8). While physically similar to the *tropical rainforest*, it consists of only two strata of trees (Bredlove 1981:8). The upper canopy is characterised by trees that range between 25 and 45 m in height, their branches adorned with epiphytes and interlaced with lianas.

2. ***Montane Rainforest*** corresponds *to Bosque Tropical Perennifolio,* in part (Rzedowski 1978) and *Selva Mediana* or *Baja Perennifolia,* in part (Miranda and Hernández 1963; Gómez Pompa 1965; Pennington and Sarukhán 1968); *Bosque Mesófilo de Montaña*, in part, and *Selva Alta Perennifolia* (INEGI 1980). This formation occurs on the steep slopes and mountain ridges. It is a three- or sometimes two-storied formation. The upper canopy is irregular, with trees reaching up to 35 m, occasionally interspersed with taller trees (Breedlove 1981:10).

3. ***Pine-Oak-Liquidambar*** corresponds to *Bosque Mesófilo de Montaña* (Rzedowski 1978; Rzedowski and McVaugh 1966) and *Cloud Forest,* in part (Leopold 1950, Martin 1958), and *Pine-Oak-Liquidambar* (Carlson 1954). This formation occurs above 1000 m in the northern and north-eastern regions of Naha (Hernandez-Nava 2003:6). Species include Lac. *pixan k'ambul (äh)* (*Quercus skinneri), Q. anglohonduensis (*syn*. Q. acutifolia),* manax, wild cherry*, tzotzash,* Lac*. hach bamax, tso'ots bamax* ***(****Pseudolmedia oxyplyllaria), Pitecellobium matudai , Lonchocarpus* ssp. Both *Quercus* species were investigated in our study.

4. ***Pine Forest*** corresponds to *Bosque de Pine y Encino* (Rzedowski and Mc Vaugh (1966). This formation occurs on the upper slopes and ridges above 1000 m elevation. The forest is populated by a few species of pines and oaks ranging between 15 and 40 m in height (Breedlove 1981:19). The dominant species are *Pinus maximinoi; P. oocarpa, P. psdeudostrobus, and P. chapensis.* Pine also occurs around the lagoons of Naha' and Ocotalito, notably *P. chapensis* (Duran 1999), where they intermingle with tropical rain species

5. Flooded ***Thorn Woodland*** corresponds to *Bosqe espinoso inundable* (CIEDAC 1991). This riparian forest is unique to Naha' and Mensäbäk. Dense populations of *Haematoxylum brassileto* and zapote bobo, santo domingo, water zapote, *uacut, kubuh*, Lac. *kubuh (ah) Pachira aquati-*

Selva Lacandona, *Selva alta perennifolia*, aerial view.

Selva Lacandona (*Selva alta perennifolia*), secondary forest or possibly the last stage of the MFGC.

> *ca*, etc. form a narrow belt around the lakes in the vicinity of Naha' and Mensäbäk (Hernández-Nava 2003:6). Nations and Nigh (1980:20) state that marshes or seasonally flooded areas bear special formations, such as the almost pure stands of the palo de tinta, Lac. *ek' (Haematoxylum campechianum*) which surround the many lakes in the Lacandon region.

A dense patchwork of secondary forest (i.e. secondary growth and successional forest) is distributed in numerous small areas to the east and northeast of Naha'. This vegetation type refers to primary forest that has been altered by natural causes and human intervention, and displays various stages of re-growth (successions).

The rate of deforestation has apparently slowed but is still high. Over-harvesting and illegal harvesting of forest resources is widespread (although less so in the tropics than in the temperate zone), exceeding sustainable levels in many areas. Community management is the major form of forest management, but in many cases communities are not equipped to manage their forests sustainably. Some of the problems that obstruct progress towards the sustainable management of the closed forest areas in communes (*ejidos*) include a lack of resources and know-how for the economic use of forest resources, and discrepancies in the objectives among communities, the private sector and forest authorities. On the other hand, good progress has been achieved in forest certification, although much of this to date has been outside the tropics. Moreover, the government has taken steps to address shortcomings in the sector and is attempting to combat illegal logging and fires (*ITTO SFM Tropics*, Mexico 2005).

The management of Mexico's forests differs greatly between the pine and oak forests in the temperate zone, the forests in subtropical regions and the moist tropical forests in the south (*ITTO SFM Tropics*, Mexico 2005).

The Lacandon forest (*Selva Lacandona*), as a part of the Maya tropical forest, stretches from Chiapas, Mexico, into Guatemala and into the southern part of the Yucatán Peninsula (*Lacandon Jungle* 2016). It is the largest unbroken tropical rainforest north of the Amazon. Archaeologically it belongs to the Central Maya zone, and it is also called the Southern Lowlands or Eastern Highlands. Major sites include famous archaeological locations such as Comalcalco, Piedras Negras, Altar de Sacrificios, Seibal, Uaxactún, Tikal, Naranjo, Yaxhá, Copan, Quiriguá, Lubaantun, Holmul, Altun Há and Palenque, Yaxchilán, and Bonampak in Selva Lacandona.

The Selva Lacandona covers approximately 1.9 million hectares. The Chiapas portion is located on the Montañas del Oriente (Eastern Mountains), centred on a series of canyonlike valleys called the Cañadas, between smaller mountain ridges oriented from northwest to southeast. It is bordered by the Guatemalan border on two sides with Comitán de Domínguez to the southwest and the city of Palenque to north. The core of the Chiapas forest is the *Montes Azules Biosphere* reserve, but it also includes some other protected areas. Dividing the Chiapas part of the forest from the Guatemalan side is the Usumacinta River, which is the largest in Mexico and the seventh largest in the world based on volume of water. The area has a mostly hot and humid climate: Aw2(w)(i')g, after the Köppen climatic classification system. The rainy season in the Maya tropical forest occurs between late May and late November with an average of 2300 to 2600 mm per year. There is a short dry season from March to May, and after completing our regular, annual pedagogical obligations at the University of Ljubljana, we set off for Mexico at this time of year for several consecutive years. We often looked anxiously up into the sky, as an early beginning to the rainy season could interrupt our fieldwork. Then, one May morning, in the middle of the night in Chancala, we were awakened by the sound of logs, which had floated over from the nearby sawmill, now bumping into our house. I remember seeing snakes swimming in the coffee coloured floodwater. We were lucky that time round as the proper rainy season had not yet begun…

The average annual temperature is 24.7 °C. May and June are the warmest months, with an average temperature of 25.6 °C (Cook 2016:14). The rainy season often begins in the lower regions near Lacanja, and mean yearly temperatures are lower in Naha' (e.g. Kashanipour and McGee 2004:49).

Despite the fact that much of the area has been reduced to a patchwork of clearings for cattle ranches and peasant communities, the Lacandon contains some of the most extensive and best preserved remnants of lower montane rainforest in Mexico and Central America, especially within the *Montes Azules Biosphere Reserve.* It contains around 1,500 tree species, 33% of all Mexican bird species, 25% of all Mexican animal species, 44% of all Mexican diurnal butterflies and 10% of all Mexico's fish species. Although most of the jungle outside the reserve has been partially or completely destroyed and damage continues inside, the Lacandon is still the largest montane rainforest in North America and one of the last ones left that is large enough to support jaguars (*Mexican forests* 2018). The Maya tropical forest is one of the most biodiverse rainforests in the world, and besides jaguar it contains many endangered species such as the red macaw, harpy eagle, tapir, and Central American spider monkey, among others.

Selva mediana alta or *mediana subperennifolia*, (a) a view from the temple-pyramid *Nohoch-Mull,* Coba, and inside the forest (a, b, c)

We also saw crocodiles deep in the forest, far from water sources.

Twice we happened across the most feared hemotoxic viper *fer-de-lance* or *barba amarilla* (*Bothrops asper*), a highly venomous pit viper species, sometimes referred to as the "ultimate pit viper"(*Bothrops asper* 2018). The first time we saw it was in the ruins of Kohunlich near Chetumal (Fig. 34), when the guide in front of me dealt a panicked death blow with a machete to an attacking *barba amarilla* in mid-air. They then told me the man would never laugh again. I found this to be true in the course of my later visits…

The second time I saw this snake was in Chancala, where we were staying. One day, during the siesta, we heard blood-curdling shouts. In the courtyard of the warehouse, the *barba* was writhing up and down and attacking a woman in her nightgown. The experienced Deocundo reacted with composure and, taking a stick, ran towards the couple and directed the snake's attention away from the frightened woman. The *barba* represents a great danger for the chicleros in their extremely dangerous and strenuous work of making cuts in the trunks of the chicozapote (sapodilla tree). The aggressive snake is also a danger for cocoa and banana farmers, loggers, hunters, military personnel, biologists, ornithologists, and those who practice ecological tourism (cf. e.g. Mathews 2009: 82, 83). The chicleros are also threatened by the insect *mosca chiclera (Lutzomia olmeca),* which transmits the dangerous illness leishmaniasis. This is how Williams (2013: 108) describes the consequences of being stung by this fly:

> The fly lays its eggs on the skin of the chiceros and the larvae rapidly hatch and burrow beneath skin and muscle where they feast on cartilage with special relish. After few seasons of work, the chicleros inevitably contact "la mosca" and gradually they lose their ears and noses becoming crippled in a way so characteristically deformed that everyone knows who is a leper…

We often came across the boa (*Boa constrictor*), luckily they were usually wound round a thick branch, satiated and immobile. As semi-arboreal snakes, young boa constrictors may climb into trees and shrubs to forage; however, they become mostly terrestrial as they become older and heavier. Once we were woken in the middle of the night by our volunteer, Patricija, who noticed a boa in her room. It really was a boa, approximately 2 m in length, and had probably been domesticated. We had difficulty convincing her (and ourselves) that it was not dangerous. Indeed, boa are frequently kept and bred in captivity.

We also saw a domesticated boa in the garden of a forester in Tuxtla Gutiérrez, the capital of Chiapas. Our humorous colleague Janez translated its scientific name into the friendlier sounding musical-construction term "*Oboa constructor*".

In the most elevated part of our study area, where we found both types of oak (*Quercus anglohonduensis* and *Q. skinneri*) and already in the cloud forest, lives the resplendent quetzal (*Pharomachrus mocinno*), whose long, brilliant green tail feathers were highly prized and played an important role in Mesoamerican mythology. Prominent in the headdresses of rulers, the feathers were an important trade item, as its rarity and green colour, as with jade, made it a symbol of wealth (Muser 1978: 134). It is the national bird of Guatemala, and its image is found on the country's flag and coat of arms. It also lends its name to the country's currency, the Guatemalan quetzal.

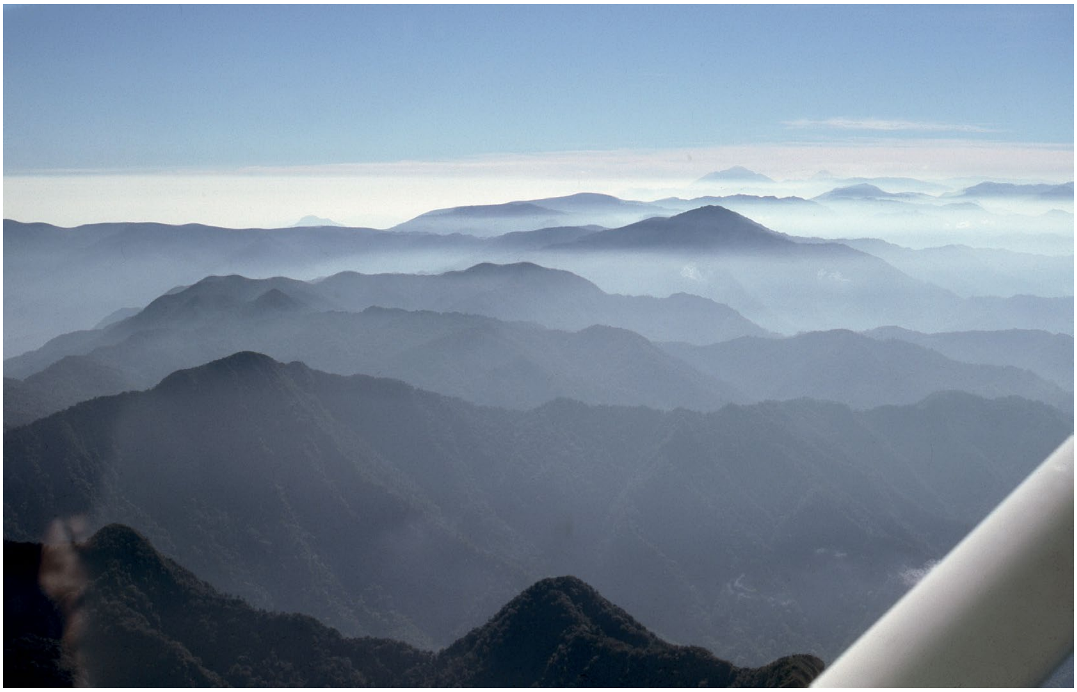
As already mentioned, "at home" at the Casa grande in Chancal we had a large, talkative (and foul-mouthed) guacamaya, scarlet macaw, Lac. *mo'* (*Ara macao cyanoptera*), which can also be seen in forests or in forest gardens. The variously coloured feathers were highly prized by the ancient Maya, and are frequently depicted on headdresses in sculptures (cf. Nations 2006:67).

We also like to remember the domesticated Pelon, mono araña or spider monkey, Lac. *ma'ax* (*Ateles geofftryi*), which greeted us happily early in the morning before we went to work and later when we returned. This species is quite common in forests and forest gardens.

Janez was once startled on a dig by an equally startled, harmless herbivore, the iguana de ribera, green iguana, Lac. *huh* (*Iguana iguana rhinolopha*), which dropped from a tree overhanging the small river.

Another "domesticated" animal I should mention is the very common bird spider. Every evening these furry creatures, measuring over 10 cm in length, watched me from the open roof timbers above my room, until one of them bit my big toe one night. The large swelling that ensued meant I could not put my boots on for a few days. I was also very surprised to see the traffic sign near Chetumal, which featured a bird spider, and at times hundreds of them crossed the road.

The diverse vegetation formations make the Selva Lacandona the richest, most biologically diverse ecosystem north of the Amazon (De la Maza 1997, quoted in Cook 2016:14). Tables 2.1 and 2.2 show the most frequent tree species. Figures 1–10 show the arboristic composition, density "profiles" and volume percentages at ten characteristic locations (see also Map 1).



Chiapas, pine forests, aerial view.

Chiapas, pine forests.

Selva baja caducifolia, Chiapas, Pacific coast.

A Morelet's or Mexican crocodile (*Crocodylus moreletii*).

Table 2.1 Botanical, Spanish/English and Maya common names (in italics) tabulated in increasing order of value of basic density (ρ_b) of tree/wood species represented (Figs. 2.25 a.b.c.d; 2.26 a.b.c.d.e.f)

Latin name	English/ Spanish name	Maya common name	Wood basic density - ρ_b (kgm^{-3})
Schyzolobium parachybum (Vell.) S. F Blake, Fabaceae	palo de picho	*petskin*	300
Dendropanax arboreus (L.) Decne. & Planch., Araliaceae		*sac-chac áh*	400
Swietenia macrophylla King, Meliaceae	caoba	*punab, punah*	430
Guatteria anomala R. E. Fr., Annonaceae	zopo	*ek'bache*	430
Cedrela odorata L., Meliaceae	cedro	*kulché*	430
Bursera simaruba (L.) Sarg., Burseraceae	palo mulato	*chacá, chaca*	430
Pseudobombax ellipticum (Kunth) Dugand, Bombacaceae	amapola	*chak kuyché*	440
Spondias mombin Jacq., Anacaediaceae	jobo	*k'aan abal, jobo*	450
Nectandra sp., Lauraceae	laurel	onté	460
Simarouba glauca DC., Simarubaceae		pasa'ak, pa sak, xpazakil	460
Talauma mexicana (DC.) Don, Magnoliaceae	yoloxóchitl	*jolmashté*	490
Calophyllum brasiliense Camb., Guttiferae	barí	*baba*	520
Luehea speciosa Willd., Tiliaceae	tepecacao	*k'an aat*	520
Terminalia amazonica (J.F, .Gmel.) Excell, Combretaceae	canshán	*canxun*	525
Lysiloma bahamensis Benth., Fabaceae	dzalam	*tzukté*	531
Guarea glabra Vahl, Meliaceae	cedrillo	*bul-ba*	560
Piscidia communis (Blake) I.M. Johnst., Fabaceae	jabín	*habí*	590
Zuelania guidonia (Sw.) Britt. & Millsp, Salicaceae	trementino, paragua	chu-ya-ak, tamay	610
Alseis yucatanrensis Standley, Rubiaceae	tbaquillo	*cacao-che, ison*	635
Guettarda elliptica Sw., Rubiaceae	hannock velvetseed		645
Blepharidium mexicanum Standl., Rubiaceae	popiste	*sak'yaxte'*	655
Simira salvadorensis (Standl.) Steyerm., Rubiaceae	chacahuanté	*sac te m'ooc, chakax*	660
Platymiscium yucatanum Standl., Fabaceae	granadillo	*chulul, sanich'té*	660
Vatairea lundelii (Standl.) Killip, Fabaceae	tinco	*canyul-tilté*	660
Vitex gaumeri Greenm., Verbenaceae	fiddle-wood	*yaxnik, sak-u-sol*	670
Aspidosperma cruentum Woodson, Apocynaceae	malerio	*sa'-yuk*	670
Aspidosperma megalocarpon Müll.Arg., Apocynaceae	malerio, fustan	*peechmaax*	675
Coccoloba cozumelensis Hemsl., Polygonaceae			675
Malmea depressa (Baill.) R.E. Fr., Annonaceae	wild coffee, che-che	*elemuil, eremuel*	722
Brosimum alicastrum Sw. Moraceae	ramón (nut)	*masicaran, ox, ujushte*	730
Lonchocarpus castilloi Kunth, Fabaceae	machiche	*manchich*	740
Cordia dodecandra DC, Boraginaceae	sirikote/zirikote	*chack opte*	752
Metopium brownei (Jacq.) Urban, Anacardiaceae	chechém negro, black poison-wood	*chechen, chen-chen*	770
Coccoloba spicata Lundell, Polygonaceae			797
Astronium gravelens Jacq., Anacardiaceae	jobillo, glassy wood	*kulim che*	800
Dialium guianense Willd., Fabaceae	guapaque	*we'ech*	800
Acosmium panamense (Benth.) Yakovlev, Fabaceae	guayacán and bálsamo amarillo	chakté, *ka che*	805
Dipholis sp., Sapotaceae		*subul*	810
Pouteria sp., Sapotaceae			820
Pouteria unilocularis (Donn.Sm.) Baehni, Sapotaceae	zapotillo		820

The most feared hemotoxic viper *fer-de-lance* or *barba amarilla* (*Bothrops asper*).

Scarlet macaw, sp. guacamaya; *Lac. Mo' (Ara macao cyanopterus*).

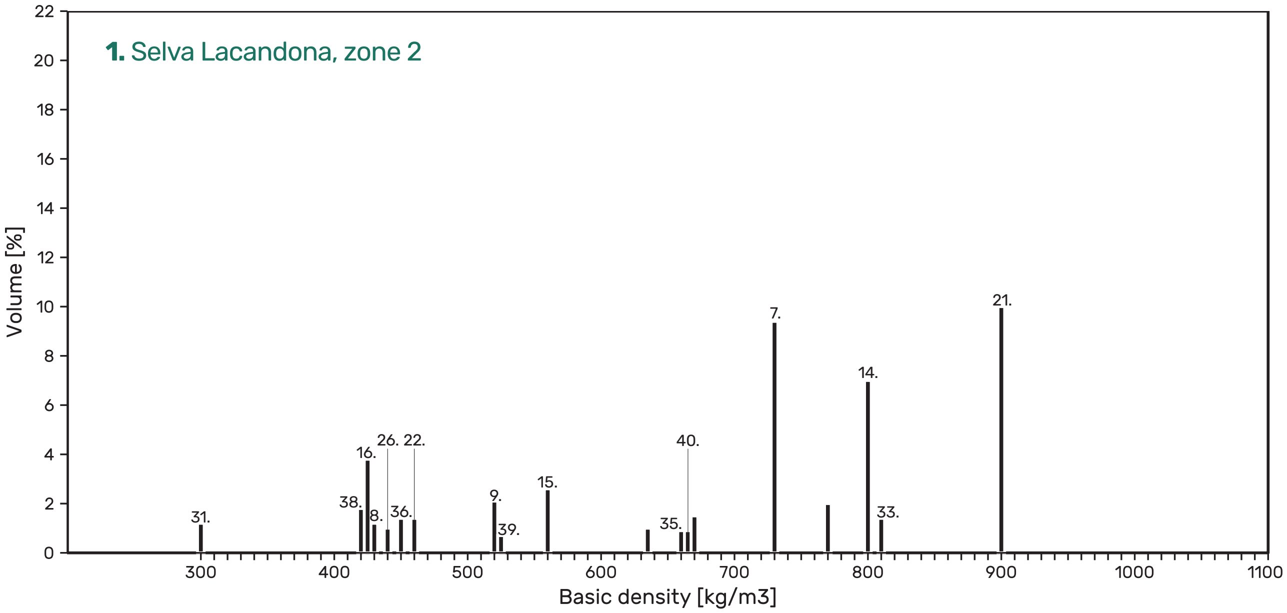
Kohunlich, North Zone, the Early Classic Maya site in southern Quintana Roo, the *Pyramid of the Masks* – a closeup of one of the masks.

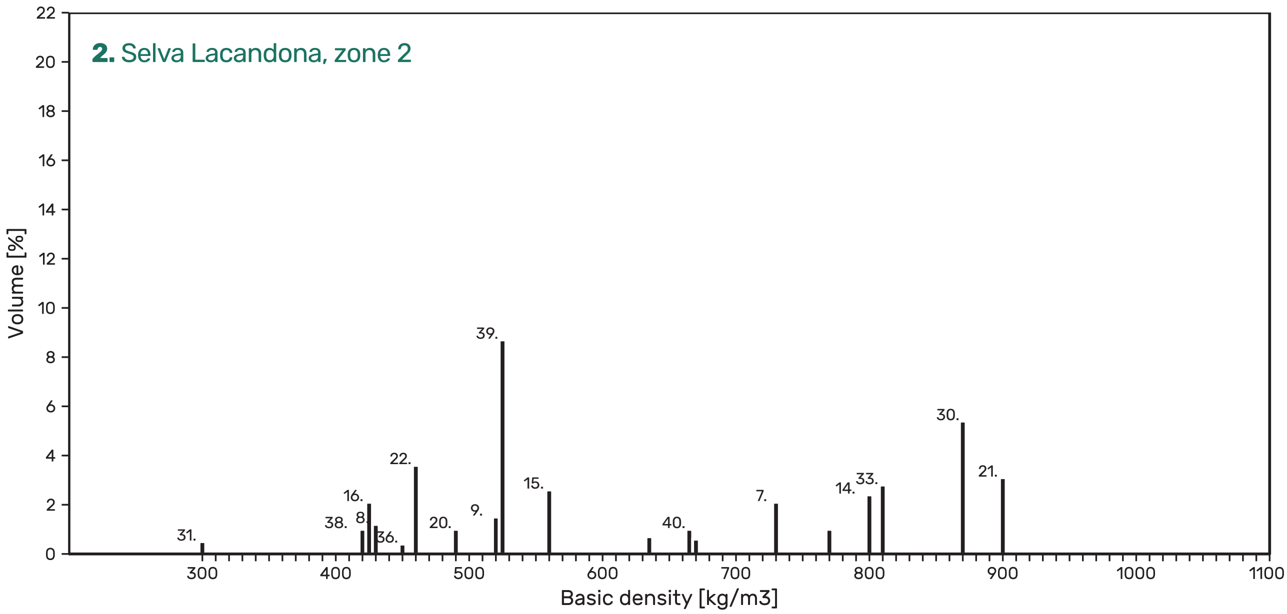
Latin name	English/ Spanish name	Maya common name	Wood basic density - ρ_b (kgm^{-3})
Caresalpinia platyloba (S. Watson) Britton & Rose, Fabaceae			825
Swartzia cubensis (Britton & Wilson) Standl., Fabaceae	corazon azul	*kat'alox*	830
Caesalpinia gaumeri Greenm., Fabaceae	quebra hacha	*kitin che*	835
Bucida buceras L., Combretaceae	bullet tree	*pukte*	850
Quercus skinneri Benth, Fagaceae		*cololté*	870
Haematoxylon campe-chianum L., Fabaceae	logwood, palo de tinta	*ek'*	871
Talisia oliviformis Radlk, Sapindaceae	cotoperiz, kinep	*wayah, uayum*	890
Pouteria campechiana Baehni, Sapotaceae	yellow sapote, zapotillo	*k'aniste'*	895
Manilkara zapota (L.) P. Royen, Sapotaceae	chico zapote, red sapotilla	*hach ya*	900
Gymnanthes lucida Sw. Ephorbiaceae	crabwood, shiny oysterwood		1100

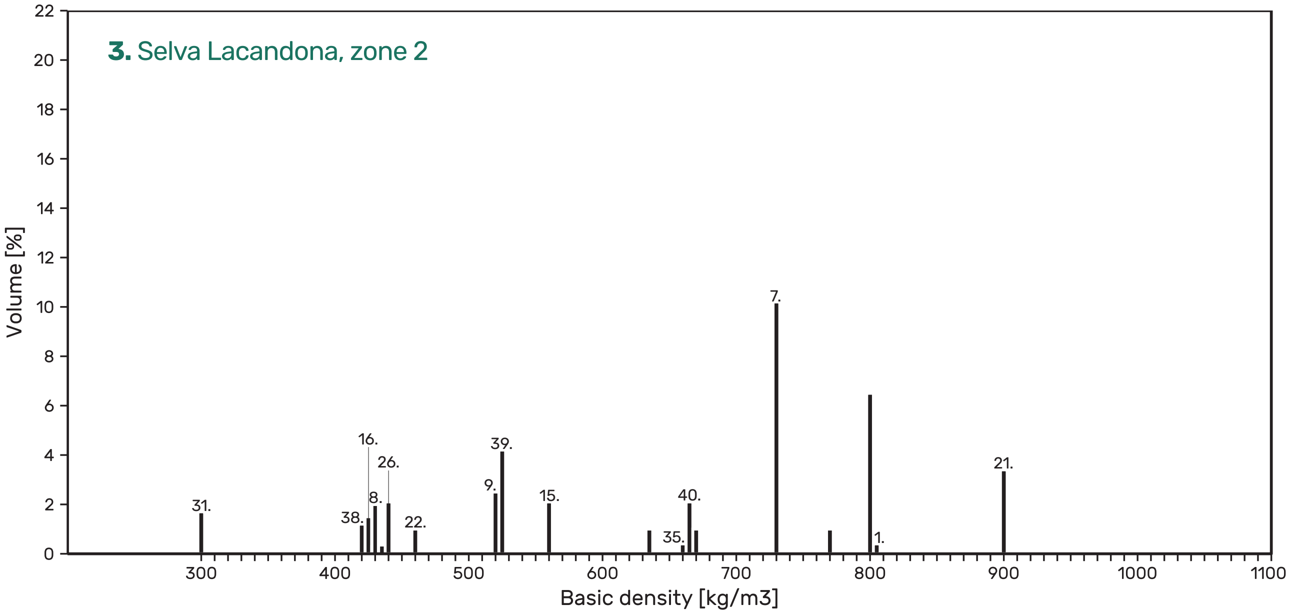
Table 2.2. Botanical names and basic density of the wood species represented

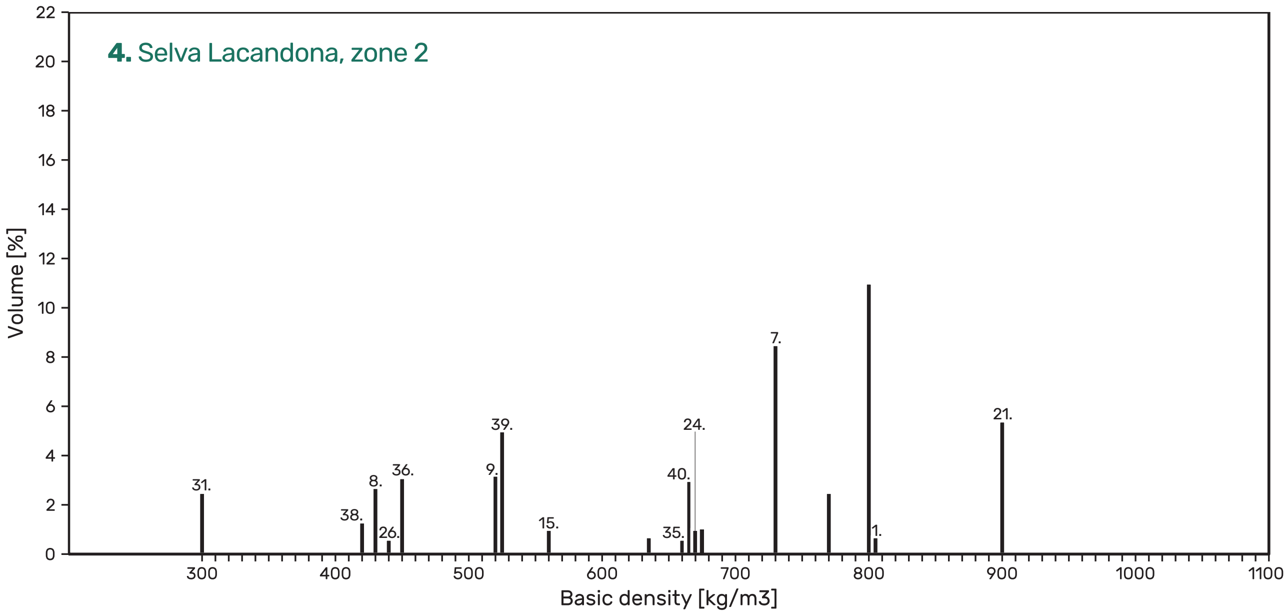
No.	Species	Basic density kg/m3
1	*Acosmium panamense* (Benth.) Yakovlev	800
2	*Alchornea latifolia* Sw.	390
3	*Ampelocera hottlei* (Standl.) Standl.	690
4	*Aspidosperma megalocarpon* Muell. Arg.	670
5	*Balizia leucocalyx* (Britton & Rose) Barneby & J.W.	520
6	*Blepharidium guatemalense* Standl.	600
7	*Brosimum alicastrum* Sw.	730
8	*Bursera simaruba* (L.) Sarg.	430
9	*Calophyllum brasiliense* Camb.	520
10	*Cojoba arborea* (L.) Britton & Rose	650
11	*Cordia alliodora* (Ruiz & Pav.) Oken	490
12	*Cymbopetalum penduliflorum* (Sessé & Moç. ex Dunal) Baill.	420
13	*Dendropanax arboreus* (L.) Decne. & Planch.	400
14	*Dialium guianense* (Aubl.) Sandwith.	800
15	*Guarea glabra* Vahl	560
16	*Guatteria anomala* R. E. Fr.	425
17	*Licaria peckii* (I. M. Johnston) Kosterm.	600
18	*Lonchocarpus castilloi* Standl.	740
19	*Lonchocarpus hondurensis* Benth.	670
20	*Magnolia mexicana* DC.	490
21	*Manilkara zapota* (L.) P. Royen	900
22	*Nectandra sp.*	*460*
23	*Pachira aquatica* Aubl.	500
24	*Platymiscium yucatanum* Standl.	665
25	*Poulsenia armata* (Miq.) Standl.	400
26	*Pseudobombax ellipticum* (Kunth) Dugand	440
27	*Pseudolmedia glabrata* (Liebm.) C.C.Berg	650
28	*Pterocarpus rohrii* Vahl	450
29	*Quercus acutifolia* Née	690
30	*Quercus skinneri* Benth.	870
31	*Schizolobium parahyba* (Vell.) S.F.Blake	300
32	*Sebastiania tuerckheimiana* (Pax & K.Hoffm.) Lundell	570
33	*Sideroxylon stevensonii* (Standl.) Standl. & Steyerm.	810
34	*Simarouba glauca* DC.	460
35	*Simira salvadorensis* (Standl.) Steyerm.	660
36	*Spondias mombin* Jacq.	450
37	*Swartzia cubensis* (Britton & Wilson)Standl.	830
38	*Swietenia macrophylla* G. King	420
39	*Terminalia amazonica* (J.F.Gmel.) Exell	660
40	*Vatairea lundellii* (Standl.)Record	660
41	*Vitex gaumeri* Greenm.	670
42	*Vochysia guatemalensis* J. D. Smith	460
43	*Zuelania guidonia* (Sw.) Britton & Millspaugh	610

Figs 1–10: Arboristic composition, density "profiles" and volume percentage at ten characteristic locations (Map 1) **1.** Chiapas, Selva Lacandona (selva alta perennifolia, zone 2); **2.** Chiapas, Selva Lacandona (selva alta perennifolia, zone 3; **3.** Chiapas, Selva Lacandona (selva alta perennifolia zone 4); **4.** Chiapas, Selva Lacandona (selva alta perennifolia, zone 5); **5.** Yuatan, Quintana Roo ,Ej. Noh-Bec (selva alta-mediana subperennifolia); **6.** Yucatan, Quintana Roo, Ej. Chacchoben, (selva alta-mediana subperennifolia); **7.** Yuctan, Quintana Roo, Ej.Divorciados (selva alta-mediana subperennifolia); **8.** Yucatan, Quintana Roo, Ej.Guadalajara (selva alta-mediana subperennifolia); **9.** Yucatan, Quintana Roo, Ej. Petcacab (selva alta-mediana subperennifolia); **10.** Yucatan, Quintana Roo, Ej. Nvo Becal (selva alta-mediana subperennifolia). (Inventario Forestal del Estado de Chiapas, SAG, Publ. No. 34, 1976; D Acopa, personal communication, 1992–3; Torelli 1994:337).

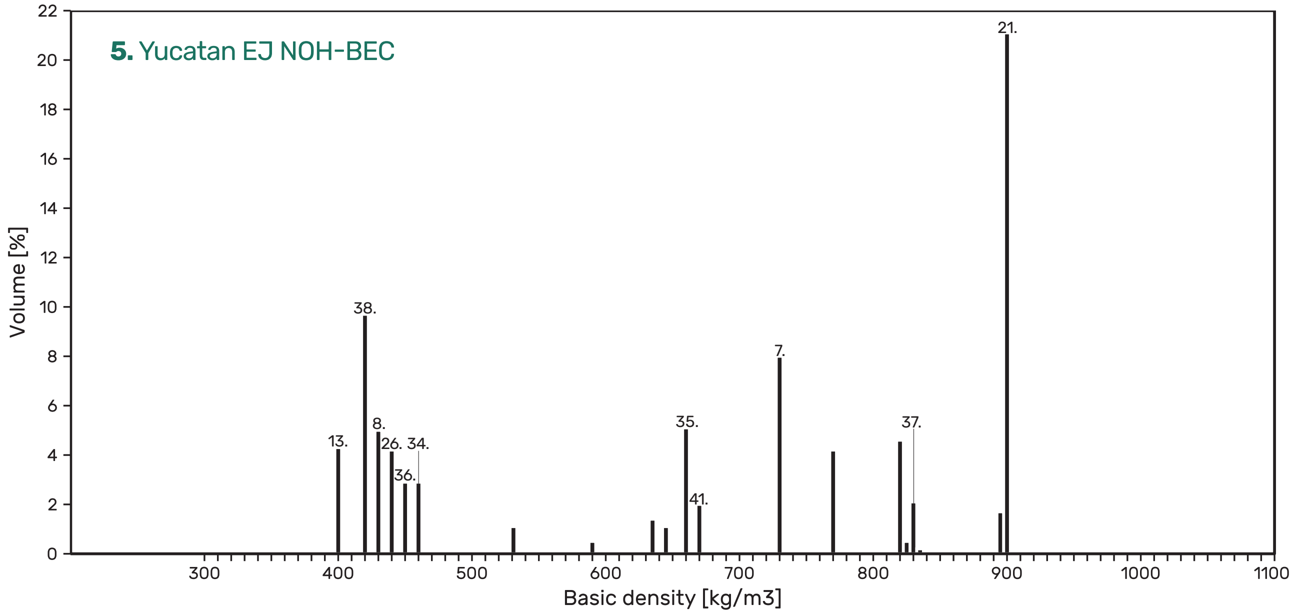


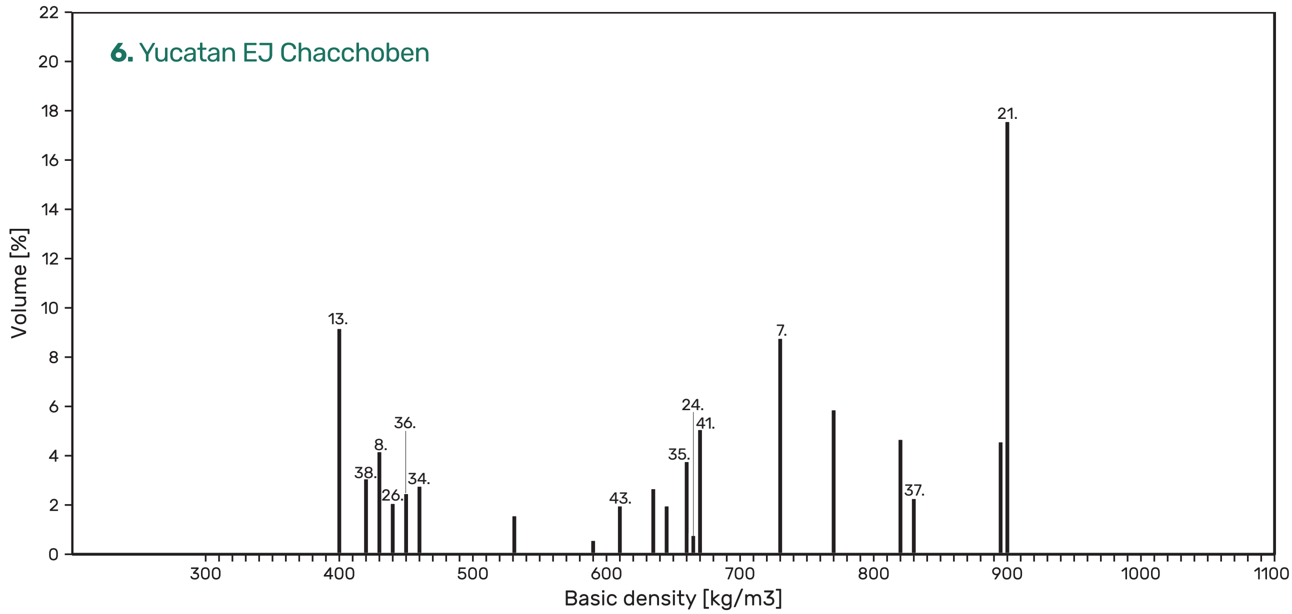


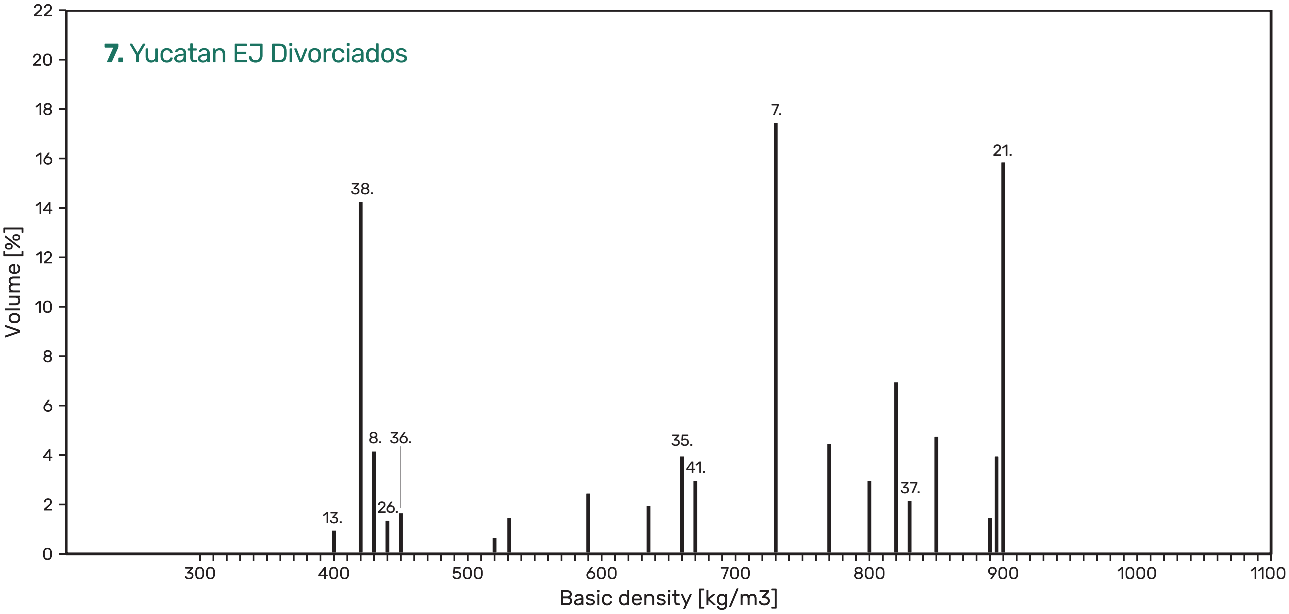


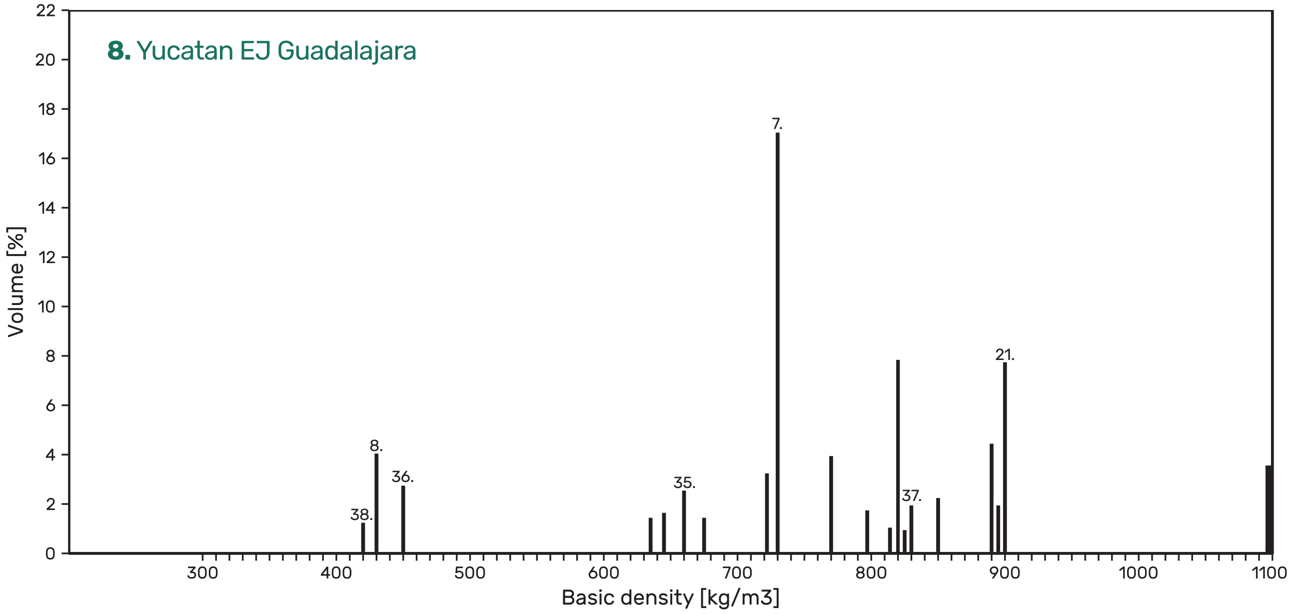


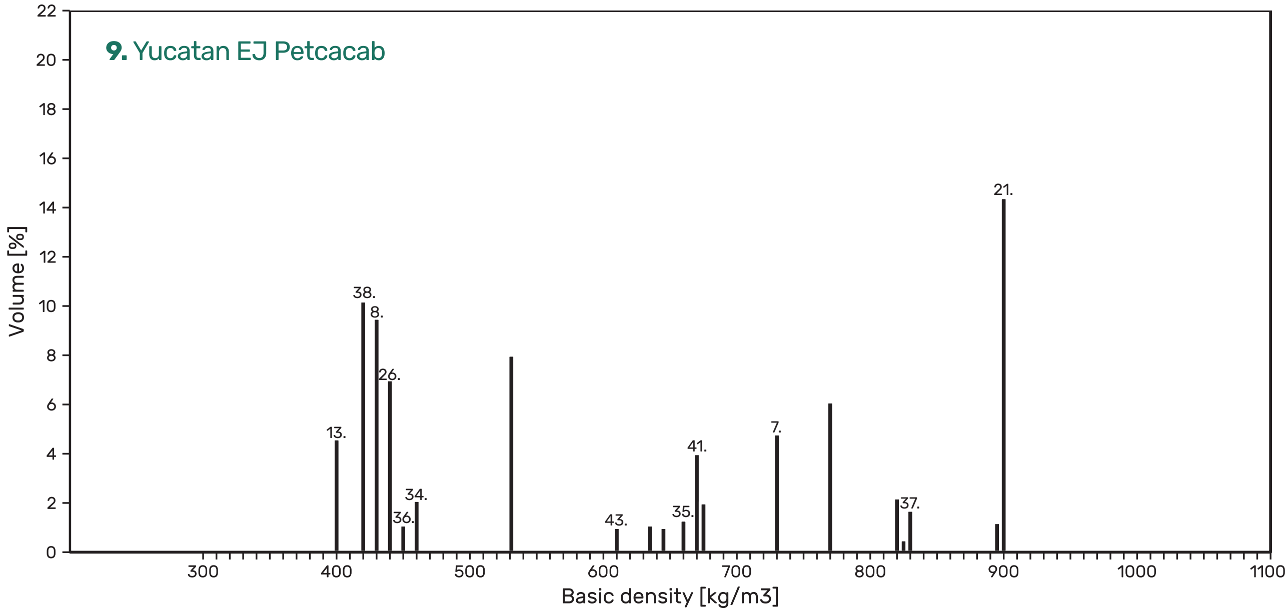
(Torelli 1994) Chiapas, Selva Lacandona (Selva alta perennifolia): tree species composition, density profiles and volume percentages at four typical locations, as shown on Map 1.

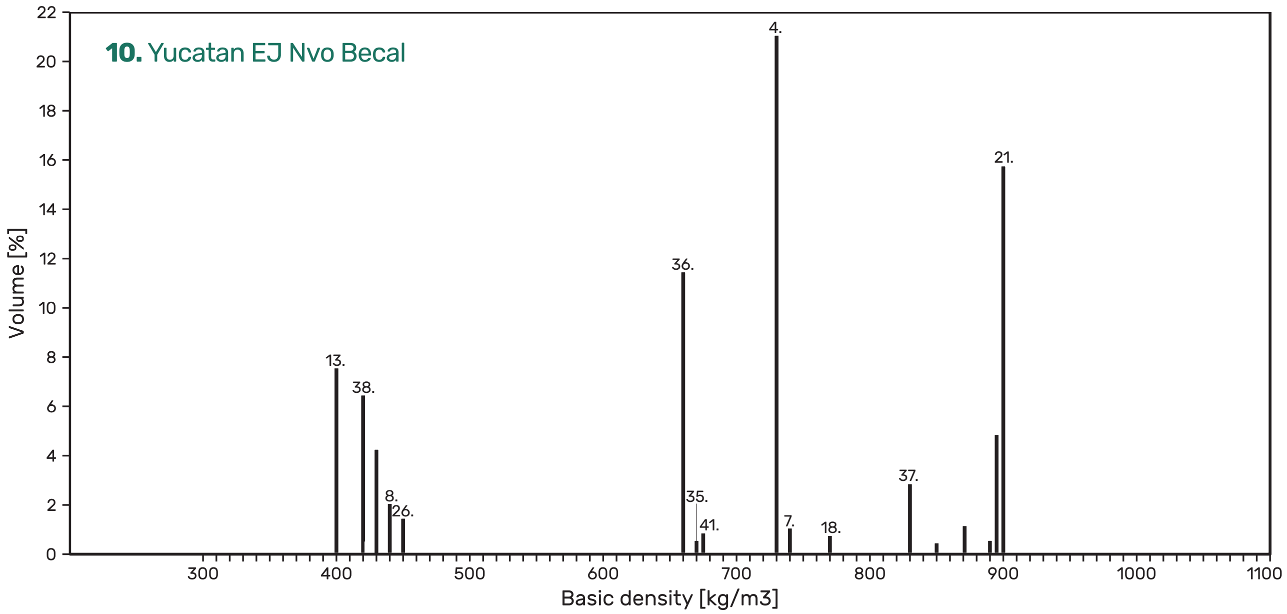

5. Yucatan EJ NOH-BEC
Volume [%]
Basic density [kg/m3]
21.
38.
7.
13.
8.
26.
34.
36.
35.
41.
37.


6. Yucatan EJ Chacchoben
Volume [%]
Basic density [kg/m3]
21.
13.
7.
24.
41.
36.
8.
35.
38.
34.
26.
43.
37.


7. Yucatan EJ Divorciados
Volume [%]
Basic density [kg/m3]
22
20
18
16
14
12
10
8
6
4
2
0
300
400
500
600
700
800
900
1000
1100
7.
21.
38.
8.
36.
35.
41.
26.
13.
37.


8. Yucatan EJ Guadalajara
Volume [%]
Basic density [kg/m3]
22
20
18
16
14
12
10
8
6
4
2
0
300
400
500
600
700
800
900
1000
1100
7.
21.
8.
36.
35.
37.
38.





(Torelli 1994a) Southern Quintana Roo (*Selva alta o mediana subperennifolia*): tree species composition, density profiles and volume percentages at five typical locations, as shown on Map 1.

Evidently, the botanical composition of the forest, i.e. the occurrence and ratio of low-density, fast-growing pioneer species and high-density slow-growing tolerant, "climax" species was influenced by man, as well as by regularly occurring cyclones, fires and prolonged dry seasons. Due to their pioneering character, the heliophilic caoba and cedar are in a relatively better position following fire or strong winds that bring down trees.

The most prominent trees everywhere are the ramón, which have many names: capomo, brednut, *ox, masicaran, ujusht*, Lac. *hach 'oox, k'än 'oox, ya'ax 'oox* (*Brosimum alicastum,* Moraceae) and the chicozapote, spodilla, *hach ya*, Lac. *chäk ya', hach ya',* ya' (*Manilkara zapota,* Sapotaceae).

There is theory that the basis of the Maya diet was not corn at all (!) but rather the ramón, which grows wild in Maya forest. "If this had been the case, control over a permanent population could be easily have been achieved, with a guaranteed basic diet and more free time to build temples and other structures within the ceremonial centers" (Cardoz de Mendez 1986:33). Notably, ramón is most abundant today where ancient settlement was most dense (cf. Ford and Nigh 2015:128). We saw this for ourselves on many occasions and archaeologists are particularly well aware of this when they search for the remains of Mayan culture in the forest.

It is an interesting fact that the ramón does not grow only in the rainy *Selva alta perennifolia* area, which corresponds well with the archeologically defined "Central area" of the Maya civilisation, but also in the more arid parts of the "Northern area" of Yucatan covering the entire state of Yucatán and most of Campeche and Quintana Roo, which are covered mainly by the *selva alta-mediana subperennifolia* and the even more arid *selva alta-mediana subcaducifolia*, with important early post-Classical archaeological sites such as the famous Chichén Itzá, Uxmal, Cobá and Tulum. Even in the distinctly xerophile and termophile *selva baja caducifolia* in the north of Yucatan (where the trees are 4-10 m high), but where ramón does not grow, the extensive city of Dzibilchaltún was built, with some 21,000 temple and habitation structures, in the vicinity of the large aquiferous *cenote* Xlacah. On the otherwise less fertile land they produced salt, honey, sisal and cotton (e.g. Foster 2002). In addition to the coastal sea routes, there were also land routes in the form of s*acbé (sacbeob*, pl.), causeways or roads of the lowland Maya, constructed with large blocks of stone, levelled with gravel, and paved with plaster. They connected parts of ceremonial centres, as well as cities. The longest known *sacbé* extends 100 km from Cobá to Yaxuná in the Yucatán peninsula (cf. Muser 1978: 140), and we came across them most often deep in the Yucatan forest.

The wind pollinated ramón also has an important and complex role in *pollen data analysis* concerning the history of forests, which is significant in connection with the presumed deforestation of the Mayan forest and the decline/collapse of Mayan culture.

It is remarkable that nearly all Maya forest trees are pollinated by various kinds of animals (as generally in tropical forests). Only ramón and other members of the family Moraceae and some rare exceptions, e.g. chaca, gumbolimbo, Lac. *chäklah* (*Bursera simarouba*, Burseraceae) are wind pollinated. Considering the composition of the dominant plants of the contemporary *forest gardens*, there, too, wind pollination is an exception.

The pollen data from the nearby lake core sediments (Peten) and their interpretations have sustained the view that the Maya civilisation, with its population growth and concomitant environmental impacts, destroyed the forest and caused its own collapse (as proposed in the popular work of Diamond 2005).

The fluctuation of the Moraceae family, and specifically the ramón, contributed to this assumption. With the increase in the share of Moraceae and ramón, the share of grasses and herbaceous species reduced, and *vice versa*: with the rise of grasses and herbaceous species, there is a drop in Moraceae and ramón. The mere presence of ramón pollen is not a good signal of the overall composition of the mature forest, because the tree is a coloniser of woodland open spaces. Its absence would thus not signal deforestation, as is often assumed in the literature on Maya paleoecology (Burn and Mayle 2008; Bush and Rivera 1998; Campbel e*t al.* 2008, quoted in Ford and Nigh 2015:89). The fluctuating percentages of ramón give an ambiguous indication of the actual arboreal composition (Bush and Rivera 1998:389, quoted in Ford and Nigh 2015:89). Furthermore, as a managed tree, ramón has figured in the development of the human ecology of the forest and garden for millennia.

Abundant Moraceae and *Brosimum*-type pollen can indicate more open areas cleared by drought, hurricane blow-down, and fires, where it has competitive edge. Alternatively, it could be a result of the abandonment of buildings and public monuments allowing the expansion of ramón into new habitats of broken limestone, to which is well adapted (Lambert and Arnason 1989, quoted in Ford and Nigh 2015:89). Equally, it could indicate regenerating forest gaps opened for agriculture. […]. Changes in ramón pollen may actually reflect consolidation of forest gardens, where preferred insect-pollinated species are more abundant. This would signal and expansion of mature forest and forest gardens rather than a loss of forest cover. It is

Chicozapote (*Manilkara zapota*), secondary and tertiary alterations in wood (original) A typical zig-zag machete incisions in herringbone pattern for tapping chicle.

Cross-section of a fresh trunk whose vascular cambium has been damaged by a chiclero. The wound has triggered the formation of wound-initiated discoloured wood, which is clearly differentiated from the more intensively coloured heartwood. The white exudate from the living inner bark is chicle-gum, which consists of coagulated milky latex.

Part of the dry tree cross-section with the intensely coloured heartwood, slightly coloured wound-initiated discoloured wood, sapwood and clearly visible ingrown injuries – consequences of the cambium being damaged with a machete during cutting of the bark.

The truly unique-looking and expensive ziricote wood, Lac. *chack opte* (*Cordia dodecandra,* Boraginaceae) with the "spider-webbing" or "landscape" grain figure, used for cabinetry, gunstocks, musical instruments (acoustic and electric guitars), turned objects, and other small specialty wood items (cf. Meier 2016:96).

A fresh cross-section of a young tree that has not been damaged and therefore has no wound-initiated discoloured wood.

likely that the changes in the abundance of ramón relate more to its management by the Maya than any other factor (Campbell *et al*. 2006, quoted in Ford and Nigh 2015:90; Ford 2008).

“Far from destroying, forest gardeners are supporting the forest, nurturing the economic plants that sustain their life and contribute to the maintenance of the Maya forest as a whole… Without them there likely will be no forest at all” (Ford 2008:194)!

In their book *The Maya Forest Garden* (2015), Ford and Nigh confront the theory that the Maya succumbed to destructive agricultural practices and thus abandoned their cities. Instead they demonstrate that the Maya have continuously gardened within the forest for over 8,000 years while practicing their sustainable traditional “milpa” system of agroforestry. This little understood system of land use cycles through phases of fields to forest over 20-30 years. This sustainable system of land management was ignored by the arriving Spaniards, and still is by scientists today.

The obligatory coloured heartwood of the chicozapote is very strong, hard and exceptionally durable. It is also not difficult to ascribe the high frequency of the chicozapote to its tasty fruits, the chicle exudate from the inner living bark, and above all to its exceptionally decay-resistant coloured heartwood, employed by the Classic Maya for inner vault supports and temple-door lintels (often intricately carved), as they did not know how to make proper arches. Some lintels are still supporting weights of several tons, a thousand years after being laid in place. Tools made from obsidian were used to remove the nondurable sapwood and shape the lintel (Figs. 2.28, 2.2, 2.30).

The Palace in Palenque boasts a four-story square tower with an interior staircase and ceilings of wooden beams (cf. Benson 1977:50; Grube 2000:203).

The fruit of chicozapote is tremendously popular among Central Americans, and a favourite of rainforest mammals like howler monkeys, kinkajous, tapirs, peccaries, and bats. The slow-growing tree may attain a height of 45 m and a diameter of over 125 cm. Chicle gum is obtained from oblique cuts or slashes made in the trunk and main branches of the tree during the rainy months. From these cuts there issues a milky latex which is coagulated by heat, and then formed into solid blocks for export. As these cuts heal, they can be used by the tapper to determine when a tree is ready to be retapped. When the vascular cambium is damaged with a machete blow, the wood turns pink, and like the sapwood it does not have the prominent characteristics of the coloured heartwood, and above all it does not possess its biological resilience. As a result of these injuries, trees often die and obstruct the forest’s normal growth (Torelli N, IUFRO World Congress, Ljubljana 1986).

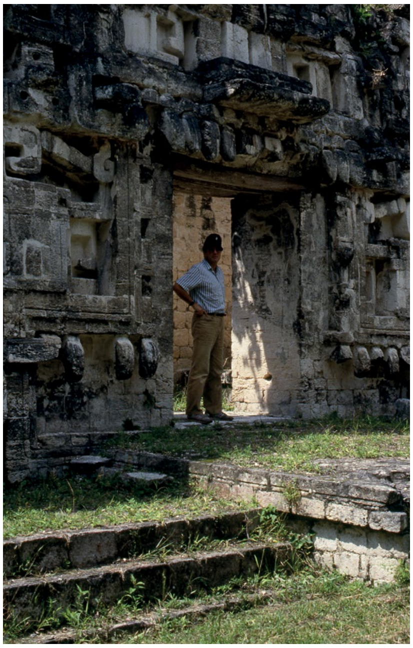
Interestingly, in the Central African Republic I studied the African relative of the chicozapote, the *Manilkara fouilloyana* Aubrév. & Pellegr. The habitus, wood and characteristics of both types are very similar. Here is what has been discovered concerning their relatedness: “Analyses of the nuclear data using a fossil-calibrated relaxed molecular clock indicate that *Manilkara* evolved 32–29 million years ago (mya) in Africa. Lineages within the genus dispersed to the Neotropics 26–18 and to Asia 28–15 Mya. Higher speciation rates are found in the Neotropical *Manilkara* clade than in either African or Asian clades” (from the abstract of Armstrong *et al*. 2014).

Among the interesting and famous tree and wood types I should also mention the autochthonous corcho, balsa*,* Lac. *polak, puh, chujum* (*Ochroma pyramidale*, Malvaceae), which in southern Mexico reaches the northern limit of its natural area of distribution, and plays an important role in renewing forests, i.e. in preserving soil fertility in the MFGC system. Lacandon farmers dispersed seed of balsa in order to create thick stands of this fast-growing, short-lived canopy tree. This species has been used by generations of Lacandon farmers to reduce the forest regeneration period, replenish soil organic matter and enhance weed control. However, a form of bracken (*Pteridium aquilinum*), which is a pyrogenetic species, has become a serious invasive weed problem in the region, as traditional control methods such as planting balsa have been abandoned (Ford and Nigh 2015:67, Nigh and Diemont 2013). A dozen other trees were also managed for their beneficial effects on soil fertility (Levy Tacher and Golicher 2004, Levy Tacher 2000, quoted in Ford and Nigh 2010:186; see also Diemont *et al.* 2006:208) (see Tables 3.9 and 3.14).

I once had a very painful experience with the chechen negro, black poison wood, Honduras “walnut”, *chechen, chen-chen*, Lac. *chechen (äh),* (*Metopium brownei*, Anacardiaceae). More than thirty years ago a droplet of morning dew fell onto my wrist from this poisonous tree. At first it looked like a burn, but the 2 cm long scar simply would not go away and it was removed for its carcinogenic nature over 30 years later by a dermatologist. I later discovered that the antidote or chemical substance that stops or controls the effect of the poison, is the tree species we referred to as jobo, otherwise called ciruela cochino, jocote, jobo, hogplum, with the Maya common names *k'aan abal, k'iinlin, jobo*, Lac. *k'inim* (*Spondias mombin*). Both species belong to the same botanical genus of Anacardiaceae

The famous Palace and Tower, Palenque, Late Classic Period. In the distance is the flood plain of the Rio Usumacinta. Palenque boasts a four-story square tower with an interior staircase and ceilings of chicozapote beams.

Campeche, Rio Bec, Late Classic period, with a lintel of chicozapote heartwood.



Campeche, Chicanná, Structure II, Classic period, with another chicozapote lintel.

and they even grow together in the forest. The combination of a tree poison, and antidote, sitting right next to each other is astounding. The trees even look alike (Peck 2016).

By the way, the wood of the chechen is beautiful and can be used for veneer, furniture, cabinetry, flooring, turned objects, and small specialty wood items. Due to its high density, grain, texture, natural lustre, and beautiful coloration, chechen is sometimes referred to as Caribbean rosewood, though botanically not related with true rosewoods of the genus *Dalbergia* (e.g. Meier 2016:166).

Known by many names and having many uses is the very famous chaca, gumbo-limbo, copperwood, palo mulato, indio desnudo (naked Indian), turpentine tree, Lac. *chäklah, chäkrah* (*Bursera simaruba*, Burseraceae). It is also comically referred to as the *tourist tree*, because the tree's bark is red and peeling, like the skin of sunburnt tourists, who are a common sight in the plant's range.

Also very interesting is hule, wild rubber, *hule, kiikche*, Lac. *k'ik' (Castilla elastica,* Moraceae) from whose latex the Maya made rubber balls for games (see also Glossary). The latex gathered from this tree was converted into usable rubber by mixing with the juice of the morning glory species (*Ipomoea alba*), which, conveniently, is typically found in the wild as a vine climbing *Castilla elastica*. The rubber produced by this method found several uses, including, as just noted, the manufacture of balls for the Mesoamerican ballgame *ōllamaliztli* v azteškem jeziku *náhuatl*;The Mayan is *pitz*. Hundreds and perhaps even thousands of years before Charles Goodyear, the Maya discovered the vulcanisation process that made commercial rubber viable. Mesoamerican peoples were carrying out this process to produce rubber artefacts for a broad variety of uses (Thomas H. Maugh II from MIT *in Los Angeles Times* May 31, 2010; cf. also Nations 2006:108). Indeed, materials scientist John McCloy, of the Pacific Northwest National Laboratory, claims that researchers "have compiled a compelling case that ancient Mesoamerican peoples were the first polymer scientists (!), exerting substantial control over the mechanical properties of rubber for various applications".

The *balché* is a mead of fermented honey with the addition of the bark of the balché tree (*Lonchocarpus longistylus*) during processing due to its narcotic effect. It is a favourite Maya intoxicant and purge, with strong religious associations. (Muser 1978:12). It is not clear if for the preparation of *balché* the Maya also use other species from the *Lonchocarpus* genus. Suzanne Cook tells us that in Chiapas state twelve species of *Lonchocarpus* are listed, and several of those are known as balché. In that group, the Lacandones recognize two kinds of balché: *Hach Balché*, which means "authentic balché," and: *Ya'ax Balché*, meaning "green balché" (Cook 2016:144,5). *Hachäkyum*, the Lacandones' principal deity, created balché as a means for his mortals to venerate him. The balché ceremony is perhaps the most important among present-day Lacandones. This traditional ceremonial drink is prepared in a sacred canoe from cedro wood. (Morales 1976:27). In our research we studied the wood of two species from the *Lonchocarpus* genus: machiche (*L. castilloi*), and palo gusano (*L. hondurensis*) with heights of between 30 and 40 m. (*L. longistylus* is much shorter, less than 20 m)

Also noteworthy is the already mentioned palo de tinta, palo de campeche, logwood, *ek*, Lac. *ek'* (*Heamatoxylon campechianum,* Fabaceae) swamp forest legume tree that grows in dense stands in seasonally inundated areas (*tintales* or *bajos*). The tree was of great economic importance from the 17th to the 19th centuries, when it was commonly logged and exported to Europe for use in dyeing fabrics. Logwood trees played a major role in the history of Belize, for it was the abundance of logwood that prompted British loggers to colonise the Belizean coast, leading to a British challenge to Spanish rule in the area that eventually became British Honduras and later Belize (cf. Torelli 2001; Nations 2006:106). Crossbeams from the very durable heartwood of logwood can be seen in the interior of the building 5D-52 in Tikal, Guatemala.

I remember how we were once caught near Rio Bec by a downpour of the approaching rainy season. The water in the *bajo* began rising very quickly. Driving rapidly down a bad road, two of the tyres on our car burst. Together with a friend we ran for help, accompanied by thunder and lightning, to Xpuhil, and succeeded in saving the jeep from the rising waters at the last minute.

Of course, the Maya tropical forest still contains a very large number of interesting tree/wood types – a real wood hot spot! There is the already mentioned *lignum vitae,* Lac. *hach chulul* (*Guaiacum Guiacum sanctum*), one of the hardest and heaviest timbers in commercial use, which grows in northern Yucatan, in central Chiapas and on the Pacific coast (*Selva baja subcadufolia*). Owing to the self-lubricating properties of this wood, associated with its high resin content of about 25% in the heartwood, it has been valued for uses such as propeller bushes and bearings. The 18th century master clockmaker John Harrison used *lignum vitae* as the basis for his nearly all-wood clocks, although the plant was originally taken to Europe as a much-needed cure for syphilis and broad spectrum of diseases. The eternally over-indebted Spanish King and Emperor Charles V handed over the financially very lucrative concession for this plant to his bankers – the Fugger family from Augsburg (Torelli 2006). The Maya used the wood to make bows, although as already noted they now only make bows for tourists and using other, more commonplace and equally dense woods such as: chicozapote (*Manilkara zapota*), *subul* (*Dipholis stevensonii*), Lac. *hac chulul* (*Tabebuia guayacan* sin. *Handroanthus gayacan)* and also from one of the densest woods known to man: Lac. *chintok'* (*Krugiodendron ferreum,* Rhamnaceae), also known as "iron wood", as indicated by the Latin name for the species (cf. e.g. Cook 2016:148, 149).

The copal, *pom,* Lac. *tsatse pom* (*Protium copal*, Burseraceae) produces a resin, one of the most sacred substances that was burned for incense in Maya temples, and was also used to make small objects that have been found in burials and in the famous Sacred Cenote at Chiché Itzá.

We must not fail to mention the "preciosa", the widely-known, medium density, all-purpose Spanish or Mexican cedar, Barbados cedar, *kulché*, Lac. *k'uche (äh), k'uche'* (*Cedrela odorata* L., syn. *C. mexicana* M.J. Roem.,Meliaceae), which grows throughout the *Selva alta perennifolia* area, all over Yucatan, and partly along the Pacific coast, and which, despite its heliophyte pioneer character, is under considerable threat and thus proposed for listing in Appendix II of CITES in accordance with the "*Características* y usos de 30 especies del bosque latifoliado de Honduras". It is sometimes called cigar-box cedar, as it is used in making humidors, and otherwise it is very similar to caoba (Gibbs 2005:78).

We did not study the wood of the ceiba, cotton tree, floss silk, *yaxche*, Lac. *ya'axche', (Ceiba pentandra* (L) Gaertn., Bombacaceae), which grows to 65 m and is mostly used in plywood manufacturing, because it is well known and also out of respect for the religious significance this mighty tree has for the Maya.

I could continue listing other interesting woods, and we studied quite a number of them ourselves. In tropical Mexico the tree/wood species generally cover the maximum range of densities: from balsa with the lowest density amongst the commercial woods (ρ_{12} from 50 - 150 kgm^{-3}) to guaiacum, or *lignum vitae*, with the maximum heartwood density (ρ_{12} 1,250 kgm^{-3} – 1,300 kgm^{-3}). Representatives of the botanical genera *Caesalpinia*, *Dalbergia*, *Ebenus* also grow here. These are precious, decorative woods with a high density.

2.3 People of the Selva Lacandona

The population of the Selva Lacandona are mostly subsistence peasants. These include indigenous groups from Chiapas such as the Tzotzil, Tzeltal, Ch'ol, Tojolabal and Lacandon Maya, as well as non-indigenous groups. However, except for the Lacandon Maya, almost all of the population has migrated to the Selva Lacandona, especially during the 20th century.

When Spaniards invaded Chiapas in the early 16th century, they found the highlands occupied by Tzotzil Maya, the foothills by Tzeltales and Tojolabales, and the Selva Lacandona by Chol and Cholti Maya. At that time, the people we call the Lacandon Maya occupied the tropical forest area of what is now the southern Campeche and the Guatemalan Peténten. *(Lacandon People, Hach winik home page*, Nations 2006:129)

Under colonial rule, the Chol and Cholti Maya fared even worse than the Tzotzil and Tzeltal. Between 1559 and 1697, the Maya of the lowland tropical forest faced a series of military and religious *entradas* that meant they were either killed, enslaved or relocated to the northern foothills to work on Spanish haciendas. The elimination of the Chol and Cholty from the Selva Lacandona created a population vacuum that was gradually filled during the 18th and 19th centuries by Yucatec-speaking Maya fleeing disease and disruption in the Guatemalan Peten. The Spaniards called these immigrants "Lacandones", a name they had previously applied to the Cholti (de Vos 1980). Etymologically, the name Lacandones derives from the name of the island fortress in Lake Miramar, *Lacantúm(n)* or *Lacam Tun* ("Big Stone"). From this the Spaniards fashioned the name of the people they sought to subdue – the Lacandon. The authorities eventually would go on to apply this term to all apostate and non-Christian Maya in this region *(Lacandon People* 2017; *The Modern Lacandon Communities*; Nations, 2006:129).

The first definite contact with the Lacandones occurred in the last decades of the 18th century (Enrique 2006). When scholars first investigated this people in the early 20th century, they thought that the Lacandones were the direct descendants of ancient Classic Maya people who fled into the rainforest at the time of the Spanish conquest and had remained linguistically and culturally pristine ever since. They made that assumption because the Lacandones' physical appearance and dress is so similar to the way the ancient Maya portrayed themselves in their murals and relief carvings. Scholars were also impressed by the fact that "the Lacandon resided near the remote ruins of ancient Mayan cities, had the knowledge to survive in the tropical jungle, and were neither Christian nor modernized" (Palka 2005). They thought that these native people were pure Maya untouched by the outside world. But in recent years researchers have revealed a more complex history for the Lacandon.

Scholars have now shown that the Lacandon are the result of a coming together of various lowland Mayan refugee groups during the period of Spanish colonial rule. Their language, clothing, and customs derive from several different Colonial Era Mayan ethnic groups. It appears that the Lacandon possess multiple origins and that their culture arose as different lowland Mayan groups escaped Spanish rule and fled into the forest. There was a blending of cultural elements as some traits of varied origin were retained while others were lost. The Lacandon seem to have arisen as a distinct ethnic group as late as the 18th century, meaning that they "cannot be the direct descendants of the ancient Maya since their culture did not exist before it was generated through inter-indigenous interaction. (Palka 2005; *Lacandon People* 2017)

The Lacandones are typically divided into two groups based on cultural, geographic, and linguistic differences. Anthropologists generally identify these groups as Northern (in the settlements of Nahá and Mensäbäk/Metzabók), and Southern Lacandones (in Lacanhá Chan Sayab/Lacanjá Chansayab. The Lacandones do not use these designations, however, and as a whole refer to themselves as *hach winik* "real people". Local lore states that the gods resided here when they lived on Earth (*Lacandon Jungle* 2016). The Lacandones still strictly observe their religious duties. Every year they go on pilgrimage to the ancient city of Yaxchilán on the banks of the mighty Usumacinta River. They are aware of the uncertainty of life and believe that our world will end when a statute in Yaxchilán, which currently does not have a head, will again have one. That is when thousands of jaguars will appear and devour all of humanity. Until then their main concern is to pacify *Mensabak* – the rain god.

US missionaries, parabolic antennae and the many tourists who besiege Palenque, Bonampak and Yaxchilán, along with the non-sustainable exploitation of timber and oil, have profoundly changed the lives of the Lacandones. Their way of life is most traditional in the village of Nahá, or at least was while their spiritual leader, the legendary Chan k'in Viejo, was still alive. Due to overwhelming numbers of tourists, researchers, missionaries and in the 1940s the *chicleros* (Mexican and foreign), who gathered chicle for making chewing gum (before they began making it synthetically), the Lacandones from Lacanhá Chan Sayab (close to Bonampak and Yaxchilán) have almost entirely lost their original identity, and many of them speak English.

Commercialisation and tourism have become important aspects of the Lacandon economy and many people today practice a mixture of subsistence farming, commercial mono-cropping, and craft production (McGee 202:71-124 from Kashanipour and McGee 2004).

The Selva Lacandona is nowadays facing unmanageable population pressure. "The 1960 population of 60,000 people had grown to 350,000 by 1995, to 603,000 by 2000, and is expected to reach 787,000 by the year 2010" (O'Brien 1998:18; Sánchez 2001, quoted in Nations 2006:141), and this is the greatest threat to the survival of the Selva Lacandona.

2.4 Did Maya agroforestry change their forest?

People's relationship with the tropical forest differs depending on time and location: from complete habitat destruction, which inevitably results from the expansion of the human population and its activities, to the rare preserved primary forests in more remote areas. In between there is a broad spectrum, from non-sustainable conventional shifting cultivation, monoculture farming (e.g. soya, sugar cane, fast growing tree species for the pulp, paper and woodworking industry, oil palms and rubber trees) to sustainable forest management (SFM) and various forms of agroforestry, including "shade" coffee and cacao and forest gardens, and especially the Mayan MFGC. In general tropical forests are easily degraded because the soils are often thin, nutrient poor, and erode readily following deforestation (cf. Primack 2008:79).

The well-known deforestation that occurred in the Mediterranean Basin started during the Greek and Roman period. It was a result of the geographical expansion of these civilisations, with their increased population, large-scale agriculture, and unprecedented economic development. After 2,000 years the last forests in this area are disappearing. Today's motorised, seasonal "touristic" population pressure, when the wealthy industrial north migrates on holiday to the deforested Mediterranean, along with their food packaging and plastic bottled water, accompanied by a greatly increased concentration of CO_2 due to the use of fossil fuel vehicles, will only accelerate its ecological destruction.

Did the Maya – the Greeks of the New World – destroy or cultivate their forest? Good question – let's try and answer it! When around 900 AD the Maya civilisation in the central and southern

Secondary selva with clusters of large trees with buttresses.

The Maya forest, as it developed under human influence.

Successional forest – terminal stage of regrowth.

lowlands collapsed, the forest that remained contained many plants, including valuable and useful ones. As Denevan (1992) writes: "The Maya forest one thought to be a wild, pristine jungle, is, in reality, the result of prehistoric, colonial, and recent human activities" (quoted in Ford and Nigh 2015:15). The same can be said for the "wild" and "pristine" Amazonian forest (e.g. Marshall 2019:26): "Far from being untouched, we are coming to realize that the landscape and ecosystem of the Amazon has been shaped by humanity for thousands of years. Long before the arrival of Europeans in the Americas, the Amazon was inhabited, and not just by a handful". It is important to understand that the developed European culture, as a part of eco-imperialism, views agriculture and forests as incompatible (Ford and Nigh 2015:17). In reality, at all stages of the milpa cycle the plot is tended and harvested. European immigrants only saw the corn as agriculture and did not recognise the other phases of production in the MFGC. As a result of millennia of forest gardens, much of the forests in the Maya areas are anthropogenic and contain a high proportion of trees and plants useful to humans, such as ramón, mamey, avocado, cacao, etc. (cf. e.g. Pilarski 2015).

Selva Maya, the Spanish term for the Maya tropical forest, is "a human artefact – a real anthropogenic forest, the result of centuries of selective clearing and manipulation by the Maya people who lived in this region" (Nations 2006:8). This may have been true for all the forest except that in the most remote areas, which were not suitable for settlement, where it may well have corresponded with this definition from the *Convention on Biodiversity* for primary forest: "made up of native species that have developed naturally, with little or no evidence of human activities. They represent untouched, pristine forest that exists in its original condition".

On the other hand, the Maya forest represents a special type of anthropogenic secondary forest with a number of useful species added in the millennia-long process of the MFGC. When the Spaniards arrived in Mesoamerica in the 16th century, they typically encountered the Maya living in villages "filled with trees" (cf. Cook 2011:75). Diego de Landa, who arrived in Yucatan as a Franciscan friar in 1549 and became bishop at Merida in 1572, describes in his important historical work *Relación de las Cosas de Yucatán*, the most important source on the pre-Hispanic Maya, Mayan homes surrounded by veritable forests consisting of useful trees – home gardens. Once the Maya settled on a landscape the forest was increasingly shaped by human management of the milpa cycle (Ford and Nigh 2015:78). In reality, Maya forest can be understood as the garden of the ancient Maya: the product of millennia of management by "forest gardeners" who cultivated the cycle of milpa, forest garden, and forest. As previously noted, 90% of plants in this forest are useful to humans, indicating considerable human influence (*El Pilar Forest Garden Network* 2007-2011).

Maya worked with their tropical environment, as opposed to exploiting and transfiguring it, to create a flourishing civilisation sustained by its natural environment or ecosystem. Contemporary conservation practices of tropical forests have relied upon the Western approach: removing the human element from the equation. Yet ecological and botanical research on the Maya forest has recently demonstrated that it is in fact a variegated garden dominated by plants of economic value, and thus highly dependent on human interaction. The co-evolution of the Maya and their environment was based on a strategy of resource management that resulted in a landscape called the *Maya forest garden*. This sets the Maya apart from those who practice conventional and industrial monoculture farming in the area. Their forest conservation strategies using traditional ecological knowledge (TEK) have been fostered purely through the maintenance of oral traditions over the last 500 years – an accumulation of wisdom, passed down over centuries and generations (Ford 2011).

> *Forest gardens* are probably the world's oldest form of land use and most resilient agroecosystem. They originated in prehistoric times along jungle-lined riverbanks and in the wet foothills of monsoon regions. In the gradual process of families improving their immediate environment, useful tree and vine species were identified, protected and improved, whilst undesirable species were eliminated. Eventually superior foreign species were selected and incorporated into the gardens.

Forest gardening (2018):

> *Forest gardens* are still common in the tropics and known by various names, such as: home gardens in Kerala in South India, Nepal, Zambia, Zimbabwe and Tanzania; Kandyan forest gardens in Sri Lanka; *huertos familiares*, the "family orchards" of Mexico; and *pekarangan*, the gardens of "complete design", in Java. These are also called agroforests and, where the woody components are short-statured, the term shrub garden is employed. Forest gardens have been shown to be a significant source of income and food security for local populations, and numerous permaculturalists are proponents of forest gardens, or food forests.

The present-day forest "shows astonishing homogeneity across woodland ecosystems, not to be expected in unmanaged forests" (Campbell *et al.* 2006, quoted in Ford and Nigh 2015:56). Today's composition of tree species reflects ancient Maya *forest gardens* (e.g. Ross 2011:75), and we can see important and useful species depicted on the famous tomb of Lord Schield-Pacal in the Pyramid of the Inscriptions at Palenque: avocado, cacao, mamey (*Pouteria sapota*), nance (*Byrsonima cassifolia*) and guayaba (*Psidium guajava*). However, the otherwise ubiquitous ramón (*Brosimum alicastrum*) is missing.

Among the native trees of the *forest gardens* are representatives of the dominant plants of the forest. Ford (2008) collected data from 18 forest gardens in west-central Belize and established that of 20 dominant species from the forest many of them are also cultivated in forest gardens. Even more, *Brosimum alicastrum* Sw., *Samira salvadorensis* (Standl.) Steyerm., *Talisia oliviformis* Radkl. and *Manilkara zapota* (L.) van Royen are also dominant in the forest gardens. This shows an important connection between the forest and the forest gardens, and the most widely represented species is ramón. "The household management of the dominant forest species is important in the conservation of the Maya forest. That the forest species occur in these gardens is demonstration that people are a crucial component in he maintenance and ultimately the regeneration of the Maya forest" (Ford 2008:187).

It is not surprising to find that many scholars have affirmed the significance of humans in shaping the Maya forest as we know it (Atran 1999; Campbell *et al.* 2006; Dunning *et al*. 2012:365; Dunning and Beach 2010; Ferguson *et al*. 2003; Ford and Nigh 2009; Gomez-Pompa 1987, 2003; Ross 2008, quoted in Ford and Nigh 2015:56).

Rather than being threats to the "pristine" environments in which they live, traditional peoples have been integral parts of these environments for thousands of years (using an ecosystem approach)! The present mixture and relative densities of plants and animals in many biological communities may reflect historical activities, such as agroforestry. Even more, many traditional societies have strong conservation ethics, employing their traditional ecological knowledge, with Lacandones being a typical and even ideal example of this (cf. Primack 2008:246).

Now the Maya forest is for the most part a feral forest, gone wild after the collapse of Maya civilisation (Ford 2001, quoted in Nations 2006:8).

Interestingly, sample plots in varied settings show astonishing botanical homogeneity across woodland ecosystems, not to be expected in unmanaged forests (Campbell *et al.* 2006, quoted in Ford and Nigh 2015:56). The modern tree species composition reflects ancient Maya "forest gardens" in northwest Belize. The data reveal a link between current forest compositional differences and the density of ancient Maya occupation around El Pilar. "After a millennium of abandonment, one might suggest that dispersal and mortality would have eliminated any sign of forest gardens, yet the research results strongly indicate they did not" (Ross 2011). Researchers have argued that the ubiquity of these ancient gardens through Mesoamerica led to the dominance of species useful to Maya in the contemporary forest, but this pattern may be localised depending on the ancient land use.

Testing the hypothesis that a human "signature" is visible in the forest today, Campbell *et al*. (2006) found that both *alpha diversity* (i.e. the species richness of a place) and *beta diversity* (i.e. the extent of species replacement or biotic change along environmental gradients) indices were low compared to similar tropical latitudes in areas relatively free of human influence (quoted in Ford and Nigh 2015:59).

There is an interesting parallel between the Maya forest and the Amazon rainforest, and the common belief that the natural environments of the Americas were relatively untouched by humans before the European conquest is no longer accepted. Scientists estimate that some eight to 50 million people lived in the Amazon basin at its peak, with 83 plant species domesticated and farmed in the area. Human farming and waste also led to the fertile *black soil* in many parts. The rich black soil, known as *terra preta*, that provides much of the fertility and allows such abundant growth in the Amazon, for example, appears to have been created by human activity (cf. e.g. Gray 2015; Marshall 2019).

Thus, time and again there are doubts as to how "virgin" the virgin forest really is (Willis, Gillson and Brncic 2004; Denevan 2011):

> …the discovery of geoglyphs uncovered following deforestation in the 1970s and *terra preta*, provide growing evidence for ancient cities in the heart of the 'virgin forest'. The documentary presents evidence that Francisco de Orellana (1511-1546), conquistador who completed the first known navigation of the entire length of the Amazon River (and which initially was named Rio de Orellana), rather than exaggerating his claims as previously thought,

> was correct in his observations that a complex civilization was flourishing along the Amazon in the 1540s. It is believed that the civilization was later devastated by the spread of diseases from Europe, such as smallpox. Some five million people may have lived in the Amazon region in 1500, divided between dense coastal settlements, such as that at Marajó, and inland dwellers. By 1900 the population had fallen to one million and by the early 1980s it was less than 200,000. (Marshall 2019; *Unnatural Histories – Amazon*, BBC Four 2011)

In the Amazon human intervention in the landscape also decreases predictably with distance from rivers. Levis *et al*. (2012, from the abstract) found "a strong negative exponential relationship between forest manipulation and distance to large rivers. Plots located from 10 to 20 km from a main river had 20-40% of useful arboreal species, plots between 20 and 40 km had 12-23%, plots more than 40 km from a main river had less than 15%. Soil charcoal abundance within the two sites closest to secondary rivers, suggesting past agricultural practices.

We should also mention that after the arrival of the Spanish the Maya introduced into their gardens many useful Old World plants, which brought about further botanical changes to the forest. Let me mention the nowadays widely distributed orange and mango trees – the national trees of India and Bangladesh – as well as Asian bananas and sugar cane. Ford (2008), among others, gives the origin of the plants in the *forest gardens*, and reports that only slightly more than half are *native*, or just 192 out of a total of 361! I was very surprised when during my first reconnaissance trip into the forest I came across a large orange tree plantation, not to mention the Asian bananas and plantains. The "Amazonian cacao" has very likely also been imported, but was domesticated here long before the arrival of Europeans and given its common name.

As Ford (2008:187) writes:

> With 500 years of plant exchange after the Spanish conquest, it is no revelation that plants from the tropics worldwide are represented in the contemporary Maya forest garden. The forest gardens of the El Pilar area and Selva Lacandona today may have banana from SE Asia, mango from South Asia, citrus from Asia and coffee from Africa together with the bounty of plants native to the Maya forest. Nevertheless, the majority (53%) of the plants are indigenous to the Maya forest and Mesoamerica in general (Table 2.2). Among the native plants of the forest gardens are representatives of the dominant plants of the forests.

Table 2.2 Origins of plants in the milpa Forest Gardens (Ford 2008:187)

Origin	Number	Percentage
Native	192	53%
Exotic	81	22%
Unidentified	74	20%
Naturalised	9	3%
Unknown	4	2%
Total	361	100%

2.5 Collapse of the Maya civilisation

The Classic period of Maya civilisation, from around 200 to 900 AD, was marked by the construction of monumental architecture, intellectual and artistic development, and the growth of large city-states. The dramatic collapse of Mayan culture in the central Maya region happened about 1,000 years ago, when their famous limestone cities were abandoned and their dynasties came to an end. The Maya then evidently resettled in highlands to the south, or in less productive dry lowlands to the north.

In an attempt to explain this enigma, scholars and lay people have proposed countless theories accounting for the collapse: drought, deforestation, overpopulation, overhunting, broken trade routes, foreign invasion, peasant revolt, the presence of foreign ethnic groups, the conflicts and rivalries between neighbouring city-states, the use of mercenaries, the prevalence of the military class, supernatural forces, unbalanced sex ratio and other diseases, as well as sustained crop failure of maize due to an epidemic of the planthopper-borne virus, maize mosaic virus (Brewbaker 1979). Eric Thompson, blamed the fall of the Classic Maya on the extension of Mexican influence to the Maya area (cf. e.g. Morales 1976:17,88, 93). There is extensive literature available on this subject, but the conclusions differ somewhat.

Certainly the proven droughts (see below) and their impacts on the forest, or deforestation and its impacts on the supply of water and food production for the growing population, were significant causes for the collapse of the Maya. It is not hard to imagine the connection between a lack of food due to the drought and revolts against the rulers. For example, in a different context Cornelius and Elbourne (2018) prove a strong association between rainfall patterns and the duration of the reigns of Roman emperors, based on dendrochronological data collected from rainfall-sensitive oak-tree rings.

The impact of long-lasting droughts was devastating, above all in the arid low-lying part of Yucatan, but less so in the hilly and mountainous areas, as well as in the coastal region due to established sea trade routes (cf. also Šprajc and Senica 2018)

In his popular science book *Collapse* (2005), Jared Diamond puts forth a theory that a prolonged drought, exacerbated by ill-advised deforestation, forced Mayan populations to abandon their cities, a theory that is now widely accepted.

Hodell *et al*. (1995, cited in Evans *et al.* 2018) provided the first physical evidence of a correlation between this period of drought at Lake Chichancanab on Mexico's Yucatán Peninsula, where the Maya were based, and the sudden fall of the Classic Maya civilisation.

Evans *et al.* (2018):

D. Hodell, Director of Cambridge's Godwin Laboratory for Palaeoclimate Research in a research supported by the European Research Council, provided the first physical evidence of a correlation between this period of drought at Lake Chichancanab and the downfall of the Classic Maya civilisation in a paper published in 1995. The researchers analysed the different isotopes of water trapped within the crystal structure of the gypsum to determine changes in rainfall and relative humidity during the Maya downfall.

> They measured three oxygen and two hydrogen isotopes to reconstruct the history of the lake water between 800 and 1000 CE. When gypsum forms, water molecules are incorporated directly into its crystalline structure, and this water records the different isotopes that were present in the ancient lake water at the time of its formation. This method is highly accurate and is almost like measuring the water itself.
>
> In periods of drought, more water evaporates from lakes such as Chichancanab, and because the lighter isotopes of water evaporate faster, the water becomes heavier. A higher proportion of the heavier isotopes, such as oxygen-18 and hydrogen-2 (deuterium), would therefore indicate drought conditions. By mapping the proportion of the different isotopes contained within each layer of gypsum, the researchers were able to build a model to estimate past changes in rainfall and relative humidity over the period of the Maya collapse.... Based on these measurements, the researchers found that annual precipitation decreased between 41% and 54% during the period of the Maya civilisation's collapse, with periods of up to 70% rainfall reduction during peak drought conditions, and that relative humidity declined by 2% to 7% compared to today.

Lake Chichancanab in the central, northern part of Yucatan, lies on the border between xerophile and thermophile forests with *Selva alta-mediana subperennifolia* in the south and *Sel-*

va mediana subcaducifolia in the north (cf. Pennington and Sarukhan 1968) with ca. 1000 mm annual rainfall and prolonged dry periods (e.g. Ford and Nigh 2015:25).

Generally, present-day plant communities indicate what the precipitation distribution was like 1,000 years ago. “Our” Selva Lacandona is wetter and lies more than 500 km to the south in Chiapas along the great Rio Usumacinta. There are also numerous lagoons, including very large ones such as Laguna Miramar. The *Selva alta perennifolia*, which predominates here, has an annual rainfall of 2000 mm and more.

Speculation on the causes of the Maya’s decline always have the most difficulty understanding their relationship with the forest, which did not only provide nourishment but also created a surplus necessary to support the hierarchical elite administration and build the luxurious sacral buildings, which demanded so much tribute of the masses that in the end they rose in bloody revolt and emigrated in search of more favourable surroundings. Nowadays, we can easily imagine the (mostly irreversible) destruction of the forest – the Mayan *alma mater* – through the practice of non-sustainable industrial monocultural milpa (“conventional” milpa!), which usually ends with cattle-breeding or complete soil degradation. However, altogether different and absolutely sustainable is the agroforestry practiced locally to this day in the form of the “traditional” milpa, based on TEK, and which is being admiringly uncovered in the MFGC form by modern science. In order to feed the large population, other intensive food producing methods besides MFGC were practiced, such as raised and channelised fields, *chinampas* (“floating gardens”) along the river, lake/laguna and swamp banks, various kinds of terracing on hilly terrain, preparation of the fertile anthrosol – dark earth, similar to the *terra preta* of the Amazon – crop domestication and highly advanced commercial activities. Only in this way is it possible to explain the historically very large population and high carrying capacity of the Maya forest.

Generally, the conclusions found in the literature on swidden cultivation, the main source of food, are extremely conflicting (Sanders and Price 1968:124). For some writers, thinking of the present-day destructive non-sustainable “conventional” milpa, swidden cultivation is characterised as unproductive and deleterious to the biotic balance. The land exhaustion brought about by this primitive non-sustainable cultivation system of clearing and burning forests thus forced farmers to go further and further away from the ceremonial centres in search of fertile lands. The time came when they were so far removed that it was easier to build a small new centre than to make frequent trips to worship at the old great one.

In the 1990s, however, researchers were able to piece together climate records for the period of the Maya collapse and found that it correlated with an extended period of extreme drought.

Not only did drought make it difficult to grow enough food, it also would have been harder for the Maya to store enough water to survive the dry season. "The cities tried to keep an 18-month supply of water in their reservoirs," says Sever (*The Fall of the Maya* 2009). "For example, in Tikal there was a system of reservoirs that held millions of gallons of water. Without sufficient rain, the reservoirs ran dry." Persistent episodes of unusually low rainfall were prevalent in the mid-9th century AD, a time period that coincides strikingly with the abandonment of Tikal and the erection of its last dated monument in 869 (*The Fall of the Maya* 2009) Archaeologists consider that the underground channels of the temple of the Inscriptions in Palenque indicate the possibility that the temple "was built around a spring of water".

In this connection, Stromberg (2012) quotes the findings of Arizona State University and Columbia University. The first assumption is based on the occurrence of extensive droughts in the 8th and 9th centuries AD, which accelerated deforestation due to the need to produce food and wood for burning limestone for construction purposes – “The experts estimate it would have taken 20 trees to produce a single square metre of city scape”!

The production of lime (calcium oxide), an essential component of plaster, required considerable fuel input, It was made by burning crushed limestone, and required 5 kg of wood to make 1 kg of lime All of the temples, plazas, causeways (*sacbeob*), reservoirs, and elite houses were covered with plaster, and, although this was not a daily need, in the long run the process consumed a substantial amount of fuel. The wood required for construction timber and the manufacturing of artefacts created an essential, but less voluminous demand (Lenz *et al.* 2014).

According to the other assumption, the land laid bare is thought to have absorbed less solar radiation, so less water would evaporate from the surface, hence fewer clouds and rainfall. The rapid process of deforestation would thus have exacerbated the already extreme droughts. As Stromberg (2012) writes “…in the simulation, deforestation reduced precipitation by 5 to 15% and was responsible for 60% of the total drying that occurred over the course of a century as the Mayan civilisation collapsed. The lack of forest cover also contributed to erosion and soil depletion…This forced peasants and craftsmen into making a critical choice, perhaps necessary to escape starvation: abandoning the lowlands. The results are the ornate ruins that stretch across the peninsula today”.

Moreover, Nations (2006:259) states that:

> All available evidence indicates that after a thousand years of successful adaptation to a tropical forest environment, Maya civilization disintegrated between AD 700 and 900 from an interrelated complex of factors – population growth, environmental degradation brought on by deforestation and erosion, increasing warfare, drought and internal civil strife. The turmoil wrought by these interwoven factors led to the death or out-migration of 90 to 99% of the Classic-era Maya people. In the population vacuum, the vegetation of the Maya tropical forest gradually regenerated.

Meanwhile, according to Coe (1977:133): "Among the causes are agricultural collapse, epidemic diseases, invasion by foreigners from Mexico, social revolution, forced evacuation by the early Toltec rulers of Yucatan, and even earthquakes and an unbalanced sex ratio!" Lenz *et al.* 2014:

> Present ecological, paleoethnobotanical, hydraulic, remote sensing, edaphic, and isotopic evidence that reveals how the Late Classic Maya at Tikal practiced intensive forms of agriculture (including irrigation, terrace construction, arboriculture, household gardens, and short fallow swidden) coupled with carefully controlled agroforestry and a complex system of water retention and redistribution. Empirical evidence is presented to demonstrate that this assiduously managed anthropogenic ecosystem of the Classic period Maya was a landscape optimized in a way that provided sustenance to a relatively large population in a preindustrial, low-density urban community. This landscape productivity optimization, however, came with a heavy cost of reduced environmental resiliency and a complete reliance on consistent annual rainfall. Recent speleothem data collected from regional caves showed that persistent episodes of unusually low rainfall were prevalent in the mid-9th century AD, a time period that coincides strikingly with the abandonment of Tikal and the erection of its last dated monument in AD 869. The intensified resource management strategy used at Tikal – already operating at the landscape's carrying capacity – ceased to provide adequate food, fuel, and drinking water for the Late Classic populace in the face of extended periods of drought. As a result, social disorder and abandonment ensued.

The end of new dates on the stelae indicate that the collapse of Classic Mayan culture is surprisingly uniform: Palenque (799), Yaxchilan (808), Tonina and Calakmul (909), Tikal (869).

The combination of very likely overpopulation and the proven long-lasting droughts must have greatly increased the pressure on the forest due to the increased need for food and wood as a source of energy and construction material. The ecological footprint of the human population exceeded the carrying capacity based on the available supplies of food, water, raw materials, and/or other similar. Due to the reduced harvest, trading routes shifted from the interior of Yucatan to the peninsula's coast. Trade and the surplus products, which were the basis of the former prosperity and power of the ruling elite, therefore fell. This is undoubtedly a very simplified explanation for the decline and final collapse of the Mayan civilisation. Despite the very different circumstances in the wake of the Spanish conquest, some Lacandones still live in and with their forest, and preserve it using TEK and MFGC, albeit in a somewhat botanically anthropogenic altered form, which however still carries out its ecosystem functions including the currently very relevant CO_2 absorption in the context of mitigating climate change.

As opposed to archaeologists and paleoecologists, who have assumed that the presence of agriculture implied woodland reduction and ultimately deforestation (so contributing to the collapse of the Maya), agroecologists studying TEK distinguish between short-term, conventional and ecologically problematic approaches, and the forest regenerating, highly diverse and intensively managed swidden system, also called *high-performance milpa* (Diemont and Martin, 2009:254; Nigh, 2008:234). In all of this, perhaps the most misunderstood aspect of milpa is its relationship with the forest. We can never emphasise strongly enough that "from the first years Maya farmers take measures that ensure the regeneration of forest vegetation" (Ford and Nigh, 2015:49)

Ford and Nigh (2015) conclude that the widely assumed cause of the collapse of the Maya civilisation due deforestation and forest degradation is not true (cf. Pilarski 2015). The forest gardens as a phase of the milpa system were sustainable, and the system involved many stages of plant cover, most of the time in forest phases. Prof. Šprajc (I. Šprajc, personal communication 4 August, 2022):

> I believe the theories concerning the decline and final collapse described in literature – including scientific literature – are frequently oversimplified. Although it is clear there were regional differences in the processes and events that happened, we now agree that one of the causes of the collapse was overpopulation, reached after centuries of incredibly successful adaptation to the local context, followed by environmental degradation, wars and droughts.

The earliest signs of a socio-political crisis (a fall in the number of dated inscriptions, etc.) appeared in the southern, predominantly aquatic lowlands, before the onset of protracted droughts, perhaps due to conflicts linked to control over the trade routes that connected the lowlands with the southern highlands. Population growth meant the central part of the peninsula (the Elevated Interior Region) was particularly vulnerable due to its lack of permanent water sources. The droughts in the 8th and 9th centuries further worsened the situation, so not even the most advanced agricultural techniques were enough to overcome the difficulties the Maya faced. Then there is the military aspect, and the ineffective response by the ruling elite to the growing shortages that had devastating consequences not only for the existence of individual parts of the Mayan Empire, but also for the much-needed trade networks for salt, obsidian, and jade. Most of the people could not survive in such conditions, so they moved to the coastal regions, where trade was strengthening along the maritime routes, or to the highlands in the south, which were not as badly affected by the drought and where the ground was more fertile, or to the north where water was closer to the surface, often in cenotes (Cf. Šprajc *et al.* 2021, 2023).

For the possible contamination of drinking water in Tikal, see Miller (2000) and what really caused the collapseof the Mayan civilisation, consider Barrios (2023).

»Dijeron que antiguamente
se fué la verdad al cielo,
tal la pusieron los hombres,
y desde entonces no ha vuelto…

Lope de Vega,-(1562-1635), one of the key figures in the golden age of Baroque ("Giglo de Oro"), contemporary of Miguel de Cervantes.

Professor Šprajc continues: after the collapse of the Classic Period of the Maya, the central and southern highlands were not completely emptied; this is why sustainable agricultural strategies were preserved in many places, although these enabled only smaller, more egalitarian communities to survive. Ford, Nigh and others base their claims primarily on ethnographic examples of such practices (El Pilar, Lacandoni, etc.), but their generalisations are isolated and without wider support. Ford and Nigh (2016:123) say that the intensive and permanent agricultural system does not require terraces, and that it can be employed without any large-scale irrigation or drainage. However, the evidence that there were extensive terraced areas and wetlands with canal systems in many places (Šprajc *et al.* 2021) indicates that the Maya had to resort to such methods of agricultural intensification to deal with the crisis. Ford and Nigh (2016) – as I have already mentioned on p. 83 – reject the view that towards the end of the Classic Period there was extensive deforestation and a demographic decline. However, archaeological data clearly shows that there was relatively little forest considering the density of the area covered by settlements, and the terraced, agriculturally modified land (cf. Šprajc *et al.* 2021, 2022), and that in the post-Classic Period the population in the central and southern highlands was very much smaller than before.

Of course, all these facts in no way discount the importance of the agricultural systems described in the literature, which have been preserved in some places and should be revived as a matter of some urgency everywhere this is possible. Prof. Šprajc believes that such efforts would also be successful because nowadays the population density in the Mayan lowlands – with the exception of urban centres such as Merida, Cancún, and Campeche – is significantly smaller than in the late Classic Period.

2.6 Deforestation and protected areas in the Selva Lacandona

Between 1976 and 1992 the state of Chiapas lost between 50,000 and 66,000 hectares of forest per year, mostly in the region that is home to the Lacandones (O'Brien 1998:75-82). In Chiapas deforestation is claiming 7% of the forest each year! (Howard and Homer-Dixon 1996, quoted in Diemont 2006). Even more, "lands devastated by nonsustainable use intensify the demand for new lands, leading to further deforestation and social conflict" (Nicholson *et al.* 1995, Howard-Dixon 1996, quoted in Diemont

2006:206). "Following crop and cattle production, these areas do not return to a mature, enriched forest, but to degraded grass and bush vegetation" (Miller 1999, quoted in Diemont 2006:206).

The community of Naha' is today a rainforest island within a sea of cattle pasture and degraded forest. The situation in Lacanja is a bit better, because the community is located about 10 km from the nationally protected archaeological site of Bonampak. O'Brien (1998:75-82), quoted in Kashanipour and McGee (2004:49):

> In 1964 private timber companies began two decades of highly selective logging cedar and mahogany from Selva Lacandona. By the 1980s there were so few of the highly prized hardwoods left that Mexican-owned timber companies stripped much of the jungle of less-valued common species of trees. Between 1976 and 1992 the state of Chiapas lost between 50 and 66 thousand ha per year, mostly in the region that is home to Lacandon. The original 13,000 square kilometres of the Selva Lacandona have been reduced by loggers, cattle ranchers, oil roads, and colonising farmers to fewer than 4,000 square kilometres, and it will be a challenge from now on to maintain what little forest remains.

"This situation is typical and endemic throughout the tropics, as increasing population densities stress the environment through demands on agricultural land" (Lal 1995, Alvarez and Naughton-Treves 2003, quoted in Diemont 2006).

Dispersed Lacandon settlements and isolation led the government of Mexico, in 1971, to deed 6,410 square kilometres of the Selva Lacandona to the Lacandon population as a communal reserve (*Comunidad Lacandona*). Although the likely impetus for this land grant was a plan to obtain timber, not indigenous land rights, the action nonetheless gave legal title of this huge block of forest to the families who had lived within it for some 200 years.

Six years after the Lacandon land grant, in 1978, the government of Mexico responded to international calls for rainforest protection by establishing the 3,312 square kilometre *Montes Azules Biosphere Reserve,* as Mexico's first biosphere reserve, 85% of which overlaps the 1971 Lacandon land grant. The Biosphere Reserve covers only one fifth of the original rainforest in Chiapas reserve (*Lacandon Jungle* 2016; Nations 2006:142-148).

The solution to conflicting demands is zoning. Primack (2008: 234); UNESCO 2017):

> The challenge in zoning is to find a compromise that people are willing to accept that provides for the long-term, sustainable use of natural resources. UNESCO has pioneered one such zoning approach with its Biosphere Reserves in an attempt to integrate human activities, research, and protection of the natural environment, sometimes at a single location (Primack 2008:233,234, see Map 2).
>
> Biosphere reserves are nominated by national governments and remain under the sovereign jurisdiction of the states where they are located. Their status is internationally recognised. Biosphere reserves have three interrelated zones that aim to fulfil three complementary and mutually reinforcing functions:
>
> The core area(s) comprises a strictly protected ecosystem that contributes to the conservation of landscapes, ecosystems, species and genetic variation.
>
> The buffer zone surrounds or adjoins the core areas, and is used for activities compatible with sound ecological practices that can reinforce scientific research, monitoring, training and education.
>
> The transition area is the part of the reserve where the greatest activity is allowed, fostering economic and human development that is socio-culturally and ecologically sustainable.

Financed in 1994 by the World Bank's *Global Environmental Fund*, the biosphere reserve is recognised by the UN *Environment Program* for its global biological and cultural significance. Its management plan endeavours to strike a balance between habitat conservation and the demand for research into its vast genetic resources. There is a significant difference in the quality of the vegetation between the reserve areas and the "jungle" outside of it. Nations (2006:143):

> Still, neither the biosphere reserve nor *Comunidad Lacandona* designations have halted forest clearing. The Tzeltal Maya, originally from the Ocosingo valley to the west, are ambitious forest farmers who dedicate exhausted cornfield land to pasture for beef cattle. They then clear more tropical forest for corn farming, and the process

> of converting forest to pasture continues. As a result, the Tzeltal are quickly exhausting the tropical forest of the northern half of the 6,143 square kilometer *Comunidad Lacandona* lands, causing their Chol and Lacandon Maya cousins in the southern portion of the territory to wonder how many years will pass before they find themselves defending their forest lands from the land grant's co-owners.

The designation of the biosphere was essential, and led to Selva Lacandona being designated a “biodiversity hotspot” by the Washington DC-based environmental group *Conservation International* and under the *Puebla-Panama Plan*. It is part of the *Mesoamerican Biological Corridor*, which aims to link similar sites from the Isthmus of Tehuantepec down through Central America for conservation purposes (*Wildlife Corridor* 2018). This is especially true for those “hotspots” located in remote trans-border tropical forests.

Thirty years ago we were already aware that the last primary forests must be protected and surrounded by buffer and transition zones, while the remaining, better preserved secondary forests should be managed according to SFM/MFM principles while at the same time preserving and reviving *traditional ecological knowledge* (TEK (Martin *et al.* 2010), which is the basis for traditional, sustainable permaculture in the form of the Mayan *milpa forest garden cycle* (MFGC). Soil fertility must be maintained in the deforested areas and sustainable agriculture practiced.

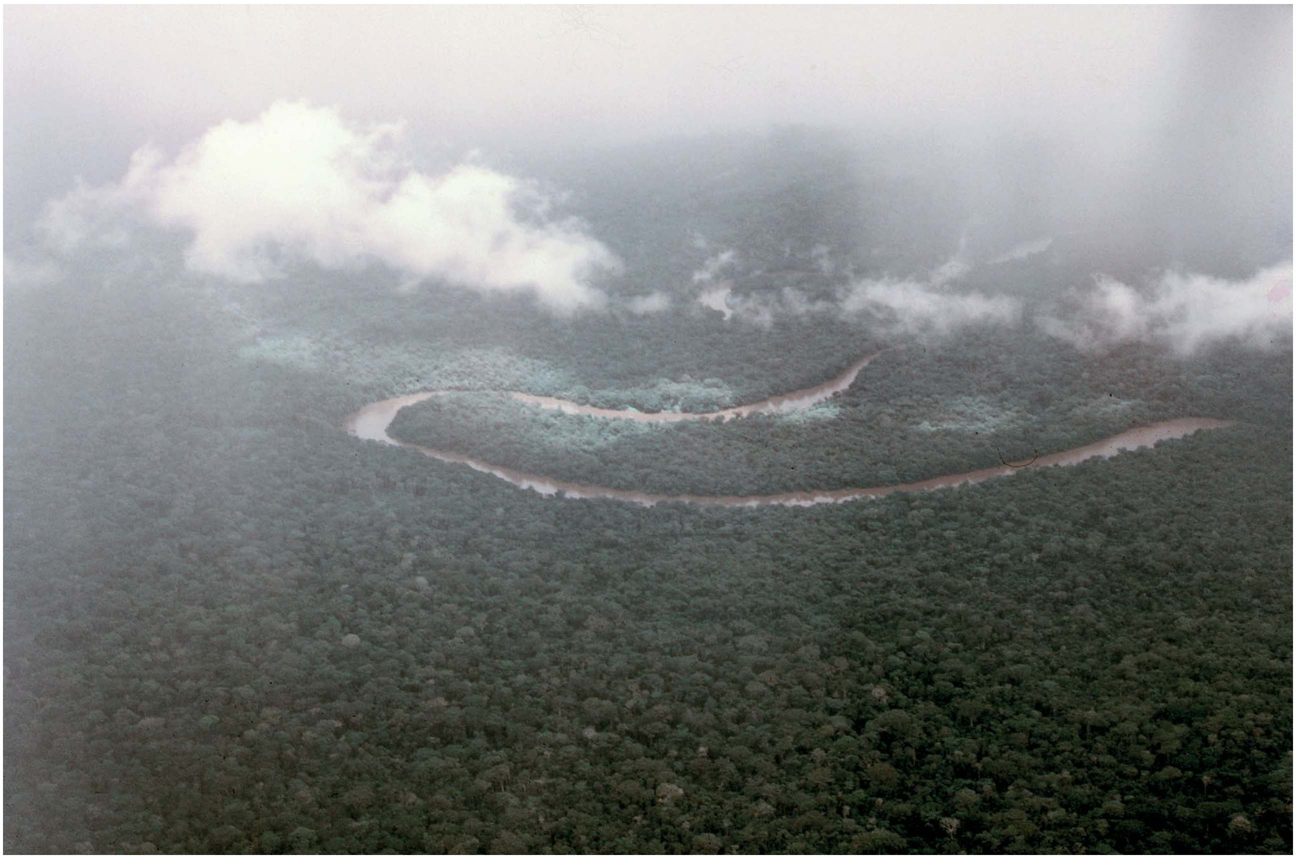
Alongside the largest, most precious and oldest *Reserva de la Biósfera Montes Azules,* two “natural monuments” were later (1992) founded with the aim of preserving an exceptional wealth of world cultural and archaeological heritage and the natural environment: (1) the *Monumento Natural Bonampak* with its *Temple of the inscriptions/Templo de las Inscriptiones* and (2) *Monumento Natural Yaxchilán* on a forested hill surrounded by a loop of the Usumacinta River at the Guatemalan border. Six years later two more *Protection Areas* were established to protect the exceptional biodiversity of flora and fauna: the *Area de Protecciońde Flora y Fauna* Najá/Naha and Metzabok/Mensäbäk around both villages of the *northern Lacandon communities*. La Cojolita is an indigenous community reserve established in 1993 by Tzeltal, Chol, and Lacandon Maya to preserve a forest connection between the Bonampak and Yaxchilán and maintain a biological corridor between the *Monte Azules Biosphere Reserv*e and the *Sierra del Lacandon National Park of the Maya Biosphere Reserve* in nearby Guatemala (Nations 2006:147,186).

Unfortunately Selva Lacandona, especially the area inside the *Biosphere Reserve*, is a source of political tension, pitting the EZLN or Zapatistas and their indigenous allies who want to farm the land against international environmental groups and the Lacandon Maya, the original indigenous group of the area and the party who has legal title to most of the lands in Montes Azules.

Until the 20th century, the Selva Lacandona covered 13,000 square kilometres. Today, two thirds of this forest has been cleared and burned for farmland and pastureland, leaving less than 4,000 square kilometres in its original vegetation. Most of this remaining forest is protected today as the *Montes Azules Biosphere Reserve*, and seven other protected that adjoin it (Nations 2006:114).

Table 2.3 Selva Lacandona - Protected Areas (Source: Diario oficial de la Federación, 23 de septiembre de 1998, from Nations, 2006:145; see Maps 1 and 2.

Area	Established	Square Km.
Reserva de la Biósfera Montes Azules	January 12, 1978	3,312
Refugio de Flora y Fauna Silvestre Chan K'in	August 24, 1992	121.84
Monumento Natural Bonampak	August 24, 1992	43.57
Reserva de la Biósfera Lacantún	August 24, 1992	618.73
Monumento Natural Yaxchilán	August 24, 1992	26.21
Reserva Comunal Sierra la Cojolita de la Comunidad Lacandona	1993	345.10
Area de Protección de Flora y Fauna Najá	1998	38.47
Area de Protección de Flora	1998	33.68



3. The Maya/Lacandon agroforestry - The milpa forest garden cycle (MFGC) (A review)

Selected basic works on Maya agroforestry:
Cook S. 2017. The forest of the Lacandon Maya. Springer: New York, Heidelberg, Dordrecht, London

Ford A and Nigh R. 2015. The Maya forest garden. Routledge: London and New York.

Gómez-Pompa A, Allen MF, Fedick SL and Jimenez-Osornio JJ. 2003. The Lowland Maya Area: Three Millenia at the Human-Wildland Interface. Food Products Press. An Imprint of The Haworth Press, Inc. New York, London, Oxford.

Nations JD. 2006. The Maya Tropical Forest – People, Parks and Ancient Cities. University of Texas Press: Austin.

Primack RB, Bray DB, Galetti HA and Ponciano I. (eds.) 1998. Timber, Tourists, and Temples. Conservation and Development in the *Maya* Forest of Belize, Guatemala and Mexico. Island Press: Washington, D.C.

Here should also be mentioned an outstanding pioneering study:

Nations JD and Nigh RB. 1980. The evolutionary potential of Lacandon Maya sustained yield tropical forest agriculture in the *Journal of Anthropological Research* (1):1-30. These authors were the first to describe in detail the Lacandones' intensive agroforestry method.

I consider the following co-authored articles to also be important works:

Ford A. and Nigh R. 2010. The milpa cycle and the making of the Maya forest garden, In: *Research Reports in Belizean Archaeology*, vol. 7:183-190.

Kashanipour RA and McGee RJ.2004. Northern Lacandon Maya medical Plant Use in the Communities of Lacanja Chan Sayab and Naha', Chiapas, Mexico. *Journal of Ecological Anthropology* 8:47-66.

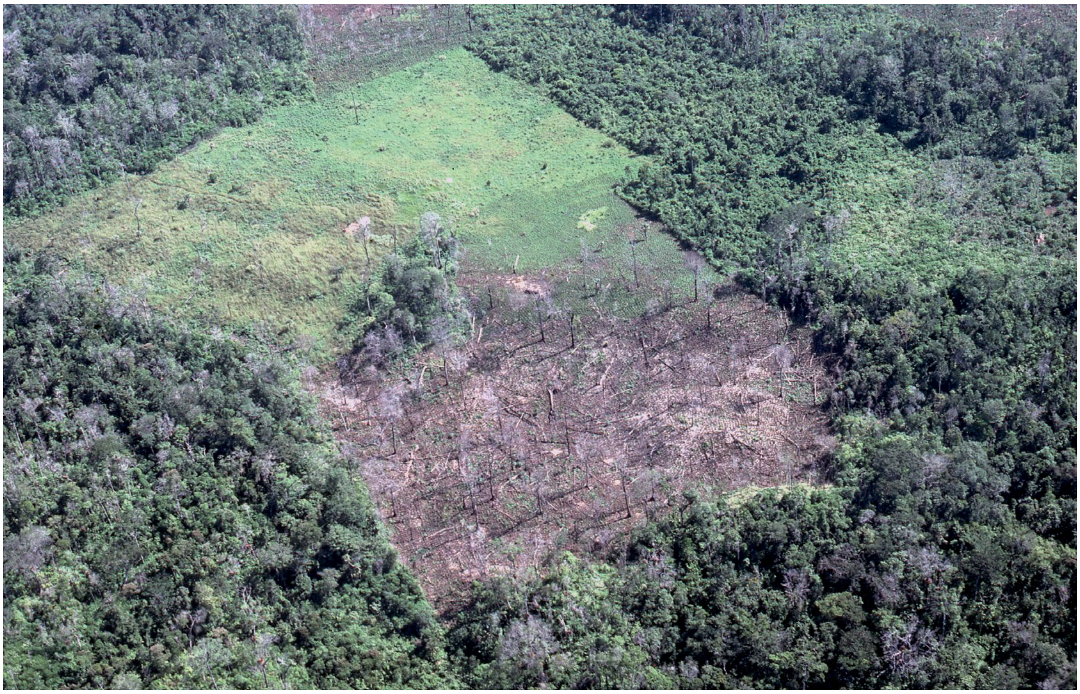
Misa B. 2008.Seing the Garden in the Jungle (article and some thoughts).Availableat:http://eurotope.ning.com/profiles/blogs/1114637:BlogPost:13545 (Accessed: 02.August 2018).

Nigh R and Stewart AW Diemont. 2013. The Maya milpa: fire and the legacy of living soil. *Front Ecol Environ* 2013; 11 (Online Issue): e45-e54, doi:10.1890/120344

3.1 Overview

Again and again we ask: what sustained the great, expanding populations of the ancient Maya in their seemingly inhospitable tropical environment? On the other hand it's long been one of ancient history's most intriguing mysteries: why did the Maya, a remarkably sophisticated civilisation made up of more than 19 million people, suddenly collapse sometime during the 8th or 9th centuries? The Mayan cities are said to have more than 800 inhabitants/km^2 at the height of their civilisation, and 80-160 inhabitants/km^2 in rural areas (cf. *The Fall of the Maya* 2009; Stromberg 2012; Benson 1977:60). Based on archaeological evidence (Turner 1990, quoted in Gómez-Pompa 2003:4), the Maya reached a high population density (up to 200 people/km^2 in rural areas) that is found today only in few highly populated regions within Central America and Asia. Gómez-Pompa (2003:4):

> This figure remains unchallenged and suggests that Maya were able – for centuries – to feed a population several times larger than the population of today in a tropical environment with soils that most agronomists would describe as marginal for agricultural purposes. There are two alternatives: either we assume that the population density figure is exaggerated, or we accept the figure and look for an explanation. Both options are challenging, the first alternative remains uncontested by archaeologists, but second has been by scientists from different disciplines. How did the Maya feed their people?



The milpa cycle – aerial view.

"Industrial" agroforestry: teak and pineapple.

A view of *Selva alta.*

Somebody practicing MFGC lives here.

> ... We know that the Maya practised intensive agriculture, but we are not sure what species they used or how they managed them. Was corn-bean-squash shifting cultivation the principal food production system? Did they practice intensive rain-fed agriculture or agrosilviculture? What other staple foods did they cultivate in addition to corn, beans, and squash. What was the importance of chinampa-like agriculture?

To this list of plants we can add the ubiquitous ramón (*Brosimum alicastrum*), which in recent times has been ascribed an increasingly important nutritional role.

However, a significant part of the answer with regard to population density is contained in the highly advanced permaculture and sustainable agroforestry that was practiced, i.e. the *milpa cycle* (MC), or more precisely the *milpa forest garden cycle* (MFGC), as practiced by the Maya on the basis of *traditional ecological knowledge* (TEK) (Martin *et al.* 2010) in their original system of agroforestry. These traditional farmers still practice sustainable, local, organic agriculture, cultivating an array of crops year-round in a polycultivation, *permaculture* system (*El Pilar Maya Forest Garden Network* 2007-2011). "Permaculture with its 12 design principles (Holmgren 2002), is a philosophy of working with, rather than against nature. Forest gardening is a term permaculturalists use to describe systems designed to mimic natural forests (Mollison 1991)" (Permaculture 2019). *Swidden*, also known as "shifting cultivation" is the oldest form of farming in the Americas (Baker 2006), and is often blamed for deforestation but also plays a role in forest conservation. Notably, the conditions for agroforestry in the flat, and drier northern part of Yucatan (*Northern area* or *Northern Lowlands)*, with significantly less precipitation and no surface watercourses, which is covered by more xerophile and thermophile forest *(Selva mediana* and *S. baja*), are different from those further south in the partially hilly *Central area* or *Southern Lowlands*, with more precipitation and large rivers, including the great Usumacinta River. Here the Maya probably also used intensive hydraulic food production methods, such as raised fields, "floating gardens"/*chinampas* and terracing on the slopes. The preserved, although in many places "utilitarianly" altered forest, also offered the possibility of fishing and hunting. Animals which were hunted include deer, peccary, turkeys, quails, ducks, curassow, guan, spider monkeys, howler monkeys, the tapir, and armadillo, while numerous watercourses made fishing possible. The Maya also gathered various edible fruits in the forest, e.g. guava, papaya, avocado, and custard apple, as well as the most diverse medicinal plants, plants for dyeing, spinning, weaving, etc. They also practiced apiculture and gathered firewood and wood for construction purposes (Kashanipour and McGee 2004, Cook 2016:90-96). In practicing MFGC they produced the fertile anthropogenic *black soils* by means of the skilful use of fire*.*

Next to their houses the Maya had home or house gardens (*kolil nah'*), into which they transplanted from the forest all manner of different, useful plants and trees, including vanilla (*Vanilla lanifolia)* and balché (*Lonchocarpus* sp.) for preparing a favourite Maya intoxicant and purge with strong religious associations. After the Spanish conquest they also planted citrus trees and bananas. A small section of the property was always reserved for a kitchen garden, with demarcated beds of cabbages, radishes, carrots and lettuce, as well as clumps of mint, garlic, and green onion, and so on (cf. Cook 2016:39).

In addition to the "local" papaya, avocado, cacao, tobacco, peanuts (*Arachis hypogaea*) and sweet potato (*Ipomea batatas*), they also grew many "post conquest" fruits and vegetables, especially Asian tropical species such as sugar cane, bananas, mango, rice, bamboo, African *watermelon* (*Citrullus vulgaris*) and Asian-Mediterranean agrumes, including lemon, orange and lime. I still remember how I stumbled upon several orange plantations during my first reconnaissance trip into the Selva Lacandona. The arrival of useful species from other continents was surprisingly quick. Spain had a global empire and primarily dominated the tropical world, and Charles V could boast that the sun never set on his empire. This is unsurprising, as besides the Americas and a good portion of Europe, the Philippines, named after his son Philip II, also belonged to him! For those times the Spanish had a fantastically organised and controlled trans-Atlantic transport system of treasure ships moving in convoys, which were defended against pirate attacks by galleons at the front and back. All ships began and ended their long intercontinental journey in Seville (*Casa de Contratación*), where seemingly infinite amounts of looted riches were delivered day and night. Interestingly, as a result of the agreement reached with Portugal in Tordesillas and recognised by the Catholic Church (Treaty of Tordesillas), Spain had to maintain its connection with the Philippines, not via the shorter route round the "Portuguese" Cape of Good Hope, but via the much longer and more dangerous combined route across the Atlantic, then overland across Mexico and from Acapulco across the Pacific to Manila using the famous "Manila Galleons", which were some of the largest wooden ships in history!

Generally the *Milpa Forest Garden Cycle* was initiated in closed-canopy forest when a modest 2-5 ha clearing was made with obsidian cutting tools and fire… In the following several years, annual cropping was practiced and fields were visually dominated by maize, but also included types of companion crops (Nations and Nigh 1980:10,16).

Human intervention is most intense during the early years of re-growth. Ecological studies have shown that events in these early stages largely determine the rate and botanical composition of the later phases of succession. (Chazdon 2008; Nigh 2008, quoted in Ford and Nigh 2009:216)

To increase soil fertility, the Maya very probably practiced other, more intensive forms of agriculture. They used raised fields, where platforms of earth are lifted from low, damp, or seasonably inundated soil, so that the water ran in drainage canals around the fields. Near lagunas and *bajos* as well as near riverbanks, the Maya probably used *chinampas*, the so-called floating gardens that existed in Aztec areas, some of which can be seen near Mexico City today (cf. e.g. Benson 1977:61). Of course, watercourses including the great Usumacinta and many large and small rivers in the preserved forest and forest gardens made fishing possible, while the forests and forest gardens were home to abundant game. The forests were managed sustainably, in close-to-nature fashion. Nowadays, we would say the Maya had an ecosystem approach.

The phase that has received the most criticism in MC is the use of fire to burn the plant debris that remains after forest clearing, since this burning destroys the humus in the soil. But in fact, today we know that the sophisticated use of fire results in long-term sequestration of carbon and an increasingly fertile *anthrosol* ("dark earth"), comparable to *terra preta* in the ancient Amazon (cf. Nigh and Diemont 2013). When properly managed the Maya swidden cycle results in enriched anthropogenic soil representing a lasting expression of agroecological skill and creativity (Wilken 1987; Peterson *et al.* 2001, quoted in Nigh and Diemont 2013).

The MC is a traditional Maya agricultural cycle that takes advantage of the ecology and microclimate of the natural environment, encouraging biodiversity. It represents a rotation of annuals with successional stages of forest perennials during which *all* phases receive careful human management. Ford and Nigh (2009:216):

> The cleared *milpa* was planted with annuals that require full sun. From the *milpa*, the field cycles into a *forest garden*, with a greater emphasis on perennials. Eventually, the farmer will plant hardwoods that will mature and look much like the forest that was there before it was cleared. The resultant forest is a highly managed, anthropogenic landscape that we call the Maya *forest garden* as element of MFGC. The management of the MC is an essential tool for the tree composition and maintenance of the *Maya forest garden* landscape over time and across space.

The Maya traditional milpa has been well-described in the academic literature (Bernsten and Herdt 1977; Diemont and Martin 2009; Everton 2012; Gómez-Pompa 1987; Hernández Xolocotzi *et al*. 1995; Isakson 2009; Nations and Nigh 1980; Parsons *et al.* 2009; Steinberg, 1998; Terán and Rasmussen, 2009; Wilken, 1987 and others, quoted in Ford and Nigh 2015:47).

However, it is still perceived through a European lens. In fact Staller (2010) suggests that to consider maize a "staple grain" and to compare the *tortilla* to the Spaniard's bread is a Eurocentric idea that may not reflect the dietary reality of the Prehispanic Mesoamerican and Maya people. Maize was an important, even sacred plant to the Maya, so it may not be analogous to wheat or rice in the Old World. The Spanish demand that maize be used for tribute in the colonial period, along with the introduction of steel tools, helped reshape the emphasis of *milpa* practice (Ford and Nigh 2015:47).

Mann (2005:197,198) writes: *"Milpa* crops are nutritionally and environmentally complementary. Maize lacks the amino acids lysine and tryptophan, which the body needs to make proteins and niacin… Beans have both lysin and tryptophan…. Squashes, for their part, provide an array of vitamins; avocados, fats… The milpa, in the estimation of H. Garrison Wilkes, a maize researcher at the University of Massachusetts in Boston, "is one of the most successful human inventions ever created".

"Maya *milpa* entails a rotation of annual crops with a series of managed and enriched intermediate stages of short-and long-term perennial shrubs and trees. The integration of the MC into neotropical woodland ecology transformed the succession of plants and turned the Maya forest into a *garden,* where more than 90% of dominant tree species have benefit for humans." While maize is visually dominant, it is interplanted with beans, squash and other plants, with more than 90 Mesoamerican possibilities! A multi-cropped maize field is just one stage of a recurring cycle. (Campbell *et al.* 2006, quoted in Ford and Nigh 2015:43)

A fundamental misconception of the milpa cycle is that fields are “abandoned” to lie fallow after several years of annual crop cultivation. In reality “high-performance milpa” (Wilken 1971, 1987, quoted in Ford and Nigh 2009:216) fields are never abandoned, even when they are forested. Thus, it is more accurate to think of the *milpa cycle* as a rotation of annuals with successional stages of forest perennials during which all phases receive careful human management. (Gómez-Pompa 1987, 1991; Gómez-Pompa and Vazquez Yáñez 1981; Gómez-Popa *et al.* 1990; Gómez-Pompa *et al.* 2003; Hernandez Xolocótz *et al.* 1995; Nations and Nigh 1980; Tera*n et al*. 1995, quoted in Ford and Nigh, 2009: 216)

The *agroforestry* system has been known for a long time, and is or was known in a similar way by other tropical forest peoples, although their approaches were not as close-to-nature and oriented towards the rapid restoration of the forest following the initial food-producing stage as those of the Maya. Moreover, the tropics surely have most to gain from agroforestry. Certain types of coffee (“robusta”) from Africa grow only under the shade of tall tropical trees, and the same is true for the “native” cacao. Leguminous trees are commonly grown for shade, but as nitrogen fixers they also help fertilise the crops around them, and their nitrogen-rich leaves make particularly fine fodder (Tudge 2005:392). A few decades ago I visited the very rich “industrial” agroforestry in Tabasco consisting of valuable arboreal cedar (*Cedrela odorata*) with excellent wood, comparable to mahogany, with aromatic epiphytic vanilla (*Vanilla planifolia*) growing in the “armpits” of the branches and cacao bushes in its shade. That was also the first time I tasted homemade Mayan chocolate, which was soft, black and exceptionally aromatic. Coming from the Eastern (“Soviet”) block, where chocolate was a real rarity, it made us particularly happy. Nowadays, we would call it “dark chocolate”, considered to be an antioxidant superstar, which lowers the risk of cancer and heart attacks. I am always reminded of this chocolate when at home we watch the film *Chocolat*, starring the sweet Juliette Binoche, who hangs a sign saying “La chocolaterie Maya” during Lent, in full view of the horrified mayor.

This tree is frequently combined with the teak (*Tectona grandis*) native to south and southeast Asia and the “local” pineapple (*Ananas comosus*). Combinations with trees that have valuable wood are very common, however, due to rapid growth with more juvenile and tension wood, these trees usually do not attain the quality of forest trees. Still, such combinations, besides producing food, at least partially replace the forest and protect the soil and its fertility. In the temperate climatic zone, there is also a spectrum of agroforestry, e.g. pigs in Central Europe used to feed on beech-nuts or “mast” in beech forests, or as still practiced nowadays in Portugal and Andalusia, on mast found under cork oaks (*Quercus suber*). This is in parallel with the production of wood and even more precious cork.

However, agroforestry does not include the increasingly common, harmful arboreal monocultures, such as the African oil palm *(Elaeis guineensis*), which is planted on the burned land where once extremely rich forests grew in Southeast Asia and where the habitat of orangutans is being destroyed without any guilt. Also problematic are the monocultures of the very fast growing Australian eucalyptus trees in Amazonia, not to mention the deforestation of the very last rosewood (*Dalbergia* spp.) and ebony species (*Diospyros* spp.) in Madagascar. The list could go on… It is difficult to be environmentally aware and protest, especially when we don’t even know where palm oil is utilised and how much paper from eucalyptus trees we use.

Lacandon agroforestry represents ecosystem management and a sustainable design for subsistence and environmental restoration (Diemont and Martin 2009). It correlates with *ecological engineering* as we understand (and admire) it nowadays, which represents “the design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both” (Mitsch 1993; Mitsch and Jorgenssen 2004; *Ecological Engineering* 2018).

3.2 Kol'milpa'

We can gain some insight into this issue by examining a recent ethnographic example of the Lacandon (also Lacandones and Lacantun) from Chiapas living in the Selva Lacandona. The Lacandones are the smallest of the Maya groups, but have the longest history of living in the lowland forest of Selva Lacandona.

Lacandon farmers utilise four food-producing zones: primary forest (*k'ax*), cornfields or milpas (*kol*), secondary milpas (*pak che' kol*) and *house gardens* (*mehen kol*) (e.g. Kashanipour and McGee 2004:50). Cook (2016:39) mentions the Lacandon expression for “house garden” – *kolil nah'*. Nigh and Diemont (2013):

> Milpa has great potential for adaptation to the extremely varied local ecosystems and cultures of the region. It can be integrated with house gardens (infield, referring to crop grown around the family house site) or may be situated some

Maya polyculture milpa. Unlike monocropped fields, crops in Lacandon milpas are dispersed, avoiding plantings of single crop.

The typical Yucatecan hut has not changed in thousands of years. Every Maya household had its own kitchen and home garden in which vegetables and fruit trees (papaya, avocado, custard apple, spodilla and ramón) were (and are) grown. The same house design was used for the stone temples (Morales 1976:49). Modern homesteads are often less romantic, but very tidy and made from modern materials (sometimes from concrete) with roofs often made of corrugated iron (Naha'). Roofs were sometimes covered with a layer of broad palm leaves of *Genoma oxycarpa* (*k'unche' pahok*) or *Chrysophilla stauracantha* (*kun*). Vertical pole walls (hi'che) were made with the timber from *Heliocarpus* spp. (*halol*). The door (hool) was made from *Swietenia macrophylla* (for more information see, for example, Cook 2016:45-61).

> kilometers from the family house, and is capable of degrees of intensity and productivity that respond to environmental constraints, marked demands, and the household domestic cycle…

Nations and Nigh (1980) were the first to describe in detail the Lacandones' intensive agricultural method (Lacanha' Chan Sayab, the southern Lacandon community). For these researchers, the Lacandon system answered the question of how the ancient, lowland Maya managed to feed several million citizens on crops produced from thin, forest topsoil.

Choosing a site to cut a small forest clearing for the milpa is the first crucial step. The Lacandones examine the natural vegetation and soils to determine the best location. They know that well-known tree species ramón (*Brosimum alicastrum*) and ceiba (*Ceiba pentandra*) flourish on rich soil, whereas areas where caoba (*Swietenia macrophylla*) and cedar (*Cedrela odorata*) grow are too wet.

When establishing the *milpa*, a firebreak was provided on all windward edges of the plot to prevent flames from escaping into surrounding forest. If the forest bordering the milpa is burned, it quickly becomes weed infested and causes increased weeding requirements within the milpa itself. An additional firebreak is provided by a ring of primary forest trees left standing on all edges of the milpa; these trees help contain the fire by creating a moist, les combustible buffer area on all surrounding sides. They also provide a source of seed for future forest regeneration and may serve were kept as a secondary ring around the la milpa to create a moist and less combustible buffer. The secondary ring was also useful as a source of seed for future forest regeneration and may serve as a windbreak and barrier to the spread of insect pests and certain crop diseases into the la milpa. (Seavoy 1973:522, quoted in Nations and Nigh 1980:9 and Yasamagachi 2012)

Burns are carried out by so=called "wind tenders" (*yum ik'ob* in Yuatec) . Wind tenders spread fire to obtain a controlled burn. One common practice is to burn against the prevailing winds and spreading the brush out to achieve an even, low-temperature burn throughout the process. For example, if the dominant and strongest winds are from the south-to-southeast, the two or more wind tenders begin in the northwest corner and proceed along the firebreaks on opposite sides, spreading the fire as much as possible. Other firing patterns have been reported. Such practices result in significant cumulative input of black carbon to soil and enhancement of other physical and chemical characteristics of anthropogenic dark earth. For more information, see Nigh and Diemont (2013) and Ford and Nigh (2015:56).

Trees and underbrush are cut by stone or obsidian axes during January, February and March and allowed to dry. In mid-April or early May, before the beginning of the rainy season, the dry underbrush is burned (Nations and Nigh 1980:9). The time at which a milpa is burned is critical, and demands extensive knowledge of the rain cycle. If it is carried out too soon, the wind blows the ash away, if it is carried too late, the material will not burn completely because of the rain. In either case, a poor harvest results (cf. Harrison 2000). Baer and Merrifield (1971:180), quoted in Nations and Nigh (1980:9):

> After burning the milpa plot, the farmer will wait a month or more before planting the area in corn, for he has to wait for the onset of the seasonal rains in June During this interim period, he prevents soil erosion and nutrient leaching by planting fast-growing root and tree crops, primarily taro *(Xanthostoma* sp.), chayote (*Sechium edule*), papaya (*Carica papaya*), bananas and plantains (*Musa* spp.). When the rain begins in May or June, he plants corn and squash using the *coa*, or dibble stick. Ten to fifteen days later, he replants areas where corn has failed to sprout. Together, the two corn seedlings require approximately eighty man-hours per hectare.

Any large tree trunks that do not burn are simply left and the crop sown around them. Partially burned trunks and other vegetation provides a gradual but continuous input of biochar and organic matter to the milpa soil (Nigh and Diemont 2013).
Lacandones plant a wide variety of other root, tree, grain, and vegetable crops during the course of the rainy season (May through October), establishing a polycropped plot. Although the word milpa or early successional stage means corn field, it may produce over 80 kinds of food and fibre crops both above and below the soil. Moreover, the root crops were planted at varying depths: taro and sweet potatoes several inches beneath the soil, manioc below them, and yam tubers below the manioc (Nations and Nigh 1980; Yasamagaci 2012).

The main felling and cultivation period is called *nah kolil*. Farmers observe the flowering of certain forest trees to guide their agricultural activities. These "indicator" species signal the foot of the agricultural cycle. The period when the plants flower is termed the "foot" of the crop (Nations and Nigh 1980:12; cf. Cook 2016:41-43; Tables 3.1 and 3.2). When the *halol* (*Heliocarpus* spp.) and *pet ak'* (unidentified) bloom, Lacandones clear the brush and unwanted trees. They sow the first crop of maize when *puuna'* (*Swietenia macrophylla*) flowers and then

Slashed milpa. One burn establishes the open field gap and initiates the milpa cycle. Debris will be removed by hand from the recently burned milpa.

Partially burned forest provides input of biochar and organic matter to the soil.

sow all the rest of the crops when the tree sheds its blossoms. The blossoms of *pukte'* (*Bucida buceras*) also signal the time to sow maize, while those of *ek' bahche* (*Guatteria anomala*) signal the time to sow black beans and tobacco, and *wäch* (*Dialium guianense*) blossoms signal the time to plant sweet potatoes and tobacco. Lacandones also plant sweet potatoes when e*k' 'oonte'* (*Nectandra* sp.) blooms.

Towards the end of the season, when *ma'ax ak' (äh)* (*Paullinia* sp.) blooms again, the Lacandones sow a second crop of white maize and tobacco. In the past, this traditional system of planting according to the flowering cycle of indicator species roughly coincided with the months of the year; and Lacandones may still refer to the Gregorian calendar when explaining the agricultural cycle to foreigners. But due the changing weather patterns, the traditional "phenological"system is a much more reliable method, considering local ecological and climatological characteristics.
It is the milpa cycle that is the axis of the resilient Maya resource management system. Altieri (2002); Ford and Nigh (2009), Teran and Rasmussen (1994):

> Lacandon men traditionally dedicated the greater part of their days to milpa work, in addition to hunting and gathering forest resources. Women and children helped during periods of high labor demand. Such dedication to milpa work allowed diversification and productivity rarely noted for this agricultural system recent times. This provides with a unique contemporary example of what Wilken (1971) called the "high-performance milpa", a form likely to have been far more commonly practiced in densely occupied ancient Mesoamerica… Lacandon farmers chose cultivation sites surrounded by forest to maintain a source of mature forest seeds for succession, The result of this practice combined with intensive daily weeding of the cropping area, was a careful control of the soil seed bank oriented towards achieving rapid forest regeneration. Careful weeding extended the useful life of the yield for annual crop production, allowing five to eight years of high-yielding continuous cropping…In traditional milpa, an ideal example being the Lacandon practice, however, small piles of weeds and crop residues were burned periodically through the year, and the ashes and charcoal spread about the field.

A hot burn over the entire field occurs only once in the 25-year milpa forest cycle, when the primary vegetation is cleared to initiate cropping. Most weeds that are pulled or cut are not burned at all, but are left in the field to decompose. As already mentioned, specialists called "wind tenders" ('*yum ik'ob*) control milpa fires by burning against the prevailing winds and spreading the brush out to achieve an even, low-temperature burn. (Ford and Nigh 2015:56). These practices provided a continuous supply of labile organic matter and biochar and resulted in a highly enriched anthropogenic soil observed on Lacandon fields (cf. Wilken, 1987), similar in some ways to the Amazonian *terra preta* (Nigh 2008; Ford and Nigh, 2010:186: Nigh and Diemont 2013; Marshall 2019),

Terra preta is a type of very dark, fertile manmade (anthropogenic) soil found in the Amazon Basin. It is also known as "Amazonian dark earth" (ADE) or "Indian black earth**"**. In Portuguese its full name is *terra preta do índio* or *terra preta de índio* ("black soil of the Indian", "Indians' black earth"). *Terra mulata* ("mulatto earth") is lighter or brownish in colour. *Terra preta* or biochar was done in such a way as to create a lot of charred material which then became incorporated into the soils during the rotations. This is excellent for long-term carbon sequestration (Pilarski 2015).

> Biochar is a principal ingredient in all variants of ADE. Biochars positive effect on agricultural soils appears to be in increasing the surface area over which biological activity can take place (cation exchange capacity, nutrient and water storage capacities).
>
> The hard, polycyclic aromatic C particles that result from low-temperature pyrolysis (300-500 °C) are chemically and biologically stable, persists for centuries, and confer long-term soil characteristics… The low-intensity burns result in incomplete combustion of vegetable This critical difference in fire intensity between conventional, contemporary milpa (or slash-and-burn) systems and the traditional Maya system is not usually appreciated, which may be why some researchers believe that ADE are not usually formed under swidden agroforestry (Denevan 2006)…
>
> Preliminary results on Lacandon milpa fields show increasing black carbon with soil depths, suggesting accumulation of black carbon over time, as fields are reused in repeated cycles of fire cultivation, and directed secondary succes-

> sion. Burned trunks and large branches from the original clearing are distributed throughout the field and shed charcoal continually, contributing to the highly enriched anthropogenic soil observed on Lacandon fields (cf Wilken 1987). Frequent small-scale fires create ash and charcoal without damaging soil life… High levels of organic matter and phosphorus as well as other characteristics (Mendoza-Vega and Messing 2005) are similar to the *terra preta* of the Amazon (Woods and McCann 1999; Peterson *et al.* 2001; Glaser *et al.* 2001; Balée 2010). Properly managed, milpa soils can be more fertile after each cultivation cycle. (quoted in Nigh and Diemont 2013)

The function of the woody vegetation in the *milpa cycle* is to build soil fertility through nutrient cycling. Deep rooted trees regain nutrients that have been leached from the upper soil layers. *U'cunte* (*Sapium lateriforium*), a successional tree used by the Lacandon Maya, works as a phosphorus pump, and brings this element from deep in the soil, through leaf litter. High levels of organic matter and phosphorus are among other characteristics similar to the Amazonian *terra preta* (Diemont *et al.* 2006, quoted in Nigh and Diemont 2013.

Later I summarise two agricultural "rounds" (Cook 2016:42 and Nations and Nigh 1980:12), which differ terminologically due to the distance between them, although both show a strong link between the forest and the milpa cycle. The regime, which determines when different tasks are carried out according to the milpa, is not based on the Gregorian calendar but is instead linked to the phenology of "indicator" tree types as influenced by seasonal and interannual variations in climate, as well as habitat factors (such as elevation). For a better understanding of the timescale the tasks are classified according to "Western" months without any fixed dates, which people here are not familiar with, not because they don't have calendars but because Western calendar doesn't have a realistic basis with regard to life in the forest.

The calendar was a definitive achievement of Mesoamerican civilisation, unknown in other cultures of the New World, reaching its highest elaboration among the lowland Maya of the Classic period (cf. Muser 1978:17). Their life was governed by the solar and ritual calendar, and their priests used the ritual calendar of 260 days – *tzolkin* – primarily for divinatory purposes. Study of the movements of celestial bodies produced several time cycles, among them the lunar calendar and the Venus cycle, principally employed for astronomical purposes.

The solar calendar answers the needs of the agricultural population and established the monthly feasts to their gods. It has 365 days, was called the Vague Year, and was composed of 18 months of 20 days each, with a period of five "unlucky days" (*Uayeb*) added at the end (20 x 18 + 5 = 365). The 360-day period was called *haab* or *tun.* They were conscious that their civil calendar (365 days) did not coincide with the true solar year. The ancient Maya were fascinated with the march of time and with the majestetically changing celestial patterns connected with the seasons of the year. With the knowledge of th zero, they were able to shape their vigesimal numbering system into a positional one. Furthermore they know to predict eclkpses. They delved into astronomy to solve the mysteries of the universe, seeking some fixed order that could be applied to their lives. They were conscious that their civil year calendar (365 days) did not coincide with the true solar year/tropical year of 365.2422 days but they regulated their seasonal activities with the aid of astronomical observations. Furthermore, they were able to predict eclipses.

The Maya were undoubtedly aware that their calendar year did not correspond with the tropical year, but they never fixed this "mistake" (nor did the ancient Egyptians, whose year also had only 365 days). For agricultural purposes the Maya observed the sky, especially the sun's path, as testified by architecture built to face the sun's rising or setting on important agricultural dates.

Here, I would like to mention the excellent work of the slovenian »Indiana Jones«, professor IvanŠprajc- an internationally renowed mayanist from the Institute of Anthropological and Spacial Studies at the Research Centre of the Slovenian Academy of Sciences and Arts (ZRC. SAZU. He, and two other scientists, discovered that the Mayan calendar was older than previously thought. The findings were published in the eminent journal Science Advances. It has been known for some time that during the period of pre-hispanic civilizations in the Mesoamerica, most civilian and ritual buildings were oriented according to sunrise or sunset on certain the days that were ritually important in the agricultural cycle. At first, they helped themselves with the aeral photographs and more recently, also using modern lidar technology to show the shape of the terrain beneath the forest canopy.

In Chalacmul Biosphere Reserve (Campeche), Šprajc and his coworkers discovered numerous, solar oriented buildings that were built between 1100 and 750 BC. We have reason to believe that the ancient Maya calender dates back to 1100 BC!

Astronomically oriented shrines and palaces were built to obviously transfer the celestial order into the Earth's environment forming the fundamental principle of calendar (Sprajc et al. 2023)

Europe is still excited about Alpine "ancient farming rules" of unidentifiable age, which on the basis of the lunar cycle and zodiac signs determine "the right time for felling" the valuable "moon timber". According to some sources, top quality tonewood is also "moon timber". Could moon timber be the secret behind the violins from Cremona and not the reduced growth during the Little Ice Age, which the genocide in America is thought to have made even colder, or (as I believe myself) a simply cooler high altitude climate and shorter vegetation period, and consequently more uniform growth, lower density and homogeneity? Moon timber is by all accounts supposed to have better properties than non-moon timber. Particularly unusual are the unexplainable fixed dates, independent of the moon, which promise a dramatic improvement of properties. Wood felled on 1 March, immediately after sundown, is supposed not to burn, and wood felled on 21 December on the day of St. Thomas, supposedly does not shrink!! (cf. e.g. Briemle 1998, 2003, Colerus 1680, Neumann 2003, Ober 1912, Paungger & Poppe 1991, quoted in Torelli 2005 a,b). It would be wonderful if the "old rules" held true and wood felled at "the right time" really acquired the promised properties. Then moon timber would really be an unbeatable material. I don't take this too seriously as the moon is, at least in Latin, a liar: "Luna mendax: "*Si crescit, decrescit, Si decrescit, crescit."* (See the bold initials of the moon shape and Latin words! The **C**rescent moon is in the shape of the letter **D** (lat. **D**ecrescere = decrease, diminish, wane) and the **D**ecrescent in the shape of the letter **C** (lat. **C**rescere = increase, wax).

It is true that in former times the Maya believed that certain days in their calendar brought good fortune while certain days were cursed; the modern Maya consider Tuesdays and Fridays unlucky, Mondays and Saturdays lucky (cf. Benson 1977:33), just as we nowadays believe that Friday the 13th is an unlucky day and some people complain about problems caused by the full moon.

The Maya had no problematic fixed dates and had always stuck to natural timing as dictated by the phenology of domestic plants and the phases of the moon, as we were able to see for ourselves (see below).

"Planting times for several crops are signalled by the flowering of certain primary forest "indicator" species. The period during which these plants flower is termed the "foot" of the crop, and Lacandons take care to plant cultigens during these "foot" periods" (Nations and Nigh 1980:9). Of course, the increasingly common and unpredictable droughts also have a decisive impact on when to sow or plant, and when the fruits are ripe**.**

Table 3.1 Lacandon agricultural cycle, activity and crops (information from the Lacadon informants quoted in Cook 2016:42)

Month	Activity and Crops	Indicator species (Lacandon)
Jan-Feb	*Halik loobil, ch'äkik uche'* "Pull out the weeds, fell the trees."	*halol* (*Heliocarpus* spp.) 161
March	*Kuch'uktik utihil, kutookik* "Wait for (the bush) to dry and then burn it."	*pukte'* (*Bucida buceras*) fn45,,62,134,143
April	*Uta'anil, kuch'uktik, kupiktik kol, upäk'ik näl (es slo mejor maize). Päk' ik ak'il bu'ul, p'ak, k'um, ik, tuwolol* "Wait for the ashes (to cool off), then sow he main crop of maize. When the maize is about 20 cm high, plant pole beans, tomatoes, squash, chili peppers, and then everything else."	*pukte'* (*Bucida buceras*)
May	*Upäk'ik che'il bu'ul. Utalha' chichin* "Plant bush beans. It starts to rain a bit."	*puuna'* (*Swietenia macrophylla*)
June	*Tan uk' äntal (näl), tan utihil. Halik uloobil. Puede upäk'ik näl, también***.** "The maize is turning yellow, it is drying. Pull out weeds. One may plant more maize."	*puuna'* (*Swietenia macrophylla*)
July	*Mixba'al'* "Nothing happens."	*ek'bahche'* (*Guatteria anomala*)
August	*Uwuts' ik näl* "Bend over the maize stalks."	*ek'bahche'* (*Guatteria anomala*)
Sept-Oct	Päybil näl "Clear weeds, pull out spent maize stalks, and then plant maize in the empty spaces."	*ek' oonte'* (*Nectandra* sp.), wäch' (*Dialium guianense*)
November	*Mäna' meyah* "There isn't any work."	*ma'ax ak'* (*Paullinia* sp.) *halol* (*Heliocarpus* spp.)

Nations and Nigh (1980:12) differentiate "foot" plants between the northern (Naha, Mensäbäk) and the southern Lacandones' communities (Lacanh'a Chan Sayab, Bonampak, Montes Azules Biosphere)


Partially burned forest.


The native flowering tobacco and our dedicated colleague Patrizia.


In the beginning: maize.

Table 3.2 Lacandon agricultural cycle, crops and "foot" indicator plants (Nations and Nigh 1980:12)

Month	Region	Crop	Indicator Species (Lacandon)
January	South	corn (*Zea mays*)	*ma'ax ak'* (*Paulinia pinnata*)
February	North	watermelon (*Citrullus vulgaris*)	*hach halol* (*Heliocarpus donnel-smithii*)
	North	corn (*Zea mays*)	*hach halol* (*Heliocarpus donnel-smithii*)
March			
April – early	South	corn (*Zea mays*)	unidentified *säk su'um*
April – late	North & South	corn (*Zea mays*)	*pukte'* (*Bucida buceras*)
May – late	North & South	corn (*Zea mays*)	*puuna' (äh)* (*Swietenia macrophylla*)
June – early	North & South	corn (*Zea mays*)	*puuna' (äh)* (*Swietenia macrophylla*)
	North	rice *(Oryza sativa)*	*puuna' (äh)* (*Swietenia macrophylla*)
	North	peanuts (*Arachs hypogaea*)	*puuna' (äh)* (*Swietenia macrophylla*)
July			
August	North	tobacco (*Nicotiana tabacum*)	*ek'bache'* (*Guatteria anomala*)
	North	black beans (*Phaseolius vulgaris*)	*ek'bache'* (*Guatteria anomala*)
September – late	North	sweet potato (*Ipomoea batatas*)	*ek' oonte'* (*Nectandra* sp.)
October	North	tobacco (*Nicotiana tabacum*)	*wäch'* (*Dialium guianense*)
	South	jicama (*Pachyrrhizus erosus*)	*mehen ts'us* (*Vitis tillifolia*)
	South	corn (*Zea mays*)	unidentified *k'uwan*
November – early	South	corn (*Zea mays*)	unidentified *piskinin*
November – late	North	corn (*Zea mays*)	*ma'ax ak'* (*Paulinia pinnata*)
December – late	North	corn (*Zea mays*)	*hach halol* (*Heliocarpus donell-smithii*)

The major crop is maize, followed by beans, while "imported" bananas are also considered a major crop when maize yields are low. Despite their nutritive value, beans and bananas are of secondary importance in the Lacandon diet. These foods are more like snacks, whereas the "sacred" maiz is the Lacandones' foremost sustenance. Of the other crops, the most widely cultivated include: *'is* "sweet potato"; *ts'in'* , manioc (*Manihot esculenta*); *k'um* , quash (*Cucurbita pepo*, *C. moschata*); and *p'ix* "vegetable pear" (*Sechium edule*). *K'uuts*, tobacco (*Nicotiana tabacum)* is an important crop for elders (Cook 2016:42,43). Nations and Nigh (1980:10, Table 1) listed numerous cultivated and protected plants in the Lacandon milpa.

Climate change has also affected the agricultural cycle by altering the cultivation cycle and jeopardising crops. Maize, normally planted in March, must now be planted in May, or even June. Even more, 20 years ago the rains were more regular but not heavy, and the climate cooler. Today Lacandones' reliance on government emergency supplies of maize has become the norm rather than the exception (Cook 2016:44).

Generally maize is harvested in August and September. Before the harvest, the stalks are bent over, to allow the ears to dry and prevent the rain from rotting the kernels. When sufficiently dry, the ears are harvested. This is done (Cook 2016:43) when the moon is full. It is believed that if they were removed while the moon was still "tender", the kernels would rot, turn into dust, and quickly dissolve.

We heard a lot from the Maya about trusting the moon with regard to building houses that cannot be attacked by termites or fungi while we were there, although I don't know if they also have a special name for this kind of wood as we do in Europe ("moon wood", ger. Mondholz). As I already mentioned, people living in the Alps continue to trust in the miraculous power of the moon, although science has not been able to confirm this (Torelli 2005a, 2005b). It is however true that I don't sleep well when there is a full moon, and that the moon inspired Beethoven to write his most beautiful and majestic Moonlight Sonata.

3.3 Pak che' kol ("planted tree garden", "forest garden", "secondary milpa", "acahual")

Although the *pak che' kol* appears to be an abandoned field, in reality it represents a stable larder of over 50 species of fruiting trees and vines, root and leafy crops and fibre-bearing plants (Nations and Nigh 1980:15, quoted also in Cook 2016:39). Table 3.3 shows dominant tree species of the Maya forest and forest garden in the nearby Peten. See also the tree species composition in 10 typical locations in Chiapas and Quintana Roo (Figure 2.28).

Table 3.3 Dominant tree species of the Maya forest and forest gardens and their use (after Campbell *et al.* 2006; Ford 2008:188, quoted in Ford and Nigh 2015:57): *Dominant in forest gardens; investigated tree species underlined. See also the species composition in various locations in the Maya forest in Mexico (Figure 2.28).

Scientific Name	Common Name	Pollination	Uses
Alseis yucatanensis	wild mamey	moths	food
*Aspidosperma cruentum**	malerio	insects	construction
*Attalea cohune**	corozo	insects	food
*Brosimum alicastrum**	ramón	wind	food
*Bursera simarouba**	chaca	bees	medicine
Cryosophila stauracantha	escoba	beetles	production
Licania platypus	succotz	moths	food
*Lonchocarpus castilloi**	manchiche	insects	construction
*Manilkara zapota**	chicozapote	bats	food
Piscidia piscipula	jabin	bees	poison
Pouteria campechiana	zapotillo rojo	insects	food
Pouteria reticulata	zapotilllo	insects	food
*Sabal morrisiana**	guano	insects	production
*Simira salvadorensis** sin. *Sickingia salvadorensis*	palo colorado	moths	construction
Spondias radlkoferi	jocote	insects	food
*Swietenia macrophylla**	caoba	insects	construction
Tabebuia rosea	macuelizo	bees	construction
Talisia oliviformis	kinep	bees	food
*Vitex gaumeri**	yaxnik	Bats	construction
*Zuelania guidonia**	tamay	bees	medicine

It is evident that there exists a high botanical coincidence between the species of forest gardens and the dominant tree species of the Maya forest in Peten (see also Tables 3.6, 3.8, 3.9, 3.11).

It is obvious that the successional communities of traditional *forest gardens* have a species composition that is more similar to the original rainforest than those that derive from contemporary milpa practices. Thus, forest restoration is hastened under traditional management (Nigh 2008, Ford and Nigh 2010:186).

The Maya milpa also entails a rotation of annual crops with a series of managed and enriched intermediate stages of short- and long-term perennial shrubs and trees, and culminates in the reestablishment of long-lived mature canopy trees on the once-cultivated parcel. The integration of the milpa cycle into the forest transformed the succession of plants and turned the Maya forest into a garden, where more than 90% of dominant trees have benefits for humans (Campbell *et al*. 2006, quoted in Ford and Nigh 2015:43). From the abstract of Diemont and Martin (2009):

The Lacandon practice a form of swidden agriculture that conserves the surrounding rainforest ecosystem while cycling the majority of their land through five successional stages. The se stages include an herbaceous stage. Two shrub stages. And two forest stages. A portion of their land is kept in primary forest.

Typically, Maya plant community succession (secondary forest succession) is in principle comparable to the understanding of succession that is current among neotropical forest ecologists (Guariguata and Ostertag 2001, quoted in Diemont and Martin 2009: 235 and Chazdon 2008, quoted in Nigh 2008:235). This is a decisive phase in the restoration and anthropogenic transformation of the Maya forest. In the last phase of the cycle, the botanic composition increasingly approaches the state of the "primary" forest. Differences between the *forest garden* and the surrounding forest become smaller and disappear.

Chasdon (Chasdon 2008, Table 3.4) compared Lacandon practice and knowledge concerning secondary forest regeneration with the knowledge of Western-trained forest ecologists. The considerable convergence of native and biological plant taxonomies has been extensively documented in the Maya area and elsewhere. Lacandon farmers take conscious measures to ensure that the species composition of regenerating vegetation rapidly approaches that of the original mature forest. Maya farmers chose cultivation sites surrounded by mature forest to maintain a source of tree seeds for succession. The result of this practice combined with intensive daily selection and weeding of the cropping area resulted in a careful control of the soil seed bank, oriented toward accelerating and directing ecological succession and achieving rapid tall forest regeneration. Not surprisingly, Maya agroforesters and field ecologists have arrived at similar representations of succession. Under Maya management canopy closure of the "stem exclusion stage" is achieved in two or three years, rather than up to ten as described by ecologists (Nigh 2008: 233-235; Nigh and Diemont 2013).

Table 3.4 shows phases of the neotropical secondary forest succession and vegetation dynamics, as defined by forest ecologists (Chazdon 2008, from Nigh 2008:236).

Table 3.4 Phases of neotropical secondary forest succession and vegetation dynamics (Chazdon 2008, quoted in Nigh 2008:236).

Phase 1 – Stand initiation phase (0-10 yrs)	Germination of seedbank and newly dispersed seeds. Resprouting of remnant trees. Colonisation of shade-intolerant and shade-tolerant pioneer trees. Rapid height and diameter growth of woody species. High mortality of herbaceous old-field colonising species. High rates of seed predation. Seedling establishment of bird- and bat-dispersed, shade-tolerant tree species.
Phase 2 – Stem exclusion phase (10-25 yrs)	Canopy closure. High mortality of lianas and shrubs. Recruitment of shade-tolerant seedlings, saplings, and trees. Growth suppression of shade intolerant trees in understory and subcanopy. High mortality of short-lived, shade-intolerant pioneer trees. Development of canopy and understory tree strata. Seedling establishment of bird- and bat-dispersed, shade-tolerant tree species. Recruitment of early-colonising, shade-tolerant tree and palm species into the subcanopy.
Phase 3 – Understory reinitiation stage (25-200 yrs)	Mortality of long-lived, shade-intolerant pioneer trees. Formation of canopy gaps. Canopy recruitment and reproductive maturity of shade-tolerant canopy and subcanopy tree and palm species. Increased heterogeneity in understory light availability. development of spatial aggregations of tree seedlings.

Ecologists no longer subscribe to "equilibrium" models of succession, in which woodlands were believed to return spontaneously to a "climax" state after disturbance (e.g. wildfire, blow-down, clearing for cultivation). However, the process of the tropical forest succession is known to develop as a series of stages, usually leading to some form of closed forest. This succession is driven by groups of dominant wood species defined by morphological, phenological, biochemical, or trophic responses (functional groups) at each stage (Chasdon 2008, quoted in Nigh and Diemont 2013).

The Maya forest garden is the traditional Maya orchard plot that evolves from the milpa. Like the milpa, it uses a polyculture and permaculture system of cultivation, and is managed with local, organic resources rather than chemical fertilisers and pesticides. Though it mostly focuses on the cultivation of perennial plants, a few annuals and herbs are still grown, providing for a diverse array of household needs. It will eventually cycle back into a hardwood forest. The "forest gardener", the traditional Maya farmer, cultivates the cycle of milpa, forest garden, and forest using extensive traditional knowledge and practices that promote the ecology, biodiversity, and growth of the ecosystem. This includes nurturing the plants, providing for animals and insects, as well as serving to meet household needs. Understanding the Mesoamerican milpa as a basic component of the forest garden is essential (El Pilar Maya Forest Garden Network. 2007 – 2011*).* Maya smallholders, scattered in Selva, employing techniques of the "high performance milpa*"* and related agroforestry, created the forest garden (Ford und Nigh 2015:159).

During fallow period, the milpa goes through stages of secondary succession, or transformations. The forest gardener plants it with such tree crops as rubber, cacao, citrus, and avocado, and continues to harvest the area for another five to fifteen years while it regrows with natural forest species. Lacandones call these regenerating plots *pak che kol*, "planted tree gardens". A better description would be "an old milpa that is undergoing or has attained second-growth regeneration". These tree gardens serve as fallow areas between milpa and primary forest (cf. also Cook 2016:39).

As the Lacadon example illustrates, the *milpa cycle* is a complex multi-cropping system built around the rotation of the maize fields with secondary stages of forest (Chazdon 2014). Forest succession and regeneration are carefully managed – tree species are selected, eliminated, planted, or encouraged – so that forest composition and regeneration are aimed at economic and cultural utility (Diemont and Martin 2009; Campbell *et al*. 2006; Ross 2011; Ross and Rangel 2011; Snook *et al*. 2005**,** quoted in Ford and Nigh 2015:67).

Although untended, fallow fields still provide fruits, leafy greens, and roots. Moreover, they attract game animals, which the Lacandones hunt to supplement their mainly vegetarian diet with high quality proteins.

Forest garden, papayas.

Milpa polyculture (banana and plantain).

Unlike monocropped fields, crops in Lacandon milpas are dispersed throughout the milpa, avoiding large plantings of single species. Below the surface, root crops are planted at varying depths, while above-ground growth includes papayas, bananas, and other forest species. The strategy of dispersing a variety of plants in time and space is a characteristic of traditional, tropical, swidden systems, which efficiently use the available space, water, and soil nutrients. Such a system circumvents widespread crop loss caused by insects, herbivores, and disease (Nations and Nigh 1980:11).

Lacandon farmers are the first to point out that aggressive, almost daily, weeding is the key factor that allows them to cultivate the same garden plot for so many years in a row. After five or seven years they clear a new forest plot, not because the soil has lost its fertility but because the labour required to weed the garden finally outweighs the labour required to clear a new plot from forest or regrowth.

When the forest finally overtakes his tree crops, the farmer clears and burns the plot again and begins the cycle anew. Thus the Lacandon agroforestry system cycles food and forest continually on small plots of forest land. The tropical forest becomes a garden plot, which becomes a planted *tree garden,* which becomes tropical-forest regrowth, which becomes a *garden* plot again, and so on through time. Using this system, a Lacandon farmer may clear as few as ten hectares of virgin tropical forest during his entire agricultural career – from the ages of seventeen to seventy.

Many useful plants are grown in forest gardens, including those imported in the wake of the Spanish conquest e.g. limes, lemons, oranges, bananas and plantains (Nation and Nigh 1980:16).

When the old milpa gardens need to regenerate, they are planted with tree crops and continue to be harvested for another five to fifteen years. These tree gardens, *pak che kol*, serve as a fallow area between milpa and primary forest. In the *pak che kol*, the Lacandon harvest many foods and other material. The strong fibre under the bark of the corkwood tree is used to make rope, strong carrier straps, and bark cloth for ceremonial garments. Fruits and nuts are harvested from these trees, as well as roots and vines for baskets. These plants also attract animals from the forest, functioning as a "managed wildlife area" , providing an easy source of meat for the Lacandones.

The final ecozone of subsistence for the Lacandon is the primary forest, which yields a wide variety of plant and animal resources. The forest is a source of both food and raw materials for various purposes: construction (wood for beams, thatch for roofing), tools (wood for bows and arrows, feathers for fletching, flint for projectile points and blades), plant fibre for twine, and crafts (clay for pottery, mineral and vegetable pigments for dyes, colourful seeds for necklaces). Many game animals live in the forest notably the *háale* (paca or tepeizcuinte) prized for its savory meat. Local lakes and rivers provide fish, shellfish, turtles and turtle eggs, snails and occasional crocodiles. Although rifles are mainly used for hunting, the bow and arrow is still occasionally used. (*Lacandon Maya* after Nations and Nigh 1980)

The Lacandones cycle of planting milpa, then *pak che kol*, then milpa can go on endlessly, keeping the use of primary forest to a minimum. Since the area was declared a protected site in the 1990z, the practice of transforming primary forest into milpa has become rare since it is prohibited. Instead, fallow milpas are rotated and reverted back into cultivation. So today, the *uyanchunil kol* refers to a milpa cut from secondary forest (Cook 2016:41).Nations and Nigh (1980):

> Everything that the Lacandons need in daily life can be found in the milpa, *pak che kol* and the nearby forest. In emulating the diversity of the forest which surrounds it, the milpa gradually becomes a living mass of food producing plants which occupy the entire cleared area both above and below the soil. Their respect for the land and independence has allowed the Lacandons to survive until recently without assistance from the outside world for their daily needs.

As we already know, the Lacandon are keen gardeners. They are constantly transplanting forest plants and trees into their home/house gardens, which they call *kolil nah/mehen kol*. A small section of the property is reserved for a kitchen garden, with demarcated beds of cabbages, radishes, carrots, lettuce and other vegetables, which resemble our vegetable gardens (cf. Cook 2016:39). Kashanipour and Mc Gee (2004:50):

> House gardens are the final zone of Lacandon horticulture. Although the yields from house gardens are minimal, they represent an important area of plant cultivation. In essence, house gardens serve two agricultural roles. First, they provide a protected growth area for plants that require long-term development and maturation periods, such coconut, lime and orange. Second, they provide an easily accessible area for supplemental and often fragile foodstuffs such as coriander and onion.

3.4 The practice

I will proceed to briefly summarise the fallow successional stages of the Maya swidden agroecosystem or plant community succession management in *forest gardens* and their arboreal compositions, as observed by different authors, beginning with the open milpa of annuals with the famous herbal annual "trilogy" or "three sisters": maize, squash beans and numerous accompanying plants, from long lived woody perennials to the closed canopy of the well-managed hardwood forest, where we come across tree types of the Maya forest, many of which we studied in our research (underlined in tables).

Essentially, what goes on in a forest garden is a guided or oriented secondary succession, which is very similar to the natural one and shows phases of the neotropical secondary forest succession, and vegetation dynamics, as defined by forest ecologists (Chazdon 2008, from Nigh 2008:236; Chazdon 2014, Table 3.4). El Pilar Forest Garden Network (2017):

> The forest gardener will let the hardwood trees grow and mature. Basically, the traditional Maya forest garden is an orchard plot that evolves from the milpa. Like the milpa, it uses a polyculture and permaculture system of cultivation, and is managed with local, organic resources rather than chemical fertilizers and pesticides. Though it mostly focuses on the cultivation of perennial plants, a few annuals and herbs are still grown, providing for a diverse array of household needs. It will eventually cycle back into a hardwood forest.

The trees can be harvested for personal use or sale, and then when the area is clear the Lacandon burn the ground and plant the field. The cycle of the milpa begins again…

The Lacandon even have special names for the individual phases of this development, which surprisingly enough proceed quite similarly to the secondary succession in the natural forest, but faster. They differentiate two phases in the secondary forest and the last phase in the mature forest. The knowledge possessed by the Maya about the soil and ways of preserving and increasing its fertility with precisely determined plants is surprising. The Lacandon Maya – as we already know – divide their agricultural system into primary forest (*taman che*), an herbaceous stage (*kor*-commonly known as *milpa*), two shrub stages (*robir* and *jurup che*-collectively known as *acauhal*), and two secondary forest stages (*mehen che* and *nu kux che*) (Diemont and Martin 2009).

The final phase of the MFGC with hardwood species in such a strong anthropogenic intervention is not exactly the same as the pristine forest, but is more or less altered. An abandoned forest can show traces of human activity even centuries later (feral forest).

The locations of the MFGC described below were relatively difficult to access in the 1980s and 1990s when we were doing our research. Nowadays, with the road network being expanded, tourism developed and the internet up and running, they are mostly easily accessible. The cited relevant literature is also more recent.

3.4.1 The southern Lacandones of Lacanja' Chan Sayab I

Nations and Nigh (1980) were the first to describe in detail the Lacandones' intensive agricultural method. Ronald Nigh from the *Centro de Investigaciones y Estudios, Superiores en Anthropologia Social* (CIESAS) described the succession in the Lacandon settlement of Lacanjá Chan Sayab in detail (Nigh 2008) at Bonampak. The location lies on the intersection of latitude 16° 45' 38'' N and longitude 91° 07' 49'' W at an elevation of 250 m (Southern Community). The climate is humid tropical, with an annual rainfall of 2300 to 2800 mm and average temperature 25 °C with minimal seasonal variation. Vegetation: tropical rainforest, lower montane rainforest and evergreen seasonal forests with three or more strata presenting a fairly uniform canopy between 35 and 45 m with occasional emergents up to 60 m (Miranda 1952, quoted in Nigh 2008:234). The most frequent canopy tree species are *Brosimum alicastrum, Aspidosperma megalocarpon, Dialium guianense, Guatteria anomala, Terminalia amazonia* and *Swietenia macrophylla,* all investigated in our study. From the abstract of Nigh (2008):

> Intervention in the early stages of regeneration after cycles of maize swidden cultivation ensures the rapid recovery of original woody vegetation, enriched by species valued by humans. As already mentioned, Maya farmers and forest ecologists have approached the tropical environment in similar ways, identifying and working with functional groups of woody species, to enhance biodiversity and ecosystem resilience. Planting or encouragement of selected tree species and the judicious use of low- intensity fires, help create "anthropic" soil of high organic matter and nutrient content, similar to the "dark" earths observed in Amazonia. The knowl-

> edge and skill revealed in Maya milpa agroforestry are invaluable tools for conservation of tropical biodiversity.

Under Maya management in the evergreen and seasonal rainforests of eastern Chiapas, canopy closure of the "stem exclusion stage" is achieved in two to three years, rather than up to ten as described by ecologists, through the propagation of fast-growing pioneer trees. Bats and birds are attracted to these pioneer species and bring the seeds of more shade-tolerant trees that eventually make up the canopy of the mature forest. Thus, the transition into the ecologists' "understory reinitiation stage", normally occurring at least 25 years after the disturbance event, is reached in half that time under Lacandon management, that is, in around 12 to 15 years. Though most Lacandon farmers would probably prefer to prolong the forest-growth stage for many more years, the field is theoretically ready to be reconverted to milpa at that time (Levy Tacher 2000; Nations and Nigh 1980; Nigh 2008:235 Nigh and Diemont 2013; Marshall 2019).

In the nearby Peten, the 20 dominant trees forming the Maya forest oligarchy (Table 3.3) – where core species account for a majority of the trees – are all found among traditional forest gardens in the region (Ford 2008) and fulfil household needs. This shows an exchange between the forest and the gardens. Among the most widely represented is ramón (*Brosimum alicastrum*). The household management of the dominant species is important in the conservation of the Maya forest. Occurrence of the forest species in these gardens is demonstration that people are a crucial component in maintenance and ultimately the regeneration of the Maya forest (Ford 2008:187); Milpa Polyculture Macroscope (2009:5):

> The Maya forest, thus, is the result of plant selection and the skills of smallholder farmers engaged with a variable environment and the local landscape (Griffith 2000). Traditional Maya farming, still practices today, represent investment in the conservation of the landscape, from the soil to the trees, promoting biodiversity and animal habitat essential to the sustainability of the subsistence system. (Ford and Nigh 2010:188)
>
> The traditional Maya agricultural cycle advantages the ecology and microclimate of the natural environment, encouraging biodiversity. It is more accurate to think of the *milpa cycle* as a rotation of annuals with successional stages of forest perennials during which all phases receive careful human management. It uses a polyculture and permaculture system of cultivation, and is managed with local, organic resources rather than chemical fertilizers and pesticides. The cycle begins with the clearing and burning of a piece of mature forest. The cleared milpa is planted with annuals that require full sun. From the milpa, the field cycles into a *forest garden,* with a greater emphasis on perennials. Alfonso Tzul, a modern Maya farmer and retired agricultural extension officer, describes how forest gardens came to be: "God created plants and animals and the world around us. Trees grew in the forest, seeds spread, birds sang, and animals flourished. All was already there. Man came along and preferred this plant, favored that seed, enjoyed those birds, and supported those animals, creating and using the forest as a garden to sustain those plants and animals. The job of the forest gardener is to manage the forest by adding, removing and nurturing plants, to make sure that certain species grow where they will be most viable."

Note: It is always necessary to differentiate between the sustainable traditional polycultural milpa, which is based on traditional ecological knowledge (TEK), acquired in the course of many centuries and which represents a "highly diverse, intensively managed swidden system practiced among all Maya groups in the past" (Nigh, 2008:234), from the mainly destructive, non-sustainable, monocultural, "conventional" milpa practiced nowadays.

As previously mentioned, the Lacandones name the distinct sucessional stages that ideally develop after several years of maize polyculture and take conscious measures to ensure that species composition of regenerating vegetation rapidly approaches that of the original mature forest (Nigh 2008:35).

The principal event defining Lacandon stage 2 (*jurupche*) is canopy closure, which aligns with the forest ecologist's view. In the Lacandon system, enrichment planting in the early years of succession helps shape the later composition of flora (Nigh 2008:237). In the *jurpche* phase (Table 3.5) we can already find all the dominant tree types in the "stem exclusion stage" (Diemont 2006). The transition from the Lacandon stage 2 (*jurupche*) to stage 3 (*mehenche*) is marked by botanic changes when short-lived pioneers, such as *Cecropia obtusifolia* (*k'o'och*) and *Ochroma pyramidale* (balsa, *chujum*) replace in-

Establishing perennial shrubs and trees in the milpa directs forest succession (cacao).

Cassava

termediary species, which are then followed by long-lived secondary species such as *Spondias mombin* and *Heliocarpus appendiculatus*. In the final phase, all the above species give way to species of the secondary forest *(nukuxche)* and the mature forest (*tamanche*), a number of which we studied in the course of our research (Table 3.5).

Table 3.5 Dominant plants of the Lacandon MFGC showing the biodiversity at each stage of the cycle (investigated species underlined) (Ford and Nigh 2010:187)

Stages 1-2 1-3 yrs 3-7 yrs	Open milpa: ~ 30 cultigens selected from approx. 70 spp, including maize, squash, beans, tomato, macal, chilli, herbs. Also major families: *Ambrosia*, Compositae, Amaranthaceae, *Cecropia, Trema, Mimosa*, Cyperaceae, Melastomataceae, Poaceae, Asteraceae, Urticaceae, Euphorbiaceae, Palms; Coppiced bushes and trees to re-sprout, as well as short lived perennials; Seedling fruit trees for stage 3-4
Stages 3-4 7-15 yrs 15-30 yrs	Long lived Perennials ~ Fruit trees: *Annona muricata* L., *Sabal morrison* Bartlett, Attalea cohune C. Mart., *Ceiba pentandra* L., *Ananas comosus* (L.) Merr., *Bursera simarouba* (L.), *Opuntia cochenillifera* (L) P. Mill., *Pachyrhizus erosus* (L.), Carica papaya L., *Cecropia pelttata* L., *Calophyllum brasiliense* Cambess, *Bucida buceras* L., *Curbita pepo* L., *Cnidoscolus chayamansa* McVaugh, *Manihot esculenta* Crantz, *Acacia cornigera* Cham., (L.) Wild, *Enterolobium cyclocarpum* (Jacq.) Griesb., *Quercus oleoides* Schltdt. & Cham., *Persea americana* P. Mill., *Byrsonima crassiflora* (L.) Kunth, *Guarea glabra* Vahl, *Brosimum alicastrum* Sw., *Pimienta dioica* (L.) Merr, *Psidium guajava* L., *Hamelia patens* Jacq., *Simira salvadorensis* (Standl.), *Talisia oliviformis* Radlk, *Manilkara zapota* (L.) van Royen, Pouteria zapota (Jacq,) Moore & Stearn, *Guazuma ulmifolia* Lam. Seedling long lived perennial hardwood interspersed with fruit trees for Stage 5. Hardwood shade fruit trees in later stages.
Stages 5 Harvest & ready for Stage 1	Closed Canopy well managed forest~*Spondias mombin* L., *Aspidosperma cruentum* Woodson, *Attalea cohune* C. Mart *Crysophila stauracantha* (Heynh) R. Evans, *Sabal morrison* Bartlett, *Bursera simarouba* L., *Licania platypus* (Hemsley) Fritsch, *Lonchocarpus castilloi* Standley. *Piscidia piscipula* (L.) Sarg., *Zuelania guidonia* Britton & Mill sp., *Swietenia macrophylla* King, *Brosimum alicastrum* Sw., *Alseis yucatanensis* (Standley), *Simira salvadorensis* (Standl.), *Talisia oliviformis* Radlk., *Pouteria reticulata* (Engl.), *Pouteria campechiana* (Kunth) Baehni, *Manilkara zapota* (L.) van Royen, *Vitex gaumeri* Greenm.

Just as in Peten, the Selva Lacandona is dominated in the final phase by tree species of the Maya forest.

3.4.2 The southern Lacandones of Lacanhá Chan Sayab II

Stewart Diemont from Environmental Resources Engineering Department, College of Environmental Science and Forestry, State University of New York, Syracuse, NY and Martin (2009:256) also studied Lacandon Maya agroforestry systems in Lacanha' Chan Sayab located at 16° 56' 60'' N and 91° 16' 60'' W at an elevation of 500 m. The soil type is luvisol and the annual rainfall 2500 mm. The Köppen climatic classification is Aw2(w)(i')g (warm and humid thermal tropical zone).

The swidden agroforestry system of the Lacandon Maya has allowed them to sustainably manage their land for hundreds of years without observed degradations. Lacandon land managers plan and care for many particular tree species during the fallow period of their multi-successional swidden system to facilitate restoration of soil fertility.

The *kor* is herbaceous stage, previously identified by the local Spanish term *milpa*. The duration of *kor* depends upon the intensity of management, which can vary daily to monthly maintenance. More intensive management will maintain the land in *kor* for up to five years. *Robir* is the first fallow shrub stage and lasts for two years, while *jurup che* is the second fallow shrub stage and lasts for two to three years. Together *robir* and *jurup che* were previously identified by local Spanish term *acahual*. *Mehen che* and *nu kux che* are the first and secondary forest stages, respectively. *Mehen che* lasts for 10 years, and *nu kux che* can last from five to 20 years. An intentional burn will cycle later successional stages (i.e. *mehen che, nu kux che*, and in some cases *jurup che*) back to *kor* (Diemont and Martin, 2009:256,257).

Table 3.6 Dominant species (Lacandon Maya) in the *kor* (herbaceous) successional stage (milpa), their immediate uses, whether they were planted (P), whether Lacandon traditional ecological knowledge (TEK) credits them as enhancing soil fertility (SF), and their relative dominance (%) (Diemont and Martin 2009:258). Species investigated underlined.

Species	Planted	Enhancing soil fertility	Lacandon Maya		Use	
Zea mays	P	SF	*sak nar*	white corn	food	54.7%
Canna indica	P,	-	*chan kara*	Indian shot	beads for necklaces	21.9%
Zea mays	P	-	*nar chak*	red corn	food	4.3%
Arachis hypogaea	P	SF	*sikatelum, kakawat*	peanut	food	4.0%
Phaseolus calcaratus	-	SF	*arrzubur*	rice bean	food	2.9%, 1.4%?
Heliconia librata	P	-	*secre'k*	-	food (leaf to wrap tamale)	1.4%
Capsicum sp.	P	-	*ik*	pepper	food	1.1%
Spondias mombin	-	SF	*jujup*	hog plum	food, lumber, firewood	1.1%
Saccharum officinarum	P	-	*azucar*	sugar cane	food	0.7%
Lycopersicon esculentum	P	-	*p'ak*	tomato	food	0.7%
Cucurbita moschata	P	-	*k'um, xnuk*	crook neck squash	food	0.7%
Ananas comosus	P	-	*p'ach*	pineapple	food	0.7%
Allium porrum	P	-	*sakekon,*	scallion	food	
Menta piperita	P	SF	*xex*	-	Food (leaves are eaten)	0.7%
Solanum americanum	-	SF	*ch'auk', chakuckum, ix ch'a yuk*	black nightshade	food	0.4%
			chakuckum		ornamental flower	0.4%
Cyperus rotundus	P	-	*guerux,*	cocograss	food (eaten with eggs)	0.4%
Serjania atrolineata	P		*marxak*	-	medicine	0.4%
Carica papaya	P	SF	*put*	papaya	fruit	0.4%
Musa spp.	P	SF	*patan*	banana	fruit	0.4%
Allium cepa	P	-	*sakibir*	onion	food	0.4%
Baccharis trinervis	-	SF	*sisik'utz*	assapeixe fino	food for wild animals, firewood	0.4%
Manihot esculenta	P	-	*tz'inj*	cassava manioc, yuca	food	0.4%
	P	SF	*ujkuch*	-	medicine for diarrhea	0.4%
Lonchocarpus guatemalensis	-	-	*yax bache'*	turtle bone	firewood	0.4%
	-	-	*sak robir*	-	firewood	0.4%

Table 3.7 Dominant species in the fallow (successional) stages *robir, jurup che, mehen che, nu kix che, and taman che),* their immediate uses, whether they were planted (P), whether Lacandon TEK credits them as enhancing soil fertility (SF), and their relative dominance (%). (Diemont and Martin, 2009:259). Species investigated underlined.

Successional stage	Species	Lacandon name	Planted	Soil fertility	Use	Relative dominance
robir (the first fallow shrub stage)	*Lonchocarpus guatemalensis*	yaxbache'	-	SF	firewood,	23.8%
	Cecropia obtusifolia	*k'o'och*	-	SF	tobacco, firewood	14.3%
	Phaseolus vulgaris	*bur*	-	SF	food	9.5%
	Piper auritum	*jover*	-	SF	food	9.5%
	Cedrela odorata	*k'uche'*	P	SF	lumber, carvings	4.8%
	Piper aduncum	*makurum*	-	SF	corn-drying hut	4.8%
	Musa sp.	*put*	P	SF	food	4.8%
	Carica papaya	*patan*	P	SF	food	4.8%
	Ocimum micranthum	*seyen*	-	-	no use	4.8%
	Baccharis trinervis	*sisik'uts*	-	-	food for wild animals, firewood	4.8%

	Ceiba pentandra	*yax che'*	P	P/SF	clothes, decoration	4.8%
jurup che **(the second fallow shrub stage)**	Cecropia *obtusifolia*	*k'o'och*	-	SF	tobacco, firewood	28.6%
	Tetrorchidium rotundatum	*mumuche'*	-	SF	lumber, fruit for birds, firewood	16.1%
	Baccharis trinervis	*sisik'uts*	-	-	food for wild animals firewood	16.1%
	Podachaenium eminens	*kibok*	-	-/SF	firewood, construction	10.7%
	Hamelia rovirosae	*cha'top-che*	P	-	flower	3.6%.
	Bursera simarouba	*chakra*	P	SF	medicine for diabetes	3.6%.
	Piper auritum	*jover*	-	SF	food	3.6%.
	Piper aduncum	*makurum*	-	SF	corn drying hut	3.6%.
mehen che **(the first secondary forest stage)**	*Spondias mombin*	*jujup*	P	SF	food, lumber, firewood	12.3%
	Lonchocarpus guatemalensis	*yaxbache'*	-	-	firewood	11.1%
	Inga pavoniana	*bitz*		SF	food, firewood	8.6%
	Tetrochidium rotundatum	*mumuche'*	-	SF	lumber	8.6%
	Quercus suber(!)	*jaror*	-	-	rafts, chicken pens	4.9%
	Podachaenium emines	*kibok*		SF	firewood, construction	4.9%
	Pleuranthodendron lindenii	*ixim che'*	-	-	fruit for birds, firewood, lumber	3.7%
	Solanum sp.	*ujkuch*	-	-	firewood	3.7%
nu kux che **(the second secondary forest)**	*Spondias mombin*	*jujup*	P	SF	food, lumber, firewood	16.5%
	Eupatorium nubigenum	*sak che'*	-	-	no use	9.7%
	Tetrochidium rotundatum	*mumuche'*	-	SF	lumber	8,7%
	Dacaena sp.	*banboo*	P	SF	construction	5.8%
	Pleuranthodendron lindenii	*iximche*	-	-	seeds for birds, construction	3.9%
	Heliocarpus	*jurum*	P	SF	to make bags	3.9%
	Piper aduncum	*makurum*		SF	construct corn drying hut	3.9%
taman che **(primary forest)**	*Guarea glabra*	*sa'bajche'*	-	SF	firewood and carvings	14.7%
	Tetrochidium rotundatum	*mumuche*	-	SF	lumber	8.8%
	Eupatorium nubigenum	sak che	-	-	no use	8.8%
	Homelia rovirosae	*chac topche*	P	-	gum, flowers	5.9%
	Simira salvadorensis	*cha'kax,*	-	SF	medicine for skin injury	5.9%
	Pleuranthodendron lindenii	*iximche'*	-	SF	seeds for birds, construction	5.9%
	Borsimum alicastrum	*ox*	-	SF	lumber, eat the seed	5.9%
	Tabernaemontana amygdalifolia	*ton simin*	P	SF	gum, firewood	5.9%
	Pseudolmedia aff. oxyphyllaria	*tux ambar*	-	-	fruit for birds, firewood, lumber	5.9%

Table 3.8 Plants identified by the Lacandon that assist soil fertility regeneration and restoration (Diemont *et al.* 2006:208, cited also in Ford and Nigh 2015:62, 63; see also Table 3.13). Species investigated underlined.

Latin name	Lacandon Maya	Use (Levy 2002, interviews)
Astrocaryum mexicanum Lieberman ex Martius	*ak te*	fruit
Belotia mexicana K, Schum.	*taw, tao*	construction
Brosimum sp.	*ba'am bax*	fruit
Bucida buceras L.	*sa puk te, sä puk te*	construction/firewood
Calophyllum brasiliense Camb.var.rekoi Standl	*baba*	construction, food for birds
Cedrela sp	*cedro fino (sp.) kulche) ??*	construction and carved art pieces
Cordia alliodora Oken	*bajum*	construction
Dialium guianense Sandw.	*wech', we'ech*	construction, food, firewood
Guatteria anomala R.E. Fries	*ek bache*	food, construction
Hampea stipitata S. Watson	*ts'uk tok*	food and rope
Hibiscus sp.	*jor*	rope for bags and hammocks
Mucuna pruriens L.	*ka a be*	drink
Ochroma pyramidale Urban	*chujum*	construction and medicine for backpains
Piper auritum H.B.K.	*jo'ber*	eat leaves with fish, wrap tamales
Piper aduncum L.	*makarum*	construction
Sapium lateriflorum Hemsl.	*u'cunte*	seeds for birds, lumber for const.
Simira salvadorensis Standl.	*chak'ax*	medicine for skin cuts
Sterculia apetala Jacq.	*anis*	beads for necklaces
Swietenia macrophylla King	*puna*	construction, furniture, canoes
Unidentified	*pok te*	not determined

In every fallow stage, the Lacandon believed that the majority of dominant species enhanced soil fertility (Diemont and Martin 2009:258). The Lacandones had surprisingly good knowledge of the roles played by different tree species in fertility regeneration and restoration. It is the use of these plants that is essential to achieve the forest's effective regeneration. Surprisingly, they include balsa, a commercial species with the lowest density (*Ochroma pyramidale* Urban), for which southern Mexico is its northern-most habitat. However the species does not grow as large as in Ecuador, for example.

U'cunte (*Sapium laterifolum*), a successional tree managed by the Lacandon Maya, serves as a phosphorus pump, bringing this limiting nutrient from deep soil through leaf litter (Diemont *et al.* 2006, quoted in Nigh and Diemont 2013).

Lacandon descriptions of plant community succession are comparable to the understanding of succession that is current among neotropical forest ecologists (Guariguata and Ostertag 2001); however, the Lacandon successional classifications likely predated Western science (Diemont and Martin 2009:256).

3.4.3 The northern Lacandones of Naha' and Mensäbäk

Thre linguist and ethnobotanist Suzanne Cook (2016:37) described agricultural methods in Naha' located between 16° 56' 41'' and 17° 00' 42'' N and between 91 °32' 52'' and 91° 37' 43'' W The elevation ranges between 910-1100 m. Kashanipour and McGee (2004:49):

> Naha' is approximately 50 km west of the Usumacinta River, which forms the border between Mexico and Guatemala, and 55 km east of the regional capital Ocosing lacks the 60 m upper canopy that is typical of tropical rainforest. The elevation of the community is 825 m and lies in an ecosystem of montane rainforest that that lacks the 6o m upper canopy that is typical of the tropical rainforest. They grow coffee as a cash crop, which is not feasible in Lacanja. The "jungles" around Naha' have been severely deforested as logging companies have removed valuable species and new communities have converted forest into cattle pasture.

The northern Lacandones differentiate four successional stages: (1) *lo'obil*, characterised by grasses and other herbaceous plants; (2) *mehen che'*, characterised by small bushes and trees; (3) *nukuch che'*, characterised by mature, fast growing evergreen trees; and (4) *taman che'* "dense forest", comprised of large deciduous trees (Cook 2016:37).

> An additional phase, *jurup che*, has been identified in the extant Lacandon agro-forestry literature. It is described as a transition from *mehen che'* to *jurup che*, wherein the short-lived, dominant canopy trees are replaced by intermediate to long-lived secondary species (Nigh 2008:237). Only one Lacandon whom Cook interviewed was familiar with this term. He described it as a fallow milpa with small trees clear of undergrowth where the soil beneath is soft and fertile. Among the species found in this succession are *bits'* *(Inga* spp.); *hach taw* (*Belotia mexicana); che'il chäk'an* "savannah tree", e.g. *Vernonathura patens; tsaah (Cnidoscolus multilobus*); and, *halol (Heliocarpus* spp.). Cook lists all the dominant *jurup che* species, mainly reported also in Nigh (2008:239, quoted in Cook 2016:37), with some small linguistic differences (see Table 3.9).

Table 3.9 Trees most commonly found by ecologists in *jurup che* phase of Lacandon succession. (After Nigh 2008:239, quoted in Cook 2016:39).

Lacandon name	English	Botanical name
chäklah	Gumbo limbo	*Bursera simaruba*
k'o'och	Pumpwood	*Cecropia* spp.
säk halol	White majagua	*Heliocarpus donnel-smithii*
bits'	Ice cream bean	*Inga* spp.
ya'ax balche'	Lancepod	*Lonchocarpus* spp.
(chuhum)	Balsa tree	*Ochroma pyramidale*
mäkuuläm	Jamaican pepper, matico	*Piper aduncum, P.hispidum*
hoben	Mexican pepperleaf	*Piper* spp.
nukuch le' *si'si'k'uuts*	American burnweed	*Erechtites hieracifolia*
huhup	Hog plum	*Spondias* sp.

The selva Lacandona is regenerated and can be harvested for use. The Maya forest garden cycle creates valuable woodlands with managed succession; looking for test trees.

3.4.4 El Pilar

Anabel Ford (2015) of the University of California, Santa Barbara, used **El Pilar** area, an ancient Maya city centre and archaeological site on the present-day border of Cayo District, Belize and Peten, Guatemala as the basis for testing the potential of the *milpa forest garden cycle*. The *forest garden* is part of the traditional Maya land management system known as the *milpa forest garden cycle*, or simply the *milpa cycle*, to sustain the ancient Maya at the height of the Late Classic period. She has led a successful campaign to draw attention to El Pilar through projects that we already know. Let us repeat that a *forest garden* is an unploughed, tree-dominated agricultural field that is cultivated year-round. Requiring skill and knowledge to nurture, it sustains biodiversity and animal habitat while producing plants to meet a diverse array of human needs, like food, shelter, and medicine. It is almost entirely maintained with local resources, such as household refuse (compost) and organic material without the chemically manufactured additives like pesticides or fertilisers.

The *milpa cycle* is the conservation method of farming and managing the Maya forest. Generally it goes through four main stages over the course of approximately 20 years: (1) from the forest to the *milpa*; (2) from the *milpa* to the *forest garden;* (3) from the *forest garden* back to the forest; and (*4*) *forest regeneration.*

The *traditional milpa* and *forest garden* is an unploughed, multi-crop field that sustains biodiversity and animal habitats while producing plants for food, spice, shelter, medicine, ornament and profit. It can be fertilised by household refuse (compost), organic material (dead weeds), ashes from kitchen fires, and manure, enriching the soil and increasing its fertility (The El Pilar Forest Garden Network 2007-2011).

Table 3.10 *The milpa cycle* (The El Pilar Forest Garden Network 2007-2011)

Stage 1: From the Forest to the Milpa	In the first stage of the milpa, a piece of forest is cleared of trees, and then burned to prepare for planting. For the first two to three years the Mesoamerican trilogy of maize, beans, and squash are cultivated in the full sun. Amidst this low canopy of maize is a dynamic ecology of herbs, tubers, and other plants that we might consider weeds, but are actually cultivated by the forest gardener to detract pests from the main crops, enhance the soil with nutrients, and help maintain moisture in the ground.
Stage 2: From the Milpa to the Forest Garden	In the second stage, the milpa evolves into the forest garden. Quick-yielding fruit trees, like plantain, banana, and papaya, are planted and begin to produce within a year. Fruit trees that need more time to produce, such as avocado, mango, citrus, allspice, guava, cherimoya, ramón, and others are planted amidst the maize, beans, and squash to bear fruit in five years.
Stage 3: From the Forest Garden to the Forest	In the third stage, the fruit trees mature and begin to produce. The fruit trees provide a new canopy, blocking the sun and inhibiting undergrowth. Maize, beans, and squash are no longer viable in the shade. Amidst the fruit tree canopy, hardwoods, such as cedar and mahogany, are planted to mature over the next decades.
Stage 4: Forest Regeneration	In stage four of the milpa cycle; the forest garden is transformed into a hardwood forest. The hardwoods rise above the fruit trees to create a high canopy. The milpa has now regenerated to look much like it did before the forest gardener cleared and burned it two decades earlier. It is now a managed forest with little to no undergrowth. The forest gardener will let the hardwood trees grow and mature. The trees can be harvested for personal use or sold, then the gardener again clears, burns, and plants the field. The cycle of the milpa begins again...

Table 3.11 shows the dominant plants of the MFGC from Greater Peten. The list of taxa in each stage of the MC is based on observation by Ford and Nigh in Mexico, Guatemala and Belize (see also Hernandez *et al*. 1995:242-246; Teran *et al*. 1998). The dominant taxa of the closed canopy are from Campbell *et al*. (2006).

As we already know, the secondary succession starts with the intensive food-producing herbs dominated by the famous milpa "trilogy": *Zea mays*, *Cucurbita* spp. and *Phaseolus* spp, followed with more and more woody plants and ending in the closed canopy of hardwoods.

Various stages of the MFGC – felling of mature test trees

One last look at the selva through the arches of the Palace at Palenque.

Opulence in the selva.

Table 3.11 Dominant Plants of the MFGC from the Greater Peten. Only native taxa included, bolded taxa wind-pollinated (Campbell *et al.* 2006, quoted in Ford and Nigh 2015:45, cf. also Ford and Nigh 2009:217). Investigated tree species underlined.

Milpa Cycle	**Dominant Plants** (Wind-pollinated spp. indicated in bold)
Open multi-crop maize field favouring sun **Phase 1 initialisation** (1-4 yrs) [In Ford and Nigh (2009:217) Open milpa: Stages 1-2 (1-4 yrs; 4-7 yrs)]	Cultigens: ~99 spp. Such as *Capsicum* spp, ***Chenopodium ambrosioides* L.**, Cnidoscolus spp., Cucurbita spp., ***Lycopersicon esculentum* Mill.**, *Phaseolus* spp., Xanthosoma *yucatense* Engl., ***Zea mays* L.** Several other genera found in Leguminosae Non-cultigens*:* ***Ambrosia* spp., *Cecropia* sp., *Mimosa* sp., *Trema* sp., and several genera found in: Amaranthaceae, Asteraceae, Cyperaceae,** Euphorbiaceae, Melastomataceae Poaceae, Urticaceae.
Long-lived perennial reforestation ~producing shade **Phase 2** **renewal cycle** (4-12 yrs) [In Ford and Nigh (2009:217) Long lived perennials: Stages 3-4 (7-15 yrs; 15.30 yrs)]	*Acacia cornigera* L. Wild., *Ananas comosus* L., Merr., *Annona mricata* L., *Attalea cohune* C. ***Brosimum alicastrum* Sw.**, *Bucida buceras* L., *Cucurbita pepo* L., ***Bursera simarouba* L.,** *Byrsonima crassifolia* L. Kunth, *Calopyllum brasiliense* Cambess, Carica papaya L., ***Cecropia peltata* L.**, *Ceiba pentandra* L., *Cnidoscolus chayamansa* McVaugh, *Enterolobium cyclocyrpum* JacQ. Griesb., *Guarea glabra* Vahl., *Guazuma ulmifolia* Lam., *Hamelia patens* Jacq., *Manihot esculenta* Crant, *Manilkara zapota* L. van Royen, *Opuntia cochenillifera* L. P. Mill., Pachyrhizuz erosus L., *Persea americana* P. Mill., *Pimenta dioica* L. Merr., *Pouteria sapota* Jacq, Moore & Stearn, *Psidium guajava* L., ***Quercus oleoides* Schitdl., & Cham.,** *Sabal morrisiana* Bartlett, *Simira salvadorensis* Standl., *Talisia oliviformis* Radlk.
Closed canopy ~favouring shade **Phase 3** **culmination** (>12 yrs) [In Ford and Nigh (2009:217) Closed Canopy: Stage 5 (>30 yrs)	*Alseis yucatanensis* Standley, *Aspidosperma cruentum* Woodson, *Attalea cohune* C. Mart., *Brosimum alicastrum* Sw., *Bursera simarouba* L., *Crysophyla stauracantha* Heynh. R. Evans., *Licania platypus* Hemsley Fritsch, *Lonchocarpus castilloi* Standley, *Manilkara zapota* L. van Royen, *Piscidia piscipula* L. Sarg., *Pouteria campechiana* Kunth Baehni, *Pouteria reticulata* Engl., *Sabal morrisiana* Bartlett, *Simira salvadorensis* Standl., *Spondias mombin* L., *Swietenia macrophylla* King, *Talisia oliviforms* Radlk., *Vitex gaumeri* Greenman., *Zuelania guidonia* Britton & Millsp.

It is clear that in the final phase it is the main tree species of the Maya forest that predominate. We studied most of them in the course of our research.

The Maya milpa entails a rotation of annual crops with a series of managed and enriched intermediate stages of short- and long-term perennial shrubs and trees and culminates in the reestablishment of long-lived mature canopy trees on the once-cultivated parcel. The integration of milpa cycle into the forest transformed the succession of plants and turned the Maya forest into a garden where more than 90% of dominant trees have benefits for humans (Campbell *et al.* 2006, quoted in Ford and Nigh 2015:43).

3.4.5 Calakmul, Campeche

Acopa and Boege (1998) describe the situation in the Maya forest in Campeche:

> The Reserve and the contiguous forested areas of the Maya Biosphere Reserve *(Reserva de la Biosfera Maya)* in the Guatemalan department of El Petén form one of the largest and least disturbed tracts of rainforest in the Americas north of Colombia (Calakmul Biosphere Reserve 2017). In Calakmul, the following sequences has been developed ("forest garden"): in the first year slash-and-burn agriculture for the production of corn is followed by the planting of fruit trees with medium-term maturation period and timber trees for longer-term cycles. The corn, other basic grains, and subsistence crops can continue to be planted on the same plot until the fifth year. In the third and fourth years, he fruit trees will start production. As the timber trees mature, the terrain begins to look more like a forest. Under this kind of regimen, growth rates are greater than those of natural regeneration, so logging of some trees is possible after 25 years. Under these plantation conditions, it is possible to cut cedar and mahogany trees with smaller diameters than allowable in natural forests.
>
> The concept is very attractive, and in Calakmul the initial experimental plots seem to be working according to he concept. The first agroforestry plots established around Calakmul are beginning to produce citrus fruits, which are being sold in local markets. Ejido nurseries are also being established that encourage the cultivation of indigenous fruit-bearing trees. These include zapote mamey *(Pouteria* zapota), black zapote (*Diospyros digyna*), chicozapote (*Manilkara zapota*), and huaya *(Talisia olivaeformis).*Improving their genetic quality and management is this program's current challenge. New planting areas must also be sought, since fruit trees will cease to flourish once the forest canopy begins to close.

3.4.6 Comparison

Recently Diemont *et al.* (2011) studied the agroforestry system of five distinct Mayan ethnic and compared them. Mayan groups in Southern Mexico and Central America continue to rely upon forested areas as integral components of their agricultural systems. They carefully manage these areas so that forests provide food, raw materials, and animals. Management practices include removing and planting of woody and herbaceous species, apiculture, and seed harvest. They believe that indigenous Mayan agroforestry could be a part of regional forest conservation and restoration (from the abstract of Diemont *et al.* 2011):

Table 3.12 System Components of Lacandon, Yucatec, Mopan and Tsotsil Maya (Diemont *et al.* 2011, p.1698), *NP, not present

Community	Ethnic group	Field polyculture (species)	Coffee	Cacao	Ranching	Number of shrub stages	Number of forest stages	Use of fire for clearing
20 de Noviembre	Yucatec Maya	10-15	NP*	NP	NP	1	2	x
Nuevo Becal	Yucatec / Tsotsil Maya	10-15	NP	NP	Few residents	1	2	x
Santa Elena	Mopan Maya	5-10	NP	Shade NP	NP	2	4	x
Santo Domingo	Tsotsil Maya	10-15	Shade	NP	Half residents	1	2	-
Lacanja Chansayab	Lacandon Maya	20-60	NP	P	NP	2	3	x

Although these systems rely upon different woody species and management techniques, common among them are: (1) the use of multi-stage and successional pathways with the forest as a part of the larger system; (2) species that are believed by traditional ecological knowledge (TEK) to accelerate forest regeneration – more than 30 tree species are recognised and managed as potential facilitators of forest regeneration; and (3) direct human consumption of forest products at all stages of regeneration (Diemont *et al*., 2011:1698).

Time and again we can admire Mayan knowledge of the role of trees in soil improvement in the process of secondary succession.

Table 3.13 Plant species used by the Yucatec Maya, Yucatec/Tsotsil Maya, Mopan Maya, Tsotsil Maya and Lacandon Maya to accelerate soil and plant community succession (Diemont *et al.* 2011:1698; (cf. also Ford and Nigh 2015:62). Species investigated underlined.

Community	Ethnic group	Plant species used for restoration
20 de Noviembre Campeche	Yucatec Maya	*Cedrela odorata* *Hampea trilobata* *Pimenta dioica* *Swietenia macriphylla*
Nuevo Becal Campeche	Yucatec Maya Tsotsil Maya	*Brosimum alicastrum* *Bursera simaruba* *Cedrela odorata* *Lonchocarpus castilloi* *Piscidia piscipula* *Swietenia macrophylla*
Santa Elena Toledo District, Belize	Mopan Maya	*Brosimum alicastrum* *Innga spp. (7 species)* *Ximenia americana* Unidentified (*pu pu te* in Mopan Maya)
Santo Domingo Las Palmas Chiapas	Tsotsil Maya	*Cecropia obtusifolia* *Cedrela odorata* *Croto draco* *Inga paterna* *Inga pavoniana* *Inga puncgata* *Schizolobium parachybum*
Lacanja Chansayab, Chiapas (Diemont *et al.* 2006)	Lacandon Maya	*Astrocaryum mexicaum* *Belotia maxicana* *Brosimum sp.* *Bucida buceras* *Calophyllum brasiliense* *Cedrela* sp. *Cordia alliodora* *Dialium guianense* *Guatteria anomala* Hampea stipitata *Hibiscus* sp. *Mucuna pruriens* *Ochroma pyramidale* *Piper auritum* *Piper aduncum* *Sapium lateriflorum* *Simira salvadorensis* *Sterculia apetala* *Swietenia macrphylla* Undentified (*pok te* in Lacandon Maya)

PART TWO

NIF, Mexico City

Searching for test trees.

Selva Lacandona, felling of test trees.

4. Maya Timbers

This chapter represents a compilation of the following original articles and reports:

Torelli N (investigador principal) y Salvador Vasques Reta (coordinador general) 1982. Estudio Promocional de 43 Especies Tropicales Forestales Mexicanas. Programa de Cooperacion Cientifica y Tecnica Mexico-Yugoslavia. Secretaria de Agricultura y Recursos hidrauicos. Subsecretaria Forestal y de la Fauna Mexico. Universidad Ljubljana, Facultad de Biotechnica, Ljubljana, Yugoslavia. 73 p.

Torelli N (investigador principal) y Eliseo Peralta P. (coordinador general) 1983. Estudio Promocional de 43 Especies Tropicales Forestales Mexicanas. (Reporte Tecnico) . Programa de Cooperacion Cientifica y Tecnica Mexico-Yugoslavia. 692 p.

Torelli N and Čufar K. 1983. Sorpcija in stabilnost lesa. Les/Wood. 35 (5-6):191-114.

Torelli N, Čufar K, Uršič J, Cunder P. 1984. Anatomske, fizikalne in nekatere kemične lastnosti 43 manj znanih oz. neznanih mehiških tropskih lesnih vrst. Univerza Edvarda Kardelja, VDO Biotehniška fakulteta, VTOZD za Lesarstvo, Ljubljana

Torelli N. 1985. A brief technological assessment of two typical forest areas in tropical Mexico and prospects for their rational utilization. IX. World For. Congr. Mexico. 12p.

Torelli N. 1988. Recursos forestales y suministro de madera. In: Programa de Action Forestal Tropical Mexico. Informe de la mision FAO. Borrador. Mexico, D.F. 1988.

Torelli N. 1994 Characteristics and prospects for rational use (harvesting) of Mexican tropical forest, *Holz Roh- Werkstoff* 52:337-341.

Torelli N and Čufar K. 1994. Comparative decay resistance of 43 Mexican tropical hardwoods, *Holz Roh- Werkstoff* 52:394-396.

Torelli N and Čufar K. 1995. Mexican tropical Hardwoods. Comparative study of ash and silica content, *Holz Roh-Werkstoff* 53:61-62.

Torelli N and Čufar K. 1995. Mexican tropical Hardwoods. pH-value«, *Holz Roh-Werkstoff* 53: 133-134.

Torelli N and Gorišek Ž. 1995a. Mexican tropical Hardwoods. Stepweise shrinkage and transverse shrinkage anisotropy«, *Holz Roh-Werkstoff* 53:155-157.

Torelli N and Gorišek Ž.1995b. Mexican tropical Hardwoods. Dimensional stability«, *Holz Roh-Werkstoff* 53:277-285.

Torelli N and Gorišek Ž. 1995 Mexican tropical Hardwoods. Seasoning characteristics and recommended drying schedules«, *Holz Roh-Werkstoff* 53:355-356.

Torelli N and Gorišek Ž. 1995. Mexican tropical Hardwoods. Mechanical properties in green condition«, *Holz Roh-Werkstoff* 53:421-423.

Torelli N and Čufar K.1996. Mexican tropical Hardwoods. Machinability, nailing and screwing, *Holz Roh-Werkstoff* 54:69-71.

Torelli N. 1996. Mexican tropical hardwoods. Attempt to end-use grouping, *Holz Roh- Werkstoff* 54: 213-216.

Torelli N. 2006. Mahagonij (*Swietenia* spp.) – naravna in kultura zgodovina. *Gozdarski Vestnik* 64(5-6):246-252, 269-278.

I also wish to mention our capable and irreplaceable coworkers, advisors and reviewers.

4.1 Wood species investigated

Table 4.1. Wood species investigated in the alphabetic order of scientific names

NO.	SPECIES	SCIENTIFIC NAME AT THE TIME OF REPORT	FAMILY	COMMON NAME	LACANDON NAME
1	*Acosmium panamense* (Benth.) Yakovlev	Sweetia panamensis Benth.	Fabaceae	Chakté	muxan che'
2	*Alchornea latifolia* Sw.		Euphorbiaceae	Cotón de caribe	luwin
3	*Ampelocera hottlei* (Standl.) Standl.		Cannabaceae	Luín	sayok (ah)
4	*Aspidosperma megalocarpon* Muell. Arg.		Apocynaceae	Bayo	
5	*Balizia leucocalyx* (Britton & Rose) Barneby & J.W.	Pithecellobium leucocalyx (Britton & Rose) Standl.	Fabaceae	Guacibán	säkyuuhche' (äh)
6	*Blepharidium guatemalense* Standl.	Blepharidium mexicanum Standl.	Rubiaceae	Popiste	hach 'oox, k'än 'oox, ya'ax 'oox
7	*Brosimum alicastrum* Sw.		Moraceae	Ramón	chäklah
8	*Bursera simaruba* (L.) Sarg.		Burseraceae	Palo mulato	babah
9	*Calophyllum brasiliense* Camb.		Calophyllaceae	Barí	
10	*Cojoba arborea* (L.) Britton & Rose	Pithecellobium arboreum (L.) Urban; Mimosa arborea L.	Fabaceae	Frijolillo	bahun che'
11	*Cordia alliodora* (Ruiz & Pav.) Oken		Boraginaceae	Bojón	ton ku'uk
12	*Cymbopetalum penduliflorum* (Sessé & Moç. ex Dunal) Baill.		Annonaceae	Orejuelo	sasakche'
13	*Dendropanax arboreus* (L.) Decne. & Planch.		Araliaceae	Sac-chacáh	wäch'
14	*Dialium guianense* (Aubl.) Sandwith.		Fabaceae	Guapaque	säk bahche'
15	*Guarea glabra* Vahl		Meliaceae	Cedrillo	ek 'bahche'
16	*Guatteria anomala* R. E. Fr.		Annonaceae	Zopo	
17	*Licaria peckii* (I. M. Johnston) Kosterm.	Misanteca peckii I.M. Jonsht	Lauraceae	Pimientillo	hach balche'
18	*Lonchocarpus castilloi* Standl.		Fabaceae	Machiche	balche', ya'ax balche'
19	*Lonchocarpus hondurensis* Benth.		Fabaceae	Palo gusano	kuti' kuti'il wits
20	*Magnolia mexicana* DC.	Talauma mexicana (DC.) G.Don	Magnoliaceae	Jolmashté	chäk ya', hach ya', ya'
21	*Manilkara zapota* (L.) P. Royen		Sapotaceae	Chicozapote	mehen 'oonte', nukuch 'oonte'

NO.	SPECIES	SCIENTIFIC NAME AT THE TIME OF REPORT	FAMILY	COMMON NAME	LACANDON NAME
22	*Nectandra sp.*		Lauraceae	Laurel	kubuh (äh)
23	*Pachira aquatica* Aubl.		Malvaceae	Palo de agua	säk chulul (äh)
24	*Platymiscium yucatanum* Standl.		Fabaceae	Chulul	ak' hu'un
25	*Poulsenia armata* (Miq.) Standl.		Moraceae	Masamorro	ch'ulte'
26	*Pseudobombax ellipticum* (Kunth) Dugand		Malvaceae	Amapola	hach bamax, tso'ots bamax
27	*Pseudolmedia glabrata* (Liebm.) C.C.Berg	Pseudolmedia oxyphyllaria J. D. Smith	Moraceae	Mamba	
28	*Pterocarpus rohrii* Vahl	Pterocarpus hayesii Hemsl.	Fabaceae	Palo de sangre	
29	*Quercus acutifolia* Née	Quercus anglohondurensis C. H. Mull.	Fagaceae	Chiquinib de montaña	pixan k'ambul (äh)
30	*Quercus skinneri* Benth.		Fagaceae	Cololté	pets'k'in
31	*Schizolobium parahyba* (Vell.) S.F.Blake	Schizolobium parahybum (Vell.) Blake	Fabaceae	Palo de picho	
32	*Sebastiania tuerckheimiana* (Pax & K.Hoffm.) Lundell	Sebastiania longicuspis Standl.	Euphorbiaceae	Chechen blanco	subul
33	*Sideroxylon stevensonii* (Standl.) Standl. & Steyerm.	Dipholis stevensonii Standl.	Sapotaceae	Guaité	
34	*Simarouba glauca* DC.		Simaroubaceae	Pasa'ak	
35	*Simira salvadorensis* (Standl.) Steyerm.	Sickingia salvadorensis (Standl.) Standl.	Rubiaceae	Chacahuanté	k'inim
36	*Spondias mombin* Jacq.	Spondias mombin L.	Anacardiaceae	Jobo	
37	*Swartzia cubensis* (Britton & Wilson)Standl.		Fabaceae	Corazón azul	puuna' (äh)
38	*Swietenia macrophylla* G. King		Meliaceae	Caoba	k'änxa'an, pukte'
39	*Terminalia amazonica* (J.F.Gmel.) Exell		Combretaceae	Canshán	
40	*Vatairea lundellii* (Standl.)Record		Fabaceae	Tinco	
41	*Vitex gaumeri* Greenm.		Lamiaceae	Ya'axnik	
42	*Vochysia guatemalensis* J. D. Smith	Vochysia hondurensis Sprague	Vochysiaceae	Maca blanca	
43	*Zuelania guidonia* (Sw.) Britton & Millspaugh		Salicaceae	Trementino	

Selva Lacandona, felling of test trees.

Selva Lacandona, preparing and marking test logs.

Selva Lacandona, preparing and marking test logs.

4.2 Sampling

The study and sampling area extended in the Selva Lacandona from the Rio Chancala (228 m) to the communities of Naha' and Mensäbäk (see Map 2). Naha', (Najá) at an elevation between 910 and 1100 m, overlooks Laguna Naja. Mensäbäk at an elevation between 470 m and 920 m is located by the lake of the same name. *Quercus skinneri* and *Q. anglohondurensis* were sampled higher in the mountains in the Pine-Oak-*Liquidambar* forest formation in the Ejido Zaragoza.

The climate is classified as a warm and humid thermal tropical zone, or Aw2(w) (i') g. under the Köppen climatic classification system. The monthly average temperature is 23.6 ^{0}C. The rainy season extends from May to December.

Lower montane rain forest (Selva alta perennifolia) is the predominant formation, while montane rain forest occurs on the moist, cool upland slopes. Total annual rainfall is between 2.000 and 3.000 mm. Large areas have been extensively transformed by settlers, and timber and oil companies, creating a patchwork of secondary forests, cultivated fields, and acahuales (fallow fields) in various stages of secondary groswth. (cf. Cook 2016: 14; Ford and Nigh 2015: 24, 25).

Fortunately, our American and Guatemalian colleagues (Kukachka 1968), conducted a similar informative research study in the neighbouring El Peten in Guatemala, mainly on the same wood species based on one exemplar per species. By combining both results it is possible to achieve a sufficient accuracy range of mean values at 95% confidence interval for practical purpose (± 15%, Noack 1971) for those tests which were conducted in both projects (basic density, modulus of rupture and elasticity, crushing strenght, Janka hardenss, stepwise shrinkage and silica content).

We sampled our test trees exclusively in the more or less degraded secondary forests outside protected areas. In most cases three randomly selected test trees authenticated by herbarium material were felled. The sampling procedure based on the assumption that the variations of properties between the trees are more significant than the variation within trees, "so that a far greater precision of the mean values is obtained by taking more trees and fewer pieces from each tree" (cf. Noack 1971).

From each randomly selected tree, authenticated by herbarium material (on deposit at the C.E.P. »San Felipe Bacalar« Quintana Roo, I.N.I.F.), two test pieces of biologically sound wood, without any visible defects, with a length of about 60 cm, and cross-sectional dimensions of about 20 x 12 cm, were taken. During felling operations in Selva Lacadona the samples were carefully stored in a special shed in Chancalá, free of contact with the soil and sprinkled regulary with water to prevent drying and biological deterioration. After three weeks (i.e., at the end of sampling) all test material was transported to Mexico City in perfect biological condition where mechanical properties in the green condition were tested at the *Instituto Nacional de Investigaciones Forestales* (INIF).

About 1 kg of wood of each selected tree species was transported to University of Ljubljana where additional investigations were conducted (shrinkage, sorption properties, dimensional stability, pH, ash and silica content, natural durability). (For gratis aerial transport we are deeply indebted to *Lufthansa*).

4.3 Test methods

4.3.1 Density

In our study we use the basic density

$$\rho_b = \frac{\text{Oven-dry mass of wood}}{\text{Volume of wood when green}}$$

The term »basic« emphasises that both parameters measured, the oven-dry mass and the swollen (»green«) volumen, have constant and reproducible values. Basic density is the most useful descriptor of wood density (Walker 1993:73).

4.3.2 Mechanical properties in green condition

All strength properties – were tested in accordance with the British Standard No 373: 1957 (static bending, compression parallel to grain, hardness) and DIN 52 189-1952 (single blow impact test) in green condition. Here it should be mentioned that testing mechanical properties of green material is sufficient for practical purposes since relatively strong correlations exist between values in the green- and air-dry condition (cf. Noack 1971). In this way it was possible to accelerate and reduce costs of our investigations.

Determining basic density at INIF.

Peter carefully marking test flitches.

Author, testing mechanical properties at INIF.

Triplay de Palenque and MIQRO Chetumal, preparing test logs for peeling and slicing.

Triplay de Palenque and MIQRO Chetumal, preparing test logs for peeling and slicing

4.3.3 Slicing, peeling and plywood

Test logs were prepared and tested in Triplay Palenque, Chiapas (peeling) and MIQRO Chetumal, Quintana Roo (slicing). Generally, there here are three methods of producing veneer: (a) rotary cutting (peeling), (b) slicing, and (very rarely) sawing. Figured veneers for decorative purposes are usually cut from selected flitches in a slicer. The visual characteristics that determine the value of a particular veneers relate to figure and colour of the wood and the manner in which the logs are sliced. For instance, species with interlocked grain are best quarter sliced. For plywood manufacturer, however, veneer must be produced by rotary cutting in a lathe.

In the present study, we performed touch probing to determine the suitability of tree species for slicing on 17 species and for peeling and plywood manufacture on 14 species. When choosing the test material, we took into account wood density, diameter, trunk shape (peeling) and decorative features (slicing).

Slicing, assessment of relevant properties:

Heating temperature

Flich degrade due to thermal treatment:

1 none, 2 moderate, 3 severe

Ease of cutting:

1 easy to cut, 2 moderately easy to cut, 3 difficult to cut

Drying degrade:

1 without checking and wrinkling, 2 some/little wrinkling and checking, 3 pronounced tendency to checking and wrinkling

Finishing quality:

1 good, 2 satisfactory, 3 unsatisfactory

Peeling and plywood, assessment of relevant properties:

Heating temperature

Log degrade due to thermal treatment:

1 none, 2 moderate, 3 severe

Ease of peeling: 1 easy to peel, 2 moderately easy to peel, 3 difficult to peel

Drying degrade:

1 without checking and wrinkling, 2 some/little wrinkling and checking, 3 pronounced tendeny to cklecking and wrinkling

Gluing: 1 good, 2 satisfactory, 3 unsatisfactory

Mechanical properties of plywood:

1 satisfactory, 2 unsatisfactory

4.3.4. Movement: Dimensional stability

The following stability characteristics — valid for the "quasi-linear area" — were measured (DIN 52 184, May 1979, cf. Noack *et al*. 1973):

$q = l_W - l_D / l_0 \ (u_W - u_D)$ 100 in % per %

$h = l_W - l_D / l_0 \ (\varphi_W - \phi_D)$ 100 in % per %

φ_W and φ_D: relative air humidity in the wet and dry climate

u_w and u_D: EMC of the wood in the wet and dry climate

l_W and l_D: length in the wet and dry climate after reaching the equilibrium condition

l_0: length in the oven-dry condition

a) the **differential swelling (ratio of swelling) symbol q**, which indicates the percentage change of tangential and radial dimensions resp. when the wood MC changes by 1% with the following valuation scale:

q_T	q_T-q_R	q_T/q_R	Swelling behaviour
>0.4	>0.2	>2.0	unfavorable
0.3-0.4	0.12-0.2	1.6-2.0	normal
<0.3	<0.12	<1.6	favorable

b) the **swelling coefficient *h*,** showing the percentage change of lateral dimensions when the RH changes by 1% :

h_T	h_T-h_R	h_T/h_R	Swelling behaviour
>0.08	>0.04	>2.0	unfavorable
0.06-0.08	0.025-0.04	1.6-2.0	normal
<0.06	0.015-0.025	<1.6	favorable
(<0.03)	(<0.015)	(<1.3)	very favorable

Chancala, air-drying experiment: stacking the boards by means of distance stickers and end coating.

Chancala, air-drying experiment: stacking the boards by means of distance stickers and end coating.

Chancala, air-drying of caoba bords in the open air.

Chancala, air-drying experiment.

c) the **sorption coefficient *s*** (ratio of sorption) *s*, denoting the amount by which the EMC will change when the RH changes by 1%:

Sorption coefficient s	Sorption behaviour
>0.22	unfavorable
0.18-0.22	normal
0.16-0.18	favorable
<0.16	very favorable

d) the **"total" (t_{eq}) and "half" ($t_{eq0.5}$) equilibrating time**, e.g. time for wood to equilibrate between EMC at 80% RH and at 65% RH in the initial desorption (Schwab 1978).

For this purpose, special samples (2.5 cm tang. x 3.0 cm x 3.0 cm) were used whose radial and transversal planes were air-proof sealed in order to provide solely the unidirectional, i.e. radial movement of moisture. The mass of each sample was measured every two days until moisture equilibrium was attained. Drying rates were expressed as E-values over time, where the dimensionless variable E is the fraction of evaporable water remaining in the specimen at any given time t. E is calculated from the equation

$$E = \frac{(w - c_1)}{(c_0 - c_1)}$$

where w is the MC of the specimen and time t, c_1 is the EMC for the drying conditions used, i.e. for the RH = 65% and c0 is the original MC of the specimen.

$$m(t) = Ae^{(-Bt)} + C$$

Approximations were calculated using the formula

$$E\,(t_{0.5}) = \frac{0.693}{B}$$

which gave correlation coefficients greater than 0.98. The time at which half of the evaporable bound water (with respect to EMC) is evaporated was named "half-time" (in analogy with "half-life" in nuclear physics.)

"Adjusting time" was defined as that time when the mass of the sample changed less than 0.1% in 24 hours. It is expressed as

$$t_A = \frac{1}{B}\ ln\,(10^n\,(1 - e^{-B})).$$

The swelling and sorption behaviour was rated according to a scheme which differs slightly from those quoted by Noack *et al.* (1973).

4.3.5 Air-drying characteristics

The following tests were conducted:

a) determination of air-seasoning time, separately for tangential and radial boards and seasoning degrade,
b) assessment of the inherent tendency to warp,
c) drying of wood blocks in the ventilated laboratory dryer at 103±2 °C in order to assess the inherent tendency to collapse, case-hardening and honeycombing, and
d) determination of time for wood to equilibrate between two EMC as an expression for overall ease with which diffusion occurs.

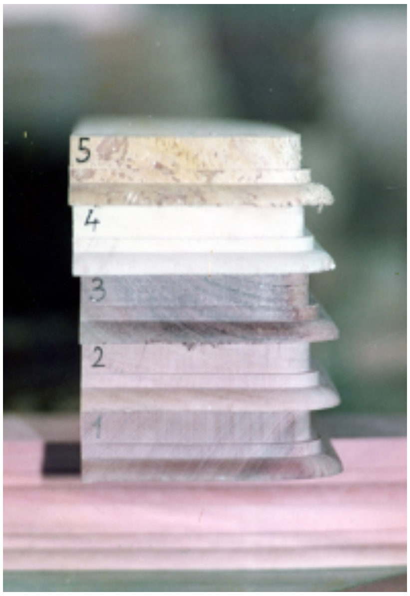
Sample material originated in one "representative" test tree per species and consisted of:

e) 15 radial and tangential boards 2.5 m long and ca. 3 cm thick,
f) 4 tangential boards 1.2 m long, 15 cm wide and ca. 3 cm thick; for geometrical reasons they were cut in the same radial distance from the tree center,
g) 4 radial blocks 20 cm long and 3 cm thick. Samples for (d) are described in Torelli and Gorisek (1995b).

After drying, boards were inspected for the presence and severity of warping and checking that had developed during seasoning. Warp was separated into cup, twist, bow, and crook. Checks were differentiated/separated into end and surface checks. Generally, measurement of drying defects was carried out in essential the same manner as employed by Longwood (1961) in his study on Puerto Rican woods.

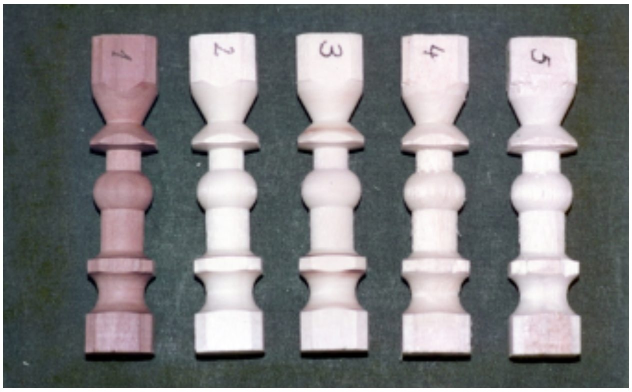
After analysing drying characteristics, drying schedules based on/developed from drying gradient (Dg), maximal, drying temperature above FSP (T1) and maximal drying temperature below FSP (T2) were proposed.

Drying schedules were successfully verified in practical tests using semiautomatized kilns.



Turning showing the range in quality of work.

Preparing machinability samples.



Preparing machinability samples.

Chancala, conservation - wetting of wood samples for pathological tests preceding long transporting to INIF Mexico City and further to Ljubljana.

4.3.6 Silica and ash content, pH value

Samples for ash and silica content determination were taken from the periferial part of the heartwood when present or from stem perifery in species without coloured heartwood.

A photometric method with ammonium molybdate was used and percentage of ash and silica based on oven-dry weight determined.

In heartwood species two samples of each tree were taken: one from sapwood and one from heartwood. In trees without heartwood or in species with discoloured heartwood, only one sample per test tree was taken.

For the approximate determination of pH-value 2 g of wood in 20 ml of distilled water was taken. The water was fresh, twice distilled with pH above 6.3. The vessel was sealed with a ground stopper and strongly agitated at the beginning, after 5 and after 10 minutes. After 15 minutes the pH was measured using a combined glass electrode (after 1 minute immersion). This gave an approximate determined pH-value. To get a more accurate value, the procedure was repeated, using new wood samples and doubly distilled water with pH slightly above and below the approximate determined pH-value. This was repeated, decreasing the pH interval of the distilled water, until the measured pH interval of the distilled water, was the same as that of the distilled water used.

4.3.7 Machining and related properties

Tests were performed in the INIF (Instituto Nacional de Investigaciones Forestales) Experimental Station, San Martinito (Mexico) with materials previously employed in air seasoning tests.

For tests flat-grained, air-dry lumber free of knots and seasoning defects originating from one "typical" test tree was used. Ten sample boards of each species, large enough to yield the minimum acceptable size (2.0 x 12.5 x 120.0 cm) and surfaced smoothly on two sides, were selected at random and cut into specimens for machining and related tests.

The machinability tests were performed according to ANSI/ASTM D 1666-64. The planing quality was determined with three cutting angles (30°, 20°, 15°), each with two feed velocities by using the thicknessing planer. The cutter-head holding two carbide-tipped knifes revolved at 4312 r.p.m. The depth of cut was 1.5 mm. To determine the quality of shaping, the hand-feed spindle sharper with one spindle, operating at 6000 r.p.m., with carbide-tipped cutter as prescribed according to standard, was used. Turnings were made on a hand lathe, at 3500 r.p.m. with one piece hardened, milled-to-pattern knife according to standard.

The nail- and screw-splitting experiments were carried out in two variants according to Davis' recommendations (1962).

The degree of specific defects in machining was assessed visually on the basis of five grades as follows (rating): (1) excellent, (2) good, (3) fair, (4) poor and (5) very poor.

Planing was evaluated for raised, fuzzy and torn grain and for chip marks; shaping for raised, fuzzy and chipped grain and rough-end grain separate for side-grain and end-grain cuts; turning for fuzzy grain, roughness and torn grain on the three typical details. Nailing and screwing quality was assessed on the basis of different degrees of splits.

4.3.8 Decay resistance

Natural durability ranks among relevant wood properties for some end uses (i.e. rail sleepers, hydraulic works, exterior constructions, flooring). To establish an estimate of comparative decay resistance of our wood species, laboratory tests by the standard ASTM soil-block test procedure (ANSI/ASTM D 2071-71) were conducted.

As for mechanical tests the sampling followed the assumption that the variation of wood properties between trees is higher than the variation within a tree. Immediately after felling of randomly selected trees, gross wood samples (ax. 60 cm x rad. 20-50 cm x tang. 15 cm) were taken from the stem 3-4 m above ground. During the 2-5 week stay in the forest area (Palenque, Chancala) samples were carefully and regularly sprinkled with water to prevent infections (deterioration). Afterwards the samples were transported to Mexico City (Instituto Nacional de Investigaciones Forestales). Immediately before aerial transport to laboratories in Ljubljana, smaller oriented specimens (ax. 15 cm x rad. 5 cm x tang. 5 cm) were prepared. Durability tests were conducted on laboratory test specimens of standard dimensions (ax. 0.9 cm x rad. 2.5 cm x tang. 2.5 cm) according to ASTM.

Samples for durability tests were taken from stem 3-4 m above ground and from the outer part of the heartwood (if present), or from stem periphery resp., where the durability is highest.

Decreased durability of heartwood from the sapwood/heartwood interface toward the pith is believed to reflect either biological detoxification, natural oxidation of heartwood extractives, or continued polymerisation of extractives to produce less toxic compounds (Anderson *et al*. 1963). Microbial activity may also reduce heartwood extractive durability with age (Jin *et al.* 1988). Decay resistance also varies with stem height with stem height with the most durable wood occurring near the base of the tree (Zabel and Morrell 1992).

Test fungi consisted of pure cultures of *Trametes versicolor* (L.) Lloyd for appraising *white rot*, and *Gloeophyllum trabeum* (Pers.) Murrill for testing *brown rot*. Results obtained with test fungus *Trametes versicolor* (L.) Lloyd indicate the class of decay resistance to be expected with ground contact. For *Gloeophyllum trabeum* (Pers.) Murrill, although it is less able to attack resistant woods, it is believed to better index the class resistance to be expected above ground.

Test and reference blocks were exposed to fungus at constant conditions (temperature 27 °C, relative humidity 70%) for approximately 12 weeks. The duration of exposure was determined by the time required by the test fungus to cause a weight loss of 60% in decay susceptible control (beech wood).

5. End use grouping

In this last section the species are grouped using 18 relevant properties with regard to 15 potential fields of end-uses.

Table.5.1 Property requirements and nesessary levels as reated to various specific fields od appliction (patially following Noack and Schwab (1973) and Brazier and Webster (1977). The ratings are not hard and fast but are indicative of relative importance of various characteristics. (For classicification according to grade see Tab. 5.2)

Nr.	Application	Basic density range	Natural durability Treatability	Grain	Strenght	Stability	Drying degrade	Machinability	Screw splitting	Nail splitting	Peeling	Slicing	Finishing	Glung	Figure	Stem form	Tension wood, growth stresses etc.	Color of heartwood
1	Paper pulp	<500																2
2	Particle board	<600						2						2				
3	Construction plywood	410-550		2		2	2				2			2		2	2	
4	Decorative face veneer	430-650		2	2	2	2				2	2	2	2	2		2	1
5	Core and cross-band veneer	320-450		2		2	2				2			2		2	2	
6	Container veneer and plywood	360-650			2	2	2				2	2		2		2	2	
7	Framework	>330	2	2	2	2	2	2	2	2			2	2		2	2	
8	Construction: interior				2	2	2		2	2			2	2		2	2	
9	Construction: exterior	>600	1		2	2	2									2		
10	Coverings: interior			2		2	2	2					2		2	2	2	(1)
11	Coverings: exterior		2	2		1	2		2	2						2		
12	Flooring	>550	2	2	1	1	1	2										(1)
13	Sleepers	>550	1		1													
14	Hydraulic works	>700	1		1													
15	Boat building		1	2	2	1		1					1	1	2			1

Tab.5.2 Classification of relevant properties

Property	Rating	Based on
Density		determination
Natural durability	1 resistant	ANSI/ASTM D 2017-71
	2 moderately resistant	
	3 non-resistant	
Grain	1 typically straight or shallowly interlocked of which the general direction is straight	visual inspection
	2 typically interlocked of which the general direction is straight	
	3 heavily interlocked or irregular	
Strength	1 high	bending strength, stiffness, resistance to impact loadiing, compres-sive strength, hardness
	2 medium	
	3 low	
Stability	1 favourable	ratio of swelling q, coefficient of swelling h, ratio of sorption s, anisotro-pies and differences, adjustingtime (c9omplex assessment)
	2 normal	
	3 unfavourable	
Drying degrade	1 minor	air-seasoning experiments with and without restraint
	2 moderate	
	3 considerable	ANSI/ASTM D 1666-64 (complex assesment)
Machinability	1 good	
	2 medium	
	3 bad	
Nail/screw splitting	1 absent	Davis 1962
	2 acceptable	
	3 severe	
Peeling/Slicing	1 easy to cut into smooth , tight veneer of uniform of thickness	tests under industrial conditions
	2 moderately easy to cut into smooth tight veneer of uniform thickness	
Finishing	1 good	experiments with nitro-cellulose and lacquer and acid-setting coating
	2 satisfactory	
	3 unsatisfactory	
Gluing	1 good	experiments with urea-formaldehyde and melanine-formaldehyde adhesive
	2 satisfactory	
	3 unsatisfactory	
Figure	1 very attractive	visual examination
	2 attractive	
	3 absent	
Stem form	1 cylindrical, straight	visual examination, measurements
	2 acceptable	
	3 poor	
Tension wood, growth stresses etc.	1 present to normal extent	
	2 present to an acceptable extent	
	3 present to a great extent	
Coloured heartwood	1 present	anatomical examination, observation tests
	2 absent	

Tab. 5.3 Relative suiatibility for end-use of 43 timber species rom Selva Lacandona.

SPECIES	Basic density range	Natural durability	Grain	Strenght	Stability	Drying degrade	Machinability	Screw splitting	Nail splitting	Peeling	Slicing	Finishing	Glung	Figure	Stem form	Tension wood, growth stresses etc.	Color of heartwood
Acosmium panamense (Benth.) Yakovlev	800	1	2	1	2	2	1	1	3		2+	1	2	2	1	1	
Alchornea latifolia	390	2	1	3	2	1	2	1	1	1			1	3	1	2	2
Aspidosperma megalocarpon	670	1	1	1	2	1	1	2	3		2	1		2	1	1	1
Ampelocera hottlei	690	2	1	1	3	2	2	3	3		2+	2		3	2	1	1
Blephardium mexicanum	600	1	1	2	3	3	1	1	3	2			2	2	1	1	2
Brosimum alicastrum	730	2	2	1	1	2	1	1	2		2+	1		2	2	1	2
Bursera simaruba	430	3	1	3	1	3	2	1	1	2			2	3	2	3	2
Callophyllum brasiliense	520	1	2	2	2	2	2	1	3	1	1	1	1	2	1	1	1
Cordia alliodora	490	1	1	2	2	2	2	2	2		1	1		1	1	1	1
Cymbopetalum penduliflorum	420	2	1	3	2									3	2	2	2
Dendropanax arboreus	400	3	1	3	1									3	1	2	2
Dialium guianense	800	1	2	1	2	1								3	2	1	1
Dipholis Stevensonii	800	1	1	1	2	2	1	3	3		2+	1		2	1	1	1
Guarea glabra	560	1	1	1	2	1	1	2	3	1	1	1	1	2	1	1	1
Guatteria anomala	430	2	1	3	1	2	2	1	1	1			2	3	3	2	2
Lonchocarpus castilloi	740	1	3	1	2	3	2	2	2		2	1		2	1	1	1
Lonchocarous hondurensis	670	1	3	1	2	3	2	1	2					2	1	1	1
Manilkara zapota	900	1	1	1	2	2	1	3	3					2	1	1	1
Misanteca Pekii	600	2	2	1	2	1	1	2	1	2			2	3	1	2	2
Nectadra sp.	460	3	3	2	2	1	2	2	3	2			2	3	1	2	2
Pachira aquatica	500	3	1	3	3	2	2	1	1					3	2	2	2
Pithecellobium arboreum	650	1	3	1	2	2	2	2	2		2	1		2	1	1	1
Pithecellobium leucocalyx	520	1	3	2	2	1	2	1	2	1			2	3	2	2	2
Platymiscium af. Yucatanum	660	1	1	1	1	1	1	2	1		2	1		1	1	1	1
Poulsenia armata	400	2	2	3	2	1	3	1	3	2			1	3	2	2	2
Pseudobombax ellipticum	440	2	1	3	1	2	2	1	3	1			1	3	1	2	1?
Pseudoimedia oxyphyllaria	650	2	1	1	3	3	2	2	3					3	1	2	2
Pterocarpus Hayesii	450	3	1	2	2	3	3	1	1	1			1	3	2	2	2
Quercus anglohondurensis	690	1	1	1	3	3	1	2	3		2+	1		1	1	1	1
Quercus Skinneri	820	1	1	1	3	2	1	3	3		2	1		1	1	1	1
Schizolobium parahybum	300	3	2	3	2	1	2	1	1	1			1	3	1	3	2
Sebastiana longicuspis	570	3	1	2	2	1	1	2	3					2	1	3	2
Simarouba glauca	460	3	1	3	1	1	2	1	1	1			1	3	1	2	2
Simira salvadorensis (Standl.) Steyerm.	660	1	1	1	3	2	1	3	3		1	1		2	1	1	1
Spondias mombin	450	3	1	3	1	3	3	1	1	2			1	3	2	3	2
Swartzia cubensis	830	1	2	1	2	2	1	3	3		2+	1		1	1	1	1
Swietenia macrophylla	420	2	2	2	1	1	2	3	2	1	1	1	2	1	1	2	1
Talauma mexicana	490	3	1	1	2	1	2	1	2				3	1	1	1	2
Terminalia amazonia	660	1	1	1	2	2	1	2	1	2+		2	3	1	1	1	1?
Vataires Lundellii	660	1	3	1	2	2	3	2	2	2	1		2	2	2	2	1
Vitex Gaumeri	670	2	2	1	2	2	1	2	3				3	3	3	2	2
Vochysia hondurensis	460	3	2	3	3	2	3	1	1	1	2	2	3	1	1	2	2
Zuelania guidonia	610	1	1	1	3	2	1	1	1				1	1	1	2	2

SPECIES	Paper pulp	Particle board	Construciton plywood	Decorative face veneer	Core and crossband veneer	Container v. and plywood	Framework	Construction: interior	Construction: exterior	Coverings interior	Coverings exterior	Flooring	Sleepers	Hydraulic works	Boat building
Acosmium panamense (Benth.) Yakovlev									A			B	A	A	
Alchornea latifolia	A	A			A	A	A	B							
Aspidosperma megalocarpon				B			B	B	B	B	B	B	B	C	
Ampelocera hottlei								B	C						
Blephardium mexicanum		B				B		B	B	B					
Brosimum alicastrum				B			A	A	B	B		A			
Bursera simaruba	A	A	B		B	B	B	B							
Callophyllum brasiliense		B	B	A			B	A	A	A	B				B
Cordia alliodora		B	B	A		B	B	A	B	A	C	C			
Cymbopetalum penduliflorum	A	A	C		B	C	B	B							
Dendropanax arboreus	A	A	C		A	B	B	B							
Dialium guianense									B				A	A	
Dipholis Stevensonii							C	C	A			B	A	A	
Guarea glabra		B	B	A		C	B	B	B		B				B
Guatteria anomala	A	A	C		C	B	A	B							
Lonchocarpus castilloi				C			C		A		B	B	A	B	
Lonchocarous hondurensis				C			C		A		B	B	A	B	
Manilkara zapota							B		A		B	A	A	A	
Misanteca Pekii		B				B	C	B							
Nectadra sp.	B	A	B		B	B	B	B							
Pachira aquatica	A	A	C		C	C		C							
Pithecellobium arboreum				B		C	C	B	B	B	B	B	B	B	
Pithecellobium leucocalyx	B	B	B			C									
Platymiscium af. Yucatanum				A		C	B	A	A	A	A	A	A	B	B
Poulsenia armata	A	A	C		B	B	B	B							
Pseudobombax ellipticum	A	A	A	B	A	B	B	B		B					
Pseudoimedia oxyphyllaria		C		B		C				B					
Pterocarpus Hayesii	B	B	B	B	B	B	B	B		B					
Quercus anglohondurensis				B					B			B	A	A	
Quercus Skinneri				B					B			B	A	A	
Schizolobium parahybum	A	A			B										
Sebastiana longicuspis		A					B	B		B					
Simarouba glauca	A	A	A		A	A	A	A		B					
Simira salvadorensis (Standl.) Steyerm.				C					B				B		
Spondias mombin	A	A	C		C	C									
Swartzia cubensis									A			B	A	A	
Swietenia macrophylla	B	B	A	A	A	B	A	A	B	A	B				A
Talauma mexicana	B	A	B		B	B	B	B		B					
Terminalia amazonia						B	B	B	A		B	B	B	B	
Vataires Lundellii				C			C	C	B			C	B	B	
Vitex Gaumeri				C		C	C	C				C			
Vochysia hondurensis	B	B	B			B		C							
Zuelania guidonia		B		B		C		C					B		

6. Concluding statement

About a half of the forests that once covered the Earth are gone. Every year, another 13 million hectares disappear (although afforestation adds another eight back), and the *World Resources Institute* (WRI) estimates that only about 22% of the world's old growth forests remain intact.

On the one hand temperate forests in the northern hemisphere are actually expanding, while on the other hand tropical and some temperate forests in the southern hemisphere are shrinking. According to the University of Michigan, 2% of the forest in Amazonia is lost annually, and with it the ecosystem services the forest supplies. The situation is not much different in other primeval forest areas.

A very illustrative unit was invented for the rate at which rainforests are destroyed – the area of a football pitch (with which we are all familiar) each minute. Or as the University of Maryland discovered, in 2017 we lost 40 football pitches of rainforest every minute! Meanwhile, the new unit for measuring volume of waste is the Olympic swimming pool. A very sporting approach, it must be said!

The destruction of tropical rain forests is frequently the result of the demand in industrial countries for cheap agricultural products (including cocoa, coffee, sugar, palm oil, orange juice, bananas, soy and beef) and wood products (cf. e.g. Primack 2008:81):

> Over half of the 13,000 square kilometre Lacandon Forest has been destroyed in the past 15 years by spontaneous and planned agricultural colonisation, lumbering and cattle farming. If present trends continue, in as little as ten years' time the entire area may be deforested.
>
> Mexico's last significant tropical forest, the Selva Lacandona, is a unique and extraordinarily rich wildlife habitat. It is one of the few remaining homes of endangered species such as jaguars, pumas, ocelots, spider and howling monkeys, crocodiles, giant tapirs and anteaters, harpy eagles, and numerous species of other birds. In modern times the area has been inhabited by the Lacandon Indians, some of whom still practice a highly efficient, ecologically sound system of tropical agro-forestry, related to ancient Mayan agricultural techniques only now being rediscovered (Buce B. 1982).

Drought and unsustainable practices are placing forests at risk, yet they are crucial to the reduction of the greenhouse gas emissions that fuel global warming. Forests also shelter natural biodiversity, recycle rainfall, and offer protection from flooding and erosion (cf. Radford 2017).

On the other hand, exploitation does not have to involve destruction. (*The Economist*, May 12th 2001). Forests can be protected by use within the framework of SFM/MFM ("Schutz durch Nutzung", Tappeser 2014). The WWF understands the threats facing forests today, but trying to prohibit the use of forest resources isn't a viable solution.

We believe that SFM/MFM, together with the accompanying protective silvicultural measures EA, RA, RIL certification and REDD+, ensure the use and preservation of the forest and its essential ecosystem functions, such as the necessary balance with the ecological and socio-cultural "pillars". The principles of SFM are most at risk from highly selective (and illegal) logging, abandoning the sustainable traditional milpa, but the most dangerous factor is uncontrollable and unregulated population pressure when the ecological footprint of the population exceeds the carrying capacity of the land, resulting in the inevitable conversion of forest to pasture and agriculture, with generally negative attitudes towards the existence of the forest and its ecosystem functions/benefits.

Being a treasure trove of biodiversity, anthropological and cultural heritage, Selva Maya and its extremely precious Selva Lacandona must be preserved by all means!

This is why all activities in the forest must follow the principles of ecological forestry, which focus on maintaining ecological integrity (cf. Hunter 1999:56), "comprising such elements as forest composition, natural regeneration, patterns of ecosystem variation, ecosystem functions and ecosystem processes over time" (CBD 2001:331). This process also should recognise that humans, with their cultural diversity, are an integral component of many ecosystems (using an ecosystem approach).

Sustainable commercial production forestry, which aims for the maximum production of timber, fuel wood and other forest products as a business enterprise, must be carried out outside established protected areas for which the strictest preservation standards are appropriate. While the conditions for production forestry outside protected areas are limited, they must abide by SFM principles. Wood production in the MFGC process serves above all for domestic use and to a reasonable extent for small-scale woodworking production.

If production forestry is to continue, there need to be cultural shifts from timber exploitation to forest management, from short-term profit taking toward sustainable forest management, from a focus on single commodity production to the multiple use management for more than one purpose, oftentimes combining two or more objectives (cf. e.g. Sayer *et al*. 2013, Sabogal *et al.* 2013, Nix 2017).

To reiterate: protected areas have strict regimes, especially for *Biosphere Reserves, which are* differentiated into *core, buffer* and *transitional* zones.

> In the *core area* the biological and ecosystems are strictly protected. In the surrounding *buffer zone* traditional human activities – such as collection of thatch, medical plants and small fuel wood – are monitored and non-destructive research is conducted. Surrounding the buffer zone is *transition zone* in which some forms of sustainable development (such as small-scale farming) are allowed, along with some extraction of natural resources (such as careful selection logging) and experimental research. (Primack 2008: 234)

In the *buffer zone* the traditional sustainable *milpa-forest garden-cycle* based on *traditional ecological knowledge* (TEK) can be practiced, together with other traditional sustainable activities (hunting, fishing, gathering tree fruits and medicinal plants, harvesting of honey, etc.), which most reliably protect the precious inner *core* zone and its indispensable biodiversity.

The Seva Lacandona does not only boast exceptional biodiversity, but is also a "cultural" forest of world importance with many first-rate discovered (and presumably still undiscovered) archaeological monuments, promising not only ecotourism but also incredible *archaeotourism* as a form of cultural *tourism.* However, this must be organised very carefully! Archaeological tourism can very quickly turn into destructive and invasive tourism!

> Archaeologists have expressed concerns that tourism encourages particular ways of seeing and knowing the past. When archaeological sites are run by tourist boards, ticket fees and souvenir revenues can become a priority, and the question remains whether a site is worth opening to the public or remaining closed and keeping the site out of harm's way. Damage to irreplaceable archaeological materials is not only direct, as when remains are disordered, altered, destroyed, or looted, but often the indirect result of poorly planned development of tourism amenities, such as hotels, restaurants, roads, and shops. These can drastically alter the environment in ways that produce flooding, landslides, or undermine ancient structures. (Archaeological Tourism 2017)

The Selva Lacandona is part of the Mesoamerican hotspot which spans most of Central America, encompassing all subtropical and tropical ecosystems from Central Mexico to the Panama Canal. Mesoamerican forests are critical for the preservation of the biodiversity of the western hemisphere (cf., e.g. Marinelli 2004). At the same time the Mexican dry forest is an ecoregion (WWF, *Global* 200). It is for this very reason that this forest ecosystem must be preserved and protected against habitat loss and fragmentation, which have long been considered the primary cause for biodiversity loss and ecosystem degradation worldwide.

What drives deforestation is the fact that forest production systems cannot generate as much profit as land use alternatives, although they are short-term and non-sustainable, combined with human lack of awareness for the environment. In this way, unfortunately, market forces replace "inefficient" production systems with systems that produce more profit – a simple competitive model of survival of the fittest. This is where the problem of the existence of tropical forests most frequently resides.

Table 6.1 lists various completely different production activities in the Selva Lacandona and other regions in Chiapas (Iñigo-Elias 1996, quoted in Nations 2006:142).

The comparison is not straightforward and is in fact impossible, as for the caoba, for example, we don't know how it was cultivated, if at all. Negligent, highly selective felling, as described by Traven (see his essay on mahogany), which has practically no expenses for management and silviculture, is in the short-term much more profitable (but detrimental for the forest and forest workers) than the sustainable SFM/MFM. Illegal plundering, with no concern whatsoever for the forest's survival, can be very lucrative to begin with but is also completely unacceptable. "The destructive activity of cattle ranching in the lowland tropical forest is lucrative enough to prompt many rural families to be, or dream of being, cattle ranchers" (Nations 2006:142).

On the other hand, cacao or coffee (Naja) can be grown quite harmlessly in the agroforestry system in combination with precious tree/wood species. In Tabasco I saw a very nice example of agroforestry in the form of a combination of cedro rojo (*Cedrela odorata*) and the even more valuable vanilla in the "armpits" of its branches. And cocoa in their shade!

Hunting, fishing, collecting medicinal and decorative plants, and apiculture can be sustainable if certain limits are respected.

I would not waste words regarding marijuana, but the scarlet macaw is so rare that hunting it can never be justified. "The birds have been seriously depleted by habitat destruction and by illegal practice of stealing young birds from their nests to sell as pets" (Nations 2006:67). Crude oil, of which there is an abundance under the Selva, is not featured in the table, although pumping it would probably bring incomparable profits…

Table 6.1. Income from various products in Chiapas (Iñigo-Elias 1996, quoted in Nations, 2006:142)

Product	Amount	Income US dol.	Labor Required	Ratio of Income per Days Worked
Maize (corn)	100 kg	6,50	56 days over 3 months*	0.11
Chili peppers	100 kg	38.70	140 days over 5 months	0,27
Cacao	100 kg	9.70	120 days over 10 months	0.08
Calf	500 kg	161	144 day over 12 months	1.12
Pig	25 kg	19.30	20 days over 5 months	0.96
Mahogany	1 cu.ft.	8,30	20 days over 1 month	0.41
Marijuana	100 kg	161	15 days over 4 months	9.66
Scarlet macaw (Ara macao cyanoptera)	1 chick	145	1 day during 1 month	145

For growing maize and manioc, less labour intensive crops than wheat, 60-70 working days used to be enough to produce enough to live off. However, following the arrival of greedy foreigners they had to work from dawn until dusk, seven days a week, for the whole year, without respite, in order to pay the high taxes… (Niess 1991:67).

Nowadays, we wonder how we can possibly preserve the forest in a situation in which there is such strong competition from more profitable non-forest products, increasing population pressure and a greatly increased need for both food and the "benefits" of modern civilisation.

In the last primary forests it is necessary to establish various protected areas, while sustainably managing the remaining better preserved secondary forest (SFM/MFM/EA), applying RIL and RA, practicing end-use grouping and marketing, as well as respecting the principles of ecological forestry, engineering and restoration. Parts of the successfully meliorated forests could later gradually be included in the protected areas. Wherever possible it is necessary to preserve or reintroduce – at least supplementarily – the traditional sustainable milpa, forest garden cycle, which alongside nutritional plants in forest gardens enables more modest, but sustainable wood production for domestic use or small industry. Forest gardens can also serve as nurseries from which tree species can again spread into devastated forests following storms or long-lasting droughts, or even after overexploitation, and contribute to its regeneration and preservation.

The terrible deforestation of the Maya forest, amounting to 800 square kilometres per year (Nations, Bray, and Wilson 1998, quoted in Nations 2006:260), demands extreme caution in forest management, which must be sustainable with an ecosystem approach preserving all ecosystem functions and benefits. Unfortunately, it is most likely that strong population pressure, increased by migrant flows from Latin America to the USA by one of the most rapidly growing human populations in the world, will contribute to faster deforestation.

Practicing non-sustainable "conventional" monocultural milpa, and the intrusion of illegal logging into better preserved and protected forests, may soon critically threaten the forest's existence.

Let's listen once again to the experienced Nations, ecological anthropologist and the foremost scholarly authority on the Lacandon Maya (1994):

> It would be fruitless to argue for the preservation of all the forests of eastern Chiapas. Most of those forests are already gone. But it makes sense, for the benefit of the indigenous inhabitants of the Selva Lacandona and for the people of Mexico, to keep alive what little forest remains. President Carlos Salinas de Gortari had exactly this goal in mind when he expanded the protected areas of the Selva Lacandona by 81,000 hectares in May, 1992.

> The challenge remains to transform the rest of eastern Chiapas into an ecologically sustainable mosaic of food production, agroforestry, small-scale cattle production, and extractive forest reserves. To do so would be positive for the region's natural ecosystems and positive for the region's inhabitants – indigenous and Ladino alike.

More than three decades ago (1988) the same Dr Nations, tried to explain the potential benefit of the Lacandones' traditional rain-forest management, i.e. their system of agroforestry, to an agronomist hired to develop sustainable agricultural systems for the Selva Lacandona. He listened politely, but it was obvious that the agronomist's mind was already filled with visions of agribusiness and cattle production. He told him that the Lacandon system was very interesting, but it wasn't modern. Nations was succinct: "…rather than eradicating indigenous systems like that of the Lacandon Maya, we should be working with traditional forest farmers as their students."

The knowledge of traditional Maya systems of agriculture and resource management is a key to decipher the past, and perhaps a path for the future for us all. Unfortunately, we are losing this knowledge at a rapid rate (Gómez-Pompa 2003:8).

This is also my deepest conviction. It is about understanding the ecosystem approach, i.e. the strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way. The "Lacandon system" means preserving the forest as their *alma mater*. Wood producing forest using SFM/MEM/EA, accompanied by the sustainable production of food, as well as wood in the MFGC system, all based on TEK, are probably the keys to the solution. It makes sense to include hard-to-access forests, which may also have been improved, in protected areas, and to surround them with buffer-zones. A precondition for any sustainability is evidently manageable population pressure and carrying capacity.

The experience of the Maya should also be followed – they usually hesitated to interfere with the preserved primary forest, keeping its use to a minimum. The Maya got all they needed by exchanging what they produced with their own hands in intensive polycultural milpa and forest gardens. Thanks to the small but regular quantities, wood from the *forest gardens* is appropriate above all for domestic and local use, however, it should not be neglected, especially because its production is an integral part of the sustainable MFGC.

Responsible forest management is an important solution, and a *credible system of certification* based on an independent environmental audit can ensure the sustainable management of these vital resources.

Warning! Due to their high-quality all-purpose wood caoba and cedro are already on the IUCN *Red list* as "vulnerable" and in CITES Appendix II. For now they are still being saved by their pioneering, light-demanding character, and by frequent hurricanes and fires! Currently more endangered are the technologically less attractive shade-tolerant species, that can therefore only grow in a more or less undamaged forest, which is disappearing.

Modern forest management is characterised variously as sustainable forestry, ecological forestry, and management with an ecological approach, with the use of a number of "green" or "eco" terms seen around this issue, such as: ecosystem, ecosystem integrity, ecosystem services, ecological engineering, restoration ecology (returning an ecosystem to a desired, more natural state after human disturbance), ecological footprint, ecotourism, etc. Unfortunately these are often simply empty words, but, as the Italian saying goes: *Se non è vero, è ben trovato* "even if it is not true, it is well conceived".

The "use" of the (tropical) forest must be such that it can sustainably be preserved as a renewable ecosystem with all its valuable functions/benefits in accordance with the definition of an ecosystem (Tansley 1935, quoted in Kemp 1998:117) as a:

> community of interdependent organisms and the physical environment they inhabit, where the relationships are dynamic and routinely respond to change, without altering the basic characteristics of ecosystem.
>
> Natural ecosystems are theoretically self-sustaining, but increasing human interference is threating their sustainability. Various methods of ecosystem management have been introduced in an attempt to preserve and protect characteristic natural ecosystems.

All harvesting in the production forests should be carried out sensitively and responsibly without affecting the remaining forest ecosystem functions/services in the sense of multiple-use forest management (MFM), which represents a common and prime management objective under sustainable forest management (SFM). This is a concept of forest management that combines two or more objectives, not only the production of wood, (Sabogal *et al.* 2013, cf. also Hunter1999:26) always recognising humans as a part of the ecosystem and that all activities in the forest both affect the ecosystem and depend on it (i.e. an ecosystem approach). In addition to the absolutely sustainable permaculture of the *milpa forest garden cycle* (MFGC), the Maya also practiced other intensive food producing methods such as raised and channelised fields, *chinampas* ("floating gardens") along the river, lake/laguna and swamp banks, various kinds of terracing on hilly terrain, preparation of the fertile anthrosol – dark earth, similar to the *terra preta* of the Amazon – crop domestication and highly advanced commercial activities on the sea, from Tabasco around the Yucatán peninsula to the Gulf of Honduras (cf. Foster 2002:319-321; Benson 1977:68), and on land, also using numerous paved roads (*sacbeob*) primarily connecting great ceremonial and commercial centres. Particularly important was the highly sophisticated use of fire, which contributed to nutrient flow and long-term soil fertility in the form of charcoal produced by low-temperature pyrolysis, resulting in long-term carbon sequestration and increasingly fertile anthrosol (cf. Wilken 1987; Ford and Nigh 2010; Nigh and Diemont 2013).

SFM/MFM with EA, RA, RIL is a move away from paying most attention to a few tree species of high commercial value to an ecosystem approach that covers the entire forest ecosystem and its potential for producing multiple goods, benefits and services, most of which have no direct market value (cf. Burch 2001:2).

On the basis of their TEK the Maya lived and survived self-sufficiently and sustainably in their tropical rainforest. They only partially, utilitarianly and botanically modified it, and it was preserved down the generations with its forest ecosystem functions and services intact. The anthropogenically altered and later abandoned *feral* forests are characterised by a high frequency of certain species, which are also predominant in forest gardens.

It should be noted that with highly selective felling only a few most valuable species, mainly the caoba *(Swietenia macrophylla*) and cedro rojo (*Cedrela mexicana*), have been logged. Large areas of forest have been degraded in order to remove only a few logs and the remaining species are/were frequently treated as weeds and burnt or otherwise wasted until the forests are completely mined of their timber, and the land becomes more valuable for agriculture or ranching than for forestry. It is thus necessary to manage the forest sustainably or lose it! If not, conserve it completely!

We believe that only SFM/MEM with the EA and RA ensure the necessary balance with the ecological and socio-cultural "pillars". The principles of SFM are most at risk from highly selective (often illegal) logging, abandoning the sustainable traditional MFGC, but the most dangerous factor is uncontrollable and unregulated population pressure when the ecological footprint of the population exceeds the carrying capacity, resulting in the inevitable conversion of forest into pasture and agriculture with a generally negative attitudes towards the existence of the forest and its ecosystem functions/benefits. Let's say this again! **Being a hotspot for biodiversity, anthropology and world cultural heritage, the Selva Maya/Lacandona ought to be preserved by all means possible.**

In addition to forest fragmentation, deforestation and forest degradation, a danger is also posed by monoculture tree plantations (e.g. eucalyptus, oil palms, rubber tree), which are not forests but "green deserts" "Plantations form part of an industrial model for the production of abundant and cheap raw material that serves as an input for the economic growth of industrialised countries. The producer countries are left with environmental degradation and rising poverty, which are the 'externalised costs' of this cheap raw material" (Simone Lovera of the *Global Forest Coalition*). Since 1980, tropical forest plantations have expanded almost fivefold globally (21 September: International Day against Monoculture Tree Plantations!).

Deforestation is claiming 7% of the forest each year! Even more, "lands devastated by nonsustainable use intensify the demand for new lands, leading to further deforestation and social conflict" (Nicholson *et al.* 1995, Howard-Dixon 1996, quoted in Diemont 2006:206). Following crop and cattle production, these areas do not return to a mature, enriched forest, but to degraded grass and bush vegetation (Miller 1999, quoted in Diemont 2006:206).

Let me repeat this once again: everything we do in the forest must be done one the basis of the following epithets "eco", "close to Nature", "sustainable", "responsible", "equilibrium", "protection", and "survival", being honest and always with the active participation of the local population. As the Maya knew how.

Almost 40 years ago, the ten-year-old Florencia Bautista Chan from the "Zamna" school in the village of Petcacab, Quintana Roo, wrote a beautiful and expressive poem:

"Al mirar los árboles
ellos son amor y cariño
y vida sus ramas fondosas

Son sus flores
maderas preciosas
en mi hogar están

Visten de bellos colores
el rojo del chactecoc

jaspeado es el ciricote
el mas hermoso es la caoba
árboles, árboles de mi bosque
viven siempre en mi eternidad

Saludamos a los hermosos árboles
que son sus ramas abiertas
pareclan saludando, sus hojas al chocar
parecia como risas, salud árboles."

At great climate conferences with thousands of participants, the importance of forests is constantly being emphasised, especially that of tropical forests for their ecosystem functions and the mitigation of climate change. Optimistic predictions concerning their protection are made with round, usually non-binding deadlines for implementation, set in the "safe" and distant future. After all we know the beautiful popular song by Silvana di Lorenzo "Palabras…palabras"!

I will finish with the words of an unknown German author: ***Mit den ersten Bäumen, die gefällt werden, begint die Kultur. Mit den letzten Bäumen, die gefällt werden, endet sie.*** (Culture begins with the first trees that are felled. It ends with the last trees being felled.)

Good luck, precious selva!

7. Mahogany

(*Swietenia* spp.) – A natural and cultural history of the famous wood (cf. Torelli 2006)

Abstract

Essay on caoba/mahogany – Natural and cultural history

The many aspects of this beautiful allpurpose historical wood, known also as a premium furniture wood are covered in separate sections of the essay: (a) discovery of mahogany, (b) ecology, exploitation and management, (c) use and abuse of the name, (d) origin of the name »mahogany«, (e) history of use and (d) xylotomy and properties. Due to uncontrolled harvesting and illegal loging endangered. Listed in CITES Appendix II.

7.1 Discovery of mahogany

There is perhaps no wood in the history of humanity that has achieved the same degree of fame and notoriety as mahogany. While it owes its fame to its outstanding biological, physical, mechanical and technological properties, including its colour and its interesting decorative textures, its notoriety or ill repute derives from a melancholy etymological (!) connection with the tragic transatlantic slave trade. A highly versatile wood suitable for a multitude of uses, its very versatility is now threatening its existence. Today it is "migrating" from the forests of Central and South America, which are experiencing deforestation and degradation, to the plantations of Asia and Africa, where unfortunately its wood does not achieve the quality of its domestic forests.

We owe the first botanical description and extremely high quality drawing of the "Mahogony Tree" (note the spelling) to Mark Catesby, who included them in his 1743 work *The Natural History of Carolina, Florida and the Bahama I*slands, Vol. II, Plate 81 (quoted in Keay 1996:3 and Lamb 1966:2), before the adoption of Linnaeus' binomial nomenclature or "two-term naming system" (*Systema Naturae*). Catesby described the tree and its wood in the following words (quoted in Keay 1996:3):

> These trees grow to a great height and are usually four feet diameter; . . . [T]he tree increases to a stupendous size in a few years, it being a quick grower. . . . The excellency of this wood for all domestic uses is now sufficiently known in England; and at the Bahamas Islands, and other countries, where it grows naturally, it is in no less esteem for ship-building, having properties for that use excelling oak and all other wood, *viz. durableness, resisting gunshots, and burying the shot without splintering.*

The description is a good one and indicates the tree's essential characteristic as a heliophyte pioneer species.

In his 1756 work *The Civil and Natural History of Jamaica,* the botanist Patrick Browne described three species of *Cedrela* and labelled or numbered them *Cedrela* 1, 2 and 3 (Keay 1996:3). The copy of this book kept by the Linnean Society of London contains a number of annotations by Linnaeus himself (Keay 1996:3). By *Cedrela* " Barbados Cedar", Linnaeus wrote "*Cedrela odorata*", and by *Cedrela* 2, "Mahagony" [sic], he wrote "*Cedrela mahagoni*". Regarding *Cedrela* 3, Browne notes that it does not grow in Jamaica and that "it was discovered by Mr Houston near the Gulf of Honduras, and is said to grow very large." He only mentions it because he wishes to draw attention to the fact that another, very similar species grows on the mainland. There are no marginal annotations from Linnaeus here. Could this have been what became known as Honduras Mahogany (*Swietenia macrophylla*)?

In 1759 Linnaeus "formally published the two species: *Cedrela odorata* Linn. and *Cedrela mahagoni* (Keay 1996:4).

A year later, in the baroquely titled work *Enumeratio Systematica Plantarum quas in Insulis Caribaeis vicinaque Americes continente detexit novas, aut jam cognitas emendavit* (1760), Nikolaus von Jacquin "separated *Cedrela mahagoni* as a genus on its own, which he called *Swietenia"* after the Dutch physician and naturalist Gerard van Swieten (Keay 1996:4). Van Swieten was the personal physician of the Empress Maria Theresa. Today his statue stands on Zumbusch's great Maria Theresa Monument in Vienna along with those of three of the Empress's most valued counsellors (Kaunitz, Liechtenstein, Haugwitz) and equestrian statues of her four favourite generals (Daun, Loudon, Abensberg-Traun and Khevenhüller). The monument is located between the Art History Museum (*Kunsthistorisches Museum*) and the Natural History Museum (*Naturhistorisches Museum*).

In 1762 Linnaeus confirmed the name ***Swietenia mahagoni*** (Linn.) Jacq. This was the first of the three mahogany trees that began to be exploited immediately after the discovery of the New World (and after five centuries was practically exhausted), commonly known *as West Indian mahogany*, *American m.*, *Cuban m.*, *small-leaved m.*; French: *acajou*, *mahogani de Saint-Dominique*, *mahogani petites-feuilles*; and Spanish: *caoba española*, *coabilla.* It is also frequently referred to simply as *Spanish mahogany*, because it came from the former Spanish colonies.

Geographic range: *West Indian mahogany* is found on the Caribbean islands and also in south Florida. Its natural distribution is hard to ascertain as it has been widely cultivated. It was the first mahogany to appear in the European market five centuries ago. Countries of occurrence: Anguilla, Antigua and Barbuda, Bahamas, Brazil, Cayman Islands, Colombia, Cuba, Dominica, Dominican Republic, Grenada, Guadeloupe, Jamaica, Martiniqùe, Montserrat, Saint Barthélemy, Saint Kitts and Nevis, Saint Lucia, Saint Martin (French part), Saint Vincent and the Grenadines, Trinidad and Tobagz, United States (Florida).

Sustainability: Today, as a result of the destruction or poor state of forests, it only survives in a few locations and has therefore been placed on the IUCN (International Union for the Conservation of Nature) Red List of Endangered Species in the "endangered" category **(EN A1cd)** and listed in CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora), Appendix II. (An *endangered species* is a species which has been categorised as likely to become extinct.)

Interestingly, there was also a serious proposal to name West Indian mahogany after "our" Scopoli: *Roja Scopoli* (*Introductio ad Historiam Naturales*. Gerle, Praga 1777, quoted in Lamb 1966). Scopoli was an Italian physician employed at the famous mercury mine in Idrija, a small town in the Habsburg realm (now Slovenia). Linnaeus greatly respected him and showed great interest in his botanical work.

Another species from the botanical genus is ***Swietenia humilis*** Zucc., Spanish: *caoba del Pacífico, caobilla, cóbano, gateado, venadillo, zapatón, zopilote*; English: *Mexican mahogany, Pacific Coast mahogany*.

Geographic range: Belize; Costa Rica; El Salvador; Guatemala; Honduras; Mexico; Nicaragua; Panama; Economically insignificant.

Sustainability: The IUCN Red List classifies *S. humilis* in the category "vulnerable" **(VU A1cd)**; also listed in CITES Appendix II. (A *vulnerable* species is one which has been categorised by the IUCN as likely to become endangered unless the circumstances threatening its survival and reproduction improve. Vulnerability is mainly caused by habitat loss or destruction of a species's home. Habitat destruction is currently ranked as the primary cause of species extinction worldwide).

It was not until 1886 that George King described ***Swietenia macrophylla*** King in Hooker's *Icones Plantarum* (Vol. 16, Pl. 1550). Owing to its very extensive geographic range and the quality of its wood, it has numerous common names: *caoba*, *mara*, *mongo*; English: *Brazilian mahogany*, *Honduras mahogany*, *large-leaved mahogany*, *bay wood* (from the bays of Campeche and Honduras, where it was exported from); French: *mahogani grandes-feuilles*. The commonest name in Latin America is, however, *caoba*, which is very similar to the name used by the Arawak people, the aboriginal inhabitants of the island of Hispaniola (Haiti): *caoban*, *caobano*. In "our" Selva Lacandona it is called ***puuna'*** (***äh***).

Geographic range: Brazil, Colombia; Costa Rica; Dominica; Ecuador; El Salvador; French Guiana; Guatemala; Guyana; Honduras; Mexico; Nicaragua; Panama; Peru; Venezuela, Bolivia.

This species is now the most commercially important of the mahoganies. It is one of the finest and best known cabinet woods. It is highy prized for interior trim, fancy veneers, musical instruments, boatbuilding, patternmaking, turnery and carving.

Sustainability: the level of exploitation has led to the exhaustion of supplies, particularly in the northern parts of its range. *S. macrophylla* is listed under the category "vulnerable" **(VU A1cd)** in the IUCN Red List; also listed in CITES Appendix II.

The *caoba* is the national tree of Belize (formerly British Honduras) and the Dominican Republic.

Coat of arms of Belize (from Wikipedia).

The shield of the coat of arms is divided into three sections by a vertical line and an inverted V. The base section represents a ship in full sail on waves of the sea. The two upper sections show tools of the timber industry in Belize: a paddle and a squaring axe in the right section and a saw and a beating axe in the left section. Supporting the shield are two woodcutters, the one on the right holding a beating axe over his shoulder in his right hand, and the one on the left holding a paddle over his shoulder in his left hand.

Above the shield rises a mahogany tree. Below the shield is the motto *Sub umbra floreo*, Latin for "Under the shade I flourish."

A wreath of leaves encircles the coat of arms. The coat of arms embodies an important aspect of the history of Belize, since the mahogany industry formed the basis of its economy in the 18th and 19th centuries.

The Dominican Republic's first national flower was the flower of the *caoba*. In 2011, the mahogany was dubbed the national tree, vacating the national flower spot for the Bayahibe rose (*Pereskia quisqueyana*) in order to bring attention to its conservation.

Unfortunately, efforts to repopulate mahogany in its native locations have turned out to be largely unsuccessful. There are four major reasons why *Swietenia* can no longer be re-grown natively (Gaskell 2015):

a) The soil is now depleted and barren.
b) The species is attacked by the mahogany shoot borer (*Hypsipyla grandella*), whose larvae bore up through the leading shoots of saplings causing their death or subsequent low branching of the mature tree. According to the lumber industry, this leads to trees with excessive branching and poor form (Lamb 1966:127, Tudge 2005:219)
c) Genetic loss.
d) Soil erosion and soil compaction leaving those areas now uninhabitable.

Attempts in the past to grow *Swietenia* in Africa resulted in uniform failure and abandonment due to attacks by *Hypsipyla robusta*, the African equivalent of *Hypsipyla grandella*. It turns out that the most successful areas where *Swietenia* can be grown outside its native location are tropical Asia and the South Pacific: Fiji 1911, India 1865, Bangladesh 1872, 1993, Sri Lanka 1897, 1990s, Solomon Islands 1978 (*Swietenia macrophylla*), Philippines 1982, China 1800s (*Swietenia mahagoni*) and Indonesia 1870 (*Swietenia mahagoni* and *S. macrophylla*) (cf. Gaskell 2015). Unlike mahogany sourced from its native locations, plantation mahogany grown in Asia is not restricted in trade and CITES limitations do not apply to Asian and South Pacific grown *Swietenia* as their plantations are sustainably managed and controlled.

It should be noted that fast-grown plantation trees generally possess an abnormally high proportion of technologically unfavourable juvenile wood (high microfibril angle resulting in excessive axial shrinkage, checking in drying, lower dimensional stability). The juvenile tree core is also characterised by a high proportion of tension wood, with strong internal/growth stresses causing checking and warping in drying. A woolly/fuzzy grain is also associated with tension wood. As opposed to normal mature trees, the proportion of juvenile wood is relatively high (plantation mahogany has a 35–40 year rotation). The proportion of desirable coloured heartwood in younger stems is generally lower. In addition it has suffered badly in plantations from the mahogany shoot borer *Hypsipyla*, which bores into shoots and deforms the tree into a mean shrub. Attack by shoot borers on the Meliaceae such as *Swietenia, Khaya, Lovoa, Cedrela, Carapa* and *Entandrophragma* is common in all tropical countries *(cf. FAO Staff 1958).*

7.2 Ecology, exploitation and management

Widespread silviculturally problematic, unplanned, unsustainable, highly selective harvesting as described by Traven and as practised by illegal loggers nowadays means that the survival chances of mahogany are considered to be very poor. Increasing fragmentation and, ultimately, habitat loss pose the greatest threat to mahogany. The world's mahogany forests (and other habitats) continue to disappear as they are harvested for human consumption and cleared to make way for agriculture, housing, roads, pipelines and the other hallmarks of industrial development. Without a strong plan to create protected areas, important ecological habitats will continue to be lost. Increasing food production due to overpopulation is a major agent for the conversion of natural habitats into agricultural land (WWF Global 2017).

The heliophytic or light-demanding and pioneer character of mahogany is the strongest survival and regeneration advantage of mahogany occupying bare land after hurricane devastation or fires, as well as abandoned milpa areas, and along forest roads.

We believe that the distribution of mahogany today is a direct result of the forest regeneration patterns established after abandonment of traditional Maya land use, in particular milpa agroforestry (Snook 1998 and Steinberg 2005, quoted in Ford and Nigh 2015:90).

Let me cite some competent sources on ecology and the possibility of natural regeneration of *Swietenia macrophylla.* The process of regeneration of the light-demanding pioneer species mahogany under natural conditions is an exceedingly complex problem that depends on whether seedlings are present and, above all, on the amount of light that filters through the upper canopy to the young trees, especially in areas where highly selective logging prevails.

Stevenson 1927 (quoted in Lamb 1966:105) states that:

> opening the canopy by cutting well-distributed merchantable trees stimulates enough mahogany regeneration to replace removals. Oliphant (1928), Stevenson (1927) and Tosi (1960) (quoted in Lamb 1966: 106) show that mahogany as a heliophyte species reproduces freely in the successional vegetation or in the secondary forest that appeared to be abandoned milpas (agricultural clearings) or abandoned sugar cane plantations. Fire and strong winds release retrogression in the succes-

> sion to secondary vegetation resulting in conditions similar to those developing on abandoned agricultural clearings (Lamb 1966:107). Wolffsohn (1961, quoted in Lamb 1966:108) came to the conclusion that "maximum stocking of young mahogany trees occurs in areas of shifting cultivation, large burned areas, or old logging roads."
>
> Mahogany is adapted to capitalise on disturbances that periodically destroy patches of forest. Mahogany is unusual among the tree species (in Quintana Roo) in having large buttresses that reach 2–3 m up the bole and can extend out 1 m or more from the stem. These characteristics contribute to their successful survival of hurricanes that knock down most large trees. Mahogany trees in Quintana Roo also survive intense fires better than any other species in the forest, probably thanks to their thick bark (Snook 1998: 68).

Mahogany seedlings and saplings are shade intolerant, exhibiting their fastest growth with overhead light and lateral shading. They are intolerant of deep shade, but can survive in a suppressed state for years in partial shade. Mahogany is adapted to regenerate after fires and hurricanes in Central America and Mexico (Lamb 1966, Snook 1993).

Adult trees survive these ephemeral disturbances better than most other trees in these communities (Gullison *et al.* 1996).

Swietenia macrophylla is amongst the pioneer species reoccupying degraded agricultural land. Caoba, on the other hand, is a non-pioneer, light-demanding timber species whose seedlings occur at low densities in the forest understorey due to limited shade tolerance. Post-logging seedling regeneration density by big-leaf mahogany is generally reported to be low to nonexistent. (Grogan and Galvao 2006).

It is difficult to increase the proportion in the wild because mahoganies are light lovers and need open ground or clearings to get going. If they are simply planted among other trees, they fail.

Regeneration of the species is stochastic, depending in nature on large-scale disturbance. This ecological strategy makes mahogany vulnerable to logging regimes. Harvesting and processing are generally only 50% efficient. There is, at present, little economic incentive to manage natural stands sustainably.

Furthermore, mahogany seedlings do not survive long in the forest understorey. The lack of mahogany regeneration in primary or selectively logged forests has been observed over and over again, not only in Quintana Roo (Snook 1993) but also in Belize (Stevenson 1927 and other sources) and elsewhere in Central and South America (Snook 1996). Mahogany seedlings and saplings are also rare and seem not to survive in canopy gaps produced by tree falls or single-tree harvesting. A consequence of this regeneration strategy is that mahogany typically occurs in even-aged aggregations that date back to catastrophic disturbances. New individuals do not become established in the shady understorey and rarely survive in gaps produced by treefalls. (Snook, 1998:68)

However, there is sufficient information on the regeneration ecology of mahogany to indicate that under natural conditions this species regenerates in essentially even-aged stands after catastrophic disturbances destroy many or most trees, and, in the case of fires and flooding, saplings and seedlings as well. Adult mahoganies tend to survive these events, and regenerate by shedding seed onto the resulting gaps or clearings. This ecological strategy makes mahogany vulnerable to logging, first because juvenile mahoganies are not found in the understorey, and secondly because logging operations shortcut mahogany regeneration processes by selectively removing almost all mahogany seed sources while leaving standing competing vegetation of other species. There has been no systematic survey of the status of mahogany in formerly logged forests. (Snook 1996, from abstract)

Where forests, logged of mahogany, still stand, they may be found to be devoid of mahogany trees years or even decades later. Quevedo (1986) noted no mahogany regeneration nine years after logging in Bolivia. Inventories carried out by personnel at the UNAM Chajul biological station found no mahoganies at all 50 years after selective logging in that portion of the Selva Lacandona, Mexico (G. Segura, personal communication). In Quintana Roo, mahogany has periodically regenerated in formerly logged forests, a consequence both of historical logging practices (a function of

> markets and technology) and of the frequency of catastrophic disturbances. Mahogany logging produces conditions that are the inverse of those produced by natural catastrophic disturbances, and these undermine the regeneration potential of this valuable timber species. Because mahogany regenerates in essentially even-aged cohorts, all mahogany trees in a commercial stand tend to be of commercial size. Logging operations commonly remove 95% or more of all mahoganies leaving only those individuals that are damaged or otherwise uncommercial (Snook 1992, Gullison *et al.* 1992). Since these stands lack mahoganies in smaller size classes, there are no younger classes to take the place of the logged trees.
>
> Logging is typically highly selective, removing only mahogany and leaving behind everything else. The resulting conditions are inhospitable to mahogany regeneration because its seedlings require high levels of light, and because they apparently do not compete well with pre-existing individuals, including seedlings of other species (quoted in Snook 1996: 40).

There is some indication that mahogany does not successfully regenerate following commercial harvesting. Mahogany is predominantly harvested by "selective logging", in which only high-value trees are extracted from the forest. This practice does not create the light conditions that seem to be necessary for mahogany regeneration and removes the majority of the seed-producing trees, reducing the chances of seedling establishment. Commercial extinction of this species, logging to the point where the species is so sparsely represented in the forest that it becomes uneconomical to harvest it, would be devastating for the species, for the local communities dependent upon the income from the harvest, and would undermine efforts to establish a permanent forest estate, areas designated for long term, sustainable timber harvest. Once roads are built, the forest is vulnerable to further exploitation and clearance for agriculture (*Big-Leaf Mahogany* 2012):

> Selective logging – the practice of removing one or two trees and leaving the rest intact – is often considered a sustainable alternative to clear-cutting, in which a large swath of forest is cut down, leaving little behind except wood debris and a denuded landscape. People go in and remove just the merchantable species from the forest. Mahogany is the one everybody knows about, but in the Amazon, there are at least thirty-five marketable hardwood species, and the damage that occurs from taking out just a few trees at a time is enormous. On average, for every tree removed, up to thirty more can be severely damaged by the timber harvesting operation itself. That's because when trees are cut down, the vines that connect them pull down the neighbouring trees. . . . That's probably the biggest environmental concern. But selective logging also involves the use of tractors and skidders that rip up the soil and the forest floor. Loggers also build makeshift dirt roads to get in, and study after study has shown that those frontier roads become larger and larger as more people move in, and that feeds the deforestation process. Think of logging as the first land-use change (Asner 2005).

Brokaw *et al.* (1998:228) studied the effects of traditional selective logging in Belize.

> At a site logged two to five years earlier, we found about one mahogany above the diameter limit (60 cm) in every 9 hectares. Some of these were hollow or malformed trees and of no value to loggers. The number of harvestable mahogany was insufficient to support a forestry enterprise. Nor did the numbers in smaller size classes promise much future yield: there were about two mahogany >10 cm diameter in every hectare of forest. Mahogany regeneration was most abundant, grew fastest and survived best along major roads or in similar, open areas. The gaps left after removal of single trees contained a few seedlings, but these survived and grew poorly.

The conclusion is that the traditional selective logging needs to be replaced with a new silvicultural method, essentially in the direction of "selection harvesting".

Experiments have been made with: (1) "selection, marking and directional felling" (Bruenig 1996), where the special goal was to use more wood species, enhance growth of remaining trees, promote regeneration and reduce damage associated with traditional selective logging (Bird 1994, quoted in Brokaw 1998:233); (2) "liberation thinning" where trees in the vicinity of the selected individuals are killed (via girdling) to improve the productivity, quality and number of selected species (Hutchinson 1987, quoted in Brokaw 1998:233); (3) "patch cuts" where locally all trees are removed to create sites favourable for the regeneration of mahogany and other timber species with similar ecology and to reduce damage (Programme for Belize in the Extraction Zone 1996, quoted in Bruenig 1998:234).

Large areas of rainforest are destroyed in order to remove only a few logs. The heavy machinery used to penetrate the forests and build roads causes extensive damage. Trees are felled and soil is compacted by heavy machinery, decreasing the forest's chance of regeneration. The felling of one "selected" tree tears down with it climbers, vines, epiphytes and lianas.

Removing a felled tree from the forest causes even further destruction, especially when it is carried out carelessly. It is believed that in many South East Asian countries "between 45–74% of trees remaining after logging have been substantially damaged or destroyed" (WWF). Logging roads are used by landless farmers to gain access to rainforest areas. For this reason, commercial logging is considered by many to be the biggest single agent of tropical deforestation. Apart from its direct impact, logging plays a major role in deforestation through the building of roads which are subsequently used by landless farmers to gain access to rainforest areas. These displaced people then clear the forest by slashing and burning to grow enough food to keep them and their families alive, a practice which is called subsistence farming (Kemon Rain Forest Essay 2017).

A four-year, comprehensive survey of the Amazon Basin in Brazil reveals that selective logging – the practice of cutting down just one or two tree species in an area – creates an additional 60–123% more damage than deforestation alone. Another concern is climate change. "When a tree trunk is removed, the crown, wood debris and vines are left behind to decompose, releasing carbon dioxide gas into the atmosphere," says Gregory Asner (2005), a tropical ecologist at the Carnegie Institution for Science at Stanford University.

> Sawmills often have an efficiency level of about 30–40%, so large amounts of sawdust and scrap also decompose into atmospheric CO_2. An estimated 400 million tons of carbon enter the atmosphere every year as a result of traditional deforestation in the Amazon, and Asner and his colleagues estimate that an additional 100 million tons is produced by selective logging. "That means up to 25% more greenhouse gas is entering the atmosphere than was previously assumed, Asner explains. This is a finding that could alter climate change forecasts on a global scale.

7.3 Use and abuse of the name

Strictly speaking the name "mahogany" only belongs to species from the genus *Swietenia* (family Meliaceae, the mahogany family): *S. mahagoni* (L.) Jacq., *S. humilis* Zucc. and *S. macrophylla* King. Lamb (1963) also "granted" the name "mahogany" to representatives of the African genus *Khaya*, since the two genera are practically indistinguishable in botanical and xylotomic terms and almost identical in terms of usefulness. Their (absolute) similarity was of course also observed by members of the Nigerian Yoruba tribe brought to Jamaica as slaves (see below!). Under this expanded definition we could refer to representatives of the American *Swietenia* genus as "American mahogany" and representatives of the African *Khaya* genus (*K. anthotheca* (Welw.) C.DC., *K. grandifolia* C.DC., *K. ivorensis* A. Chew and *K. nyasica* Stapf) as "African mahogany".

> The history of the term mahogany raises a taxonomic controversy. When members of the Yoruba tribe were brought from Nigeria to Jamaica as slaves, they recognised a tree in Jamaica that was just like one at home. The American mahogany, *S. mahagoni*, looked almost identical to the African mahogany, *Khaya senegalensis*. For this reason the Yoruba referred to American mahogany with the same word they used for African Mahogany, *M'Oganwo*. Over time the term was changed to *M'Ogani* by the Yoruba. Americans spelled it how they heard it, and thus *M'Ogani* became *Mahogany*. The controversy is that the Yoruba believed African and American mahogany to be the same tree, but French botanist Adrien de Jussieu (1830) insisted that they were from two different genera. He based this on his African mahogany specimens having four-parted flowers instead of the five parts displayed by American mahogany. In March 1960 a study of American mahogany was carried out in Mexico. It resulted in enough fruits and flowers with four parts to disprove the myth that American mahogany is only five-parted, this being the only diagnostic difference between African mahogany, *Khaya* and American mahogany, *Swietenia.*

The Yoruban insistence, in the Jamaica of the 1600s, on both mahoganies being the same tree prompted the 1960 study that verified their belief (Herron 1999).

The classification of the species of the American genus *Swietenia* as “genuine mahoganies” and all the commercial members of the Meliaceae family, i.e. the genera *Toona*, *Cedrela*, *Entandrophragma*, *Guarea*, *Chukrasia*, *Cabralea*, *Trichilia*, *Carapa*, *Dysoxylum*, *Synoum*, *Melia* and *Lovoa,* as “true mahoganies” is problematic and scientifically unsustainable. While the terminology dividing mahoganies into "genuine" and "true" mahoganies is attractive for commercial reasons, since it broadly emphasises the magic name "mahogany", the difference between "genuine" and "true" is barely perceptible. It is generally used by guitar makers (cf. Gaskell 2015).

One further “division”: Melville (1936) distinguishes between “true mahoganies”, which only include the members of the genus *Swietenia*, and all other “mahoganies” – including the other members of the Meliaceae family – which he classifies as “false mahoganies”.

Though misleading and unnecessary from the botanical point of view, the epithets “genuine”, “true” and “false” are unfortunately widely established and it will not be easy to get rid of them. “False mahoganies” in particular would better be named “substitutes” on account of their usefulness.

Malone (1965), who has researched the origin of the name “Mahogany” claims that the name means nothing more or less than “wood” and could therefore be used more broadly. This, however, would further increase the already somewhat unmanageable terminological confusion.

Mahogany’s long popularity as a cabinet wood is the reason why so many “substitutes”, completely unrelated to mahogany, bear its name. Any wood which approximates to it, even remotely, in colour and texture, seems to qualify for the magic name “mahogany”. The mahoganies of commerce are thus a huge and motley collection of timbers (Jane 1970:368). Mahogany’s renown as a material for piano cases is also the background of an amusing anecdote about the composer Rossini (1792–1868). His famous William Tell, the legend of Switzerland’s national hero of liberty, had long been announced, yet there was no sign of it. Rossini’s legendary laziness was well known, as was his passion for fine cuisine, which almost exceeded his passion for composing. After countless fruitless attempts to encourage the great composer to sit down to work, the critic Charles Maurice came up with a brilliant ruse as a last resort. One morning a startling piece of news appeared in Le Courrier des théâtres: “The mahogany tree that is to provide the wood for the piano that will be presented to Rossini to enable him to set the promised work to music has finally been planted in America.” Apparently Rossini delivered the finished score two weeks later. We know, of course, that the tree was *Swietenia macrophylla* or caoba.

Table 7. shows the members of the genus *Swietenia* (“genuine mahoganies”), other species of the Meliaceae family (“true mahoganies”) and the botanically entirely unrelated “false mahoganies”, which in texture and figure are at least slightly (“at a distance”) similar to “genuine mahogany” with the following characteristics present in varying degree: reddish colour of the heartwood, blister, stripe or roe, curl and mottle figure. Naturally this list is only a limited selection, but it nevertheless indicates the incredible popularity of mahogany, which has encouraged the false naming of substitutes (cf. e.g. Zinnkann 2002:44). The result is names that have nothing to do with botanical classification, for example “Filipino mahogany”, which is not mahogany at all, or “African walnut”, which is not even remotely botanically related to the walnuts (genus *Juglans*), and yet is not classified among the “false mahoganies” (see Table 7.) because to the British and the Germans it seemed more similar to walnut, another precious wood, and so on. In a technical description or determination of types of wood, the only sensible approach is to always use the scientific names or normalised “primary” names as used in, for example, the German DIN system or the British Standards (BS) system. The Germans refer to incorrect names as “Fehlnamen” (cf. Holzlexikon 2003:356).

The problem of false names also occurs elsewhere. Such names unquestionably bring disorder to the already overabundant and technically problematic terminology of commercial names. Thus the *Afrikanisch Nussbaum* (“African walnut” is not a *Nussbaum* (walnut) from the genus *Juglans* and the botanical family Juglandaceae, but a dibétou (*Lovoa trichilioides*), which is actually from the Meliaceae family.

TABLE 7. 1 "Genuine" mahoganies (species of the genus Swietenia) and limited selection of "true" mahoganies (species of genera of the Meliaceae family other than *Swietenia*) as well as "false« mahoganies" ("mahoganies" other than Meliaceae), standardised name bolded, see also Melville 1936).

	Latin name	Common name	Comercial name	Region of origin
"Genuine mahoganies" (members of the genus *Swietenia*)	*Swietenia mahagoni* Jacq.	West Indies mahogany, Spanish mahogany		
	S. macrophylla King	caoba, Honduras, Mexican, Nicaraguan, Brazilian, Peruvian mahogany, Bigleaf mahogany		
	S. humilis Zucc.	caobilla, Pacific mahogany		
"True mahoganies" (members of the Meliaceae family other than the three *Swietenia* species)	*Carapa guianensis* Aubl.	Demerara mahogany, Brazilian m., royal m.	**andiroba**	Guyana, Central and S America
	Chukrassia tabularis A. Juss.	Indian mahogany,	**chickrassy**	SE Asia
	Dysoxylum fraserianum Benth	Australian mahogany, rose m., Australian rosewood, rosewood		Australia.
	Dysoxylum spectabile Hook.f.	New Zealand mahogany	**kohekohe**	New Zealand
	Entandrophragma angolense (Welw). C.DC.	quibaba da queta mahogany	**tiama**,	Angola
	Entandrophragma candollei Harms	kosipo-mahogany, heavy m., scented m	**kosipo**	tropical W Africa
	Entandrophragma cylindricum Sprague	sapelli-mahogany, cedar m.	**sapelli**	tropical W Africa
	Entandrophragma utile Sprague	sipo mahogany, cedar m.,	**sipo**	tropical W Africa
	Guarea cedrata Pellegr.	pink mahogany, bosse m.	**bossé**	Ivory Coast
	Khaya anthotheca C.CD.	Gaboon mahogany, white m.	"**African mahogany**" (the only commercial name)	Nigeria, Ivory Coast
	Khaya ivorensis A. Chev.	red mahogany, Lagos m., Grand Bassam m., African m.	"**African mahogany**" (the only commercial name)	Ivory Coast to Gabon
	Khaya senegalensis A. Juss.	Benin mahogany, Togo m., African m.	"**African mahogany**" (the only commercial name)	Sudan, Uganda
	Melia composita Willd.	Indian mahogany	**hill neem, Malabar neem**	Sri Lanka, India
	Soymida febrifuga A. Juss.	East Indian mahogany	**Indian red wood**,	Sri Lanka, India
	Toona calantis Merr. & Rolfe	Philippine mahogany	**kalantas**	Indonesia, Malaysia, Philippines
	Toona ciliata M.Roem. (syn. *T. australis*)	Indian mahogany	**Indian mahogany**	Bangladesh, Cambodia, India, China, SE Asia, Australia
	Toona sinensis (A. Juss.) M. Roem.	chinese mahogany	**Chinese toon**	E and SE Asia
	Toona sureni (Blume) Merr. (syn. *T. febrifugaz*	Indonesian mahogany, Vietnamese m.	**suren toon**	SE Asia
	Turraeanthus africana(Welw. Ex C.DC) Pellegr.	African white mahogany	**avodiré**	Congo, Sierra Leone, Angola
	Trichilia emetica Vahl.	Natal mahogany	"**Natal mahogany**" (the only commercial name)	Cape m., S Africa
	Trichilia dregeana Sond.	forest Natal mahogany	"**forest Natal mahogany**" (the only commercial name)	S Africa

	Latin name	Common name	Comercial name	Region of origin
"False" mahoganies ("mahoganies" other than Meliaceae)	*Aucoumea kleineana* Pierre, Burseraceae	Gabon mahogany	**okoume**	W Africa
	Canarium euphyllum Kurz, Burseraceae	Indian white mahogany	**white dhup**	SW India
	Canarium schweinfurthii Engl., Burseraceae	Gaboon mahogany	**aiélé**	Nigeria, Central Africa
	Cariniana legalis O. Ktze, Lecythidaceae	Brazilian m.	**Jequitiba**	S America
	Cariniana pyriformis Miers, Lecythidaceae	Brazilian mahogany, Columbi-an m.	**abarco**	S. America
	Enterolobium cyclocarpum (Jacq.) Griseb., Fabaceae	juana costa-m.	**guanacaste**	Central and S America
	Eucalyptus acmenioides Schauer, Myrtaceae	white mahogany	**white mahogany**	NSW, Queensland
	Eucalyptus marginata Sm., Myrtaceae	bastard mahogany	**jarrah**	W Australia
	Eucalyptus resinifera Sm., Myrtaceae	Australian red mahogany, for-est m.	**red mahogany**	NSW, Queensland
	Eucalyptus robusta Sm., Myrtaceae	white mahogany, swamp m.	**swamp mahogany**	NSW, Queensland
	Gossweilerodendron balsamiferum Harms, Fabaceae	pink mahogany	**agba**, **tola branca**	W Africa
	Guibourtia coleosperma (Benth.) J. Léonard, Fabaceae	Rhodesian mahogany	**mehibi**	DR Congo, Zambia, Angola, Na-mibia, Botswana, Zimbabwe
	Nothofagus procera Poep. & Endl., Fagaceae	Chilean mahogany	**rauli**	Chile
	Pentace burmanica Kurz, Tiliaceae	Burma mahogany	**thitka**	Burma
	Prunus serotina Ehrh., Rosaceae	New England mahogany	**American cherry**, **black cherry**	East USA
	Pterocarpus dalbergioides Roxb., Fabaceae	East Indian mahogany,	**Andaman padauk**, **Andaman redwood**, **vermillion wood**	Andaman Islands
	Pterocarpus indicus Willd., Fabaceae	Indian mahogany	**amboyna**	India
	Shorea spp., esp. *S. paucifolia*, Dipterocarpaceae	Borneo mahogany	**/**	Borneo
	Shorea almon Foxw. /*Shorea exima* Fokw., Dipterocarpaceae	Philippine mahogany	**white lauan**, **almon**	Philippines
	Shorea polysperma Merr. and *Shorea* spp., e.g. *S. negrosensis* Foxw., and *S. squamata* Dyer / *Shorea palosapis* Merr., Dipterocarpaceae	Philippine mahogany	**red lauan**, **tangile**	Philippines
	Sickingia salvadorensis (Standl.) Standl. syn. *Simira salvadorensis* (Standl.) Steyerm.), Rubiaceae	Dominican mahogany	**chacte coc**	Mexico, Mid. America
	Tabebuia donnell-smithii Rose, syn. *Cybistax donnellsmithii* Seibert, Bignoniaceae	white mahogany	**primavera**, **tabebuia**	Mexico, Mid. America
	Tarrietia utilis Sprague, Sterculiaceae	brown mahogany	**niangon**	W Africa
	Tieghemela heckelii Pierre, Sapotaceae	cherry mahogany	**makore**	W. Africa

7.4 Origin of the name "mahogany"

The name appeared in initially "Spanish" Jamaica after it was captured by the English in 1655 with little resistance from the Spanish (the name "Jamaica" derives from the Arawakan word *Xaymaca* meaning "land of wood and water"). The Oxford English Dictionary (1989), the Longman Modern English dictionary (1976) and Merriam-Webster's Collegiate Dictionary (1994) state that the name is of unknown origin. The Random House Webster's Unabridged Dictionary (1993) is a little more cautious, giving the etymology of the word as "some non-Carib language of the West Indies". The American Heritage Dictionary of the English Language, 4th edition, Houghton Mifflin Comp. (2000) even states that the name is of Mayan origin! Record and Hess (1943) state that the name mahogany is "presumably a term of native origin". Beyse (1994) claims without evidence that the name is of "Indian" origin, and so it goes on. In fact it is possible to trace the origin of today's name "Mahogany" to the West African or Nigerian rainforest (cf. Lamb 1963, 1966). Members of the *Khaya* genus from the Meliaceae family (*K. ivorensis* A. Chev., *K. anthotheca* C. DC. and *K. grandifolia* C. DC., Meliaceae), which are marketed under the name "African mahogany" and, depending on their geographical provenance, may also be known as "Benin mahogany", "Lagos mahogany" and "Nigerian mahogany" are known to the Nigerian Yoruba or Ibo (Igbo) people as *M'Oganwo* or *Ogangwo* (cf. Lamb 1963, 1966; Keay 1996). It is perfectly logical that the Yoruba, after being forcibly transported from Nigeria to the New World by English slave traders should have given the botanically closely related and extremely similar looking "mahogany" tree the same name as the khaya of their old homeland: M'Oganwo! In the Yoruban language *oganwo* means "very tall", while the prefix "*M*" means "abundant" (Keay 1996). Perhaps this tree was the only thing to cheer up the unfortunate slaves who had survived their months-long inhumane journey to the New World. The name had certainly arrived in Jamaica by 1697 (if not earlier), when the Parliament of England passed a law extending the right to participate freely in the slave trade to all subjects of the kingdom. This prompted a boom in the trade in African slaves. In just two years (1698–1700), private slave traders had brought 42,000 black slaves to Jamaica (Ki-Zerbo 1977). Jamaica remained the centre of the slave trade until the abolition of slavery in the British Empire (1833). The art of the Yoruba was of astonishingly high quality. One legend claims that it had its roots in Etruria (now Tuscany) and reached Africa via the fabled island Atlantis. The performing arts of the New World, Caribbean calypso, blues from St Louis and the boundless wealth of North American black music all have their roots in Yoruba culture. For more than two hundred years, English, Dutch and Portuguese slavers traded in human beings for profit. White Europeans referred to the coast of the Gulf of Guinea as the Slave Coast.

The name "mahogany" thus conceals the tragic history of African slavery. How many people – "negroes", to use the term in use at the time – did Africa lose because of the slave trade? Estimates range from 40 million to 100 million! (Paczensky 1979: 165). No one has apologised to the Africans, let alone materially compensated them for their tragic destiny. The slave traders' strongholds or slave ports of Gorée in Senegal, Elmina on Ghana's Cape Coast and Gbererfu Island in Badagry, Nigeria, from where the slaves were transported to the New World, are today a permanent reminder of the slave trade.

The further development of the name, as stated by a wide variety of sources and summarised by Lamb (1963, 1966), was roughly as follows, before the name eventually consolidated itself as the "mahogany" we know today:
mogno (1661) > mahogeney (1671) > moganeel (1700) > mohogony (1700) > mohagony (1702) > muhagnees (1709) > mohoganees (1710) > mahoganey (1711) > mahoganees (1713) > mahogany (1732) > mehogana (1733).

7.5 History of use

Mahogany was used by native peoples in pre-Columbian times because of its noteworthy dimensions, form and other properties. The ancient Maya city of Chactemal ("place where the red wood grows" – a reference to mahogany), present-day Chetumal, the capital of Mexican state of Quintana Roo, was a centre of the manufacturer of large mahogany canoes. On his fourth voyage in 1502, Columbus encountered a 25-metre long, three-metre wide mahagony canoe crewed by Maya traders travelling between the Yucatán Peninsula and the coast of Honduras.

This was also European explorers' first encounter with mahogany (and with cocoa beans, which the Maya and Aztecs used as a means of payment).

Although probably utilised earlier for ship repair and construction, the fist recorded use of mahogany by the Spaniards was in 1514, when they used it in the construction of the cathedral in Santo Domingo. Wooden carvings and a rough-hewn mahogany cross bearing this date are still very well preserved today. The remains of Christopher Columbus and his son Diego reposed in this cathedral for almost 250 years. The early accounts of mahogany were given by early explorers shortly after the discovery of America.

The value of the wood for repairing ships was soon appreciated, Cortés using it in 1521 and Sir Walter Raleigh in 1597 (Melville 1936).

Many of the first vessels constructed by the Spaniards were made of mahogany (Chambers 1851, quoted in Lamb 1966:10): “The wood was probably used by [Velázquez] at Santiago, Cuba in the ships outfitted for Grijalva, Olid, [Cortés] and Narváez for their voyages of exploration and the conquest of Mexico (Chaloner 1850, Greenway 1947, Oviedo 1539, quoted in Lamb). Santiago has been one of the main sources of Cuban mahogany since the discovery of the New World”.

Almost 500 years have passed since Don Gonzalo Fernández de Oviedo y Valdés, court chronicler to Emperor Charles V, summed up the outstanding qualities and beauty of mahogany (not yet known by that name!) with the following words, written in 1535: “*En todas partes del mundo sería estimada esta madera*” (In all parts of the world this wood would be esteemed). He certainly was not wrong.

The first recorded use of mahogany in Spain, and thus in Europe, was for furniture and fittings at El Escorial, the royal palace, monastery and burial site of the Spanish Habsburgs near Madrid, which Philip II began building in 1579 (it was completed in 1584). One feature of the palace was an enormous and magnificent library with large *mahogany* bookcases inlaid with ebony, cedar and other woods: magnificence which redounded to the monarch’s glory. The Spanish Armada (navy) used *S. mahagoni* and later caoba (*S. macrophylla*) to build ships. The choir stalls of the cathedral at Lima in Peru and other Spanish colonial cathedrals were built of mahogany in around 1650.

The earliest imports of mahogany into England were from the cargoes of numerous Spanish prize ships captured by British privateers late in the sixteenth century (Symonds 1934; quoted in Lamb 1966:12). A “privateer” was a private person or ship commissioned by a belligerent nation to attack enemy shipping, particularly merchant shipping. Famous privateers, who could also be described as pirates, included Sir John Hawkins (1532–1595) the first British slave trader (whose ship was called the *Jesus*!); Sir Francis Drake (1543?–1596), an English landed gentleman, writer, poet, soldier, politician; and the most famous Englishman of that period, Sir Walter Raleigh (1554?–1618), with his *Golden Hind*, one of the most successful privateer ships in history. Among his other exploits, Raleigh went on a quest to find the fabled El Dorado in what is today Guaiana and “discovered” mahogany for the English (in 1595 or 1597). We actually owe the first description of mahogany to his ship’s carpenter, who used mahogany to repair the expedition’s ships during its South American voyage. Queen Elizabeth was so taken with the South American mahogany timber brought to England by Sir Walter Raleigh that she commissioned his ship’s carpenter to make her a mahogany table. This is said to be the first domestic use of mahogany in England.

Mahogany was certainly employed in England for shipbuilding and constructing wharves by the mid-seventeenth century, but its take-up as a furniture timber was slow. The reason for this was its glorious predecessor, European walnut (*Juglans regia*), the leading wood of the baroque period. The era between 1660 and 1730 was even known as the “Age of Walnut”.

In 1709 a particularly harsh winter destroyed most of Europe’s walnut tree stock. Matters were remedied, particularly in England, by importing walnut from America and the Caucasus. After 1730, however walnut was less often used in England and began to be replaced by mahogany.

Generally speaking, England depended largely upon international trade for the majority of its furniture timber – “deal” (pine from the Baltic, “wainscot” (oak) from Holland and walnut from Italy (Ancona), Spain and predominantly France, but taxes on exotic newcomers like mahogany put it beyond the reach of most timber merchants and cabinetmakers. Extant examples of early eighteenth-century mahogany furniture, though few, are made from the most exquisite Jamaican timber which confirms the high regard for the timber and bears out the theory of its high cost (Zinnkann 2002:70; Plane 2010).

England only came by its “own”mahogany with the conquest of Jamaica (1655). The first recorded purchase of “Jamaican wood” in England appears in the accounts for Hampton Court Palace in 1661. The first recorded piece of furniture, a chair (now in the museum at Trinity Hall, Aberdeen), dates from the same year. The mahogany panelling in several rooms of Nottingham Castle dates from 1680.

The use of mahogany in England really took off after the Naval Stores Act of 1721 reduced the tariffs on timbers imported from the Americas, marking the beginning of the general use of mahogany in Britain. The relaxation of duty was welcomed by English cabinetmakers at two levels: First, they realised mahogany’s unique properties – its ability to hold finer detail than walnut and its higher comparative strength. Secondly, the timing of the arrival of mahogany could not have been more opportune. The imported European walnut that England had relied so heavily on since the latter part of the seventeenth century was drying up. Brutal frosts during the winter of 1709 (Zinnkann 200:270) had devastated much of France’s walnut and the final blow came when France banned its exportation in 1720. Formerly the English walnut tree was much propagated for its wood, but since the importation of mahogany and the Virginia walnut, its reputation had decreased considerably. Walnut began to be used less in England after 1730 and was eventually replaced by mahogany. In 1733, the British Prime Minister Sir Robert Walpole reluctantly declared war on Spain, which endured until 1742. By this date, supplies of Jamaican mahogany were virtually exhausted and the conflict with Spain had predictable repercussions on the supply of mahogany from Spanish America. Domestic and colonial supplies of mahogany diminished rapidly and what there was of it fetched outrageous prices. In the ensuing years, shipments of *S. macrophylla* were imported from British-held Honduras. Relations with Spain improved again in 1748, resulting in the importation of the much sought after Cuban and Santo Domingo varieties of *S. mahagoni.* Further treaties with Spain in the second half of the eighteenth century saw the English extract enormous amounts of *S. macrophylla* from Belize. This continued until the Victorian period of the nineteenth century, when woods were imported from Italy and France, particularly the Auvergne (oyster veneer) (Zinnnkann 2002:70. In the latter half of the eighteenth century, French *ébénistes* also adopted mahogany and by the end of the century its reputation had spread across the whole of Europe (Maldonado and Boone 1968).

As regards shipbuilding, mahogany was also prized for its resistance to the elements. Mahogany planks and beams showed vey little deterioration, whereas other woods used in the same vessel, especially English oak, would be so decayed as to require replacement. (Chaloner 1850, quoted in Lamb 1966:13). Mahogany timbers removed from broken-up ships were often built into new ships or sold at high profit to cabinetmakers. Lamb (1966:13) describes the history of the most glorious mahogany plank as follows:

> One of the most famous men-of-war to be captured from Spanish fleet by the British was the eighty-gun *Juan de Córdoba*, built in Havana in about 1750 using mahogany brought from the Isthmus of Tehuantepec (Payton, 1926). She was captured in 1780 by Lord Rodney and renamed Gibraltar. When broken up in 1836 at the Royal Dockyard in Pembroke after many years of distinguished service, she was, according to Captain Chappel of the Royal Navy, who was present, one of the oldest ships afloat and yet her mahogany timbers were still sound (Chambers,1851, Lecky, 1914). This material was distributed to the royal shipyards and soon every important ship in the Royal Navy had a prized "Gibraltar table". These tables became traditional pieces of furniture in the Navy.

The period between 1725 and 1825 was a golden age for mahogany in England. It saw the development of four magnificent styles of furniture named after the cabinetmakers Thomas Chippendale, Robert and James Adam, George Hepplewhite and Thomas Sheraton. This was the Georgian period of the reigns of George II and George III. In France it coincided with the Louis XV, Louis XVI and Empire styles (cf. Forrest 1996). In the eighteenth century timbers from old ships were frequently reused in new ships or sold at a very high price to cabinetmakers. Chippendale has become a generic term applied to furniture made in London between about 1750 and 1765, and has come to represent timeless design excellence (Miller 2005:98).

Mahogany, cedar and other woods were shipped more or less regularly from the West Indies to Spain long before 1575, for Spain at that time dominated the world and its demand for shipbuilding timbers was enormous. Spain itself had no timber suitable for building ships and its unfriendly relations with northern Europe made drawing supplies from that source impossible; consequently it obtained timber from San Domingo, Cuba and Jamaica for building many ships of the Spanish Armada prior to 1588. A number of the largest Spanish ships were built of West Indies mahogany.

Spain turned to Cuba for supplies of timber suitable for ship masts, since the rebellion in Flanders (the Eighty Years' War began in 1566) had shut off that source. According to a passage quoted by the British naval historian Halton Stirling Lecky, Spain continued building ships from West Indies mahogany for two hundred more years.

The felling and transport of caoba in the basin of the great Río Usumacinta on the border between Mexico and Guatemala in the early twentieth century resulted in terrible suffering for the Maya. This is described in detail by the "mysterious" author B. Traven.

In order to evaluate biodiversity protection efforts in the southern region of the Montes Azules Biosphere Reserve, James D. Nations (1999) travelled on the Río Lacantún and Río Tzendales and visited Ejido Ixcán and the ruined logging camp La Constancia (See Map 2), which was set up in early 1894 and owes its much of its nefarious reputation to the works of Berick Traven Torsvan, who wrote in the early twentieth century under the name B. Traven (best known for the Mexico-based novel *The Treasure of the Sierra Madre*, later made into a film starring Humphrey Bogart) (Nations 2006:115–117).

The identity of Traven, who published a series of darkly impressive novels from Mexico, is mysterious. Traven has been described variously as English, American, Swedish, Norwegian, Lithuanian and German. He concealed his identity his whole life by using different names, among them Hal Croves, Ret Marut, Traven Torsvan and B. Traven. He also frequently referred to himself as "El Gringo". The Germans believe that he was German. According to some sources, his real name was Moritz ("Mauricio") Rathenau and he was the son of a rich German Jewish businessman and an Irish actress. Some claim that between 1917 and 1921 Traven was the publisher of the radical left-wing newspaper *Der Ziegelbrenner* in Munich (Hermann 2004:140).

But he may be Slovene! Brother and sister Ivana and Martin Traven from the village of Utik (north of Ljubljana) identified their brother Franc Traven, who had disappeared after the First World War, in a photograph printed by a Ljubljana weekly that purported to show a man named Hal Croves, supposedly Traven's agent. A number of clues indicate that "B. Traven" was not a pseudonym and that Hal Croves and B. Traven were the same person: the missing son of a Slovene carpenter. To me personally the matter is even more interesting because I live in the village of Skaručna, just 4 kilometres from Utik. Not only that, but the roof of my house was built by a master carpenter called Traven from Utik!

The Rebellion of the Hanged (in the German original *Die Rebellion der Gehengten*) is the fifth of B. Traven's six legendary "Jungle Novels", also known as the "Caoba Cycle", which together form an epic of the birth of the Mexican Revolution. Set in the slave-labour mahogany forests of tropical Mexico in 1910, at the time of the uprising against the rule of Porfirio Díaz and the beginnings of revolution, *Rebellion* is a powerful and sombre tale of the tortures suffered by downtrodden Indians.

According to Nations (2006:115), "Traven travelled in the Selva Lacandona three times: 1925, 1929 and 1930) and interviewed workers who had laboured in the logging camps of Casa Romano, a profitable enterprise owned by two brothers from Spain. The resulting *Rebellion of the Hanged*, established *La Constancia* as the scene of cruel, forced labour under terrifying conditions." (Zogbaum 1992:97, Tello Diaz 2004:34, quoted in Nations 2006: 116).

> If he (the *montero*) encountered a promising stand of mahogany or cedar, the operator would construct a main house and work quarters on the banks of the river closest to the stand of trees. The names of emerging camps expressed faith in the potential *bonanza* to be generated by these *monterías*: "Hope", "Destiny", "Forthcoming", "Desire", "Paradise", "Progress" and "Constancy" – *La Constancia* (De Vos 1988a:55-56, quoted in Nations 2006:123)

Rodulfo Brito Foucher, who visited *La Constancia* in the 1920s, wrote a scathing account of living conditions there (quoted in Nations 2006:123-124):

> The life of the workmen, from the day they arrive until they die, is one of monotony and indescribable difficulty. At three or four in the morning the foreman sounds his horn and the workmen wake up and breakfast on black coffee and black beans. When the sun rises, they must be at the foot of the tree they will cut or besides the felled tree trunk they are to debark. There they work until noon, when they pause for a meagre lunch. In the afternoon, they return to camp, ingest more black coffee and beans, and fall asleep, only to rise again the following day and continue this eternal drill. They dress in twill pants, cotton shirts, sombreros, and straw sandals.

Today only a few brick columns remain standing at *La Constancia.*

Conditions in the land of caoba are also described by Rudi Palla in his interesting work *Unter Bäumen* (2006) in the chapter "Der Marsch ins Reich der Caoba" (literally: March into the Kingdom of the Caoba), which also happens to be the original German title of the third of Traven's "Jungle Novels", published in English as March to the Montería (1934). Traven drew the material of the novel from his own experiences when taking part in a scientific expedition led by Enrique Juan Palacios, inspector of archaeology. Some commentators (e.g. Westphal 1986:344) even assume that Traven worked for a time in one such *montería.* He described the uprisings of caoba workers during the Mexican Revolution in around 1911. In the former *monterías* – woodcutters' camps deep in the Usumacinta forests – he visited the "El Real" ranch, part of the *latifundio* (estate) of the Bulnes family, who were originally from Spain. It should be remembered that under the dictatorial regime of President Porfirio Díaz (ousted by Francisco Ignacio Madero in 1911), rich Mexico had opened its doors to foreign investors, many from the USA and Britain. Díaz also expropriated communal landholdings ("*terra devoluta*") that actually belonged to indigenous peoples (Indios) and incorporated them in the *latifundios* of rich landowners. At that time as much is 85% of the territory of Mexico belonged to approximately 800 *finqueros* (landowners), while the native people lived as peons in desperate poverty. The Bulnes family were among these *finqueros*. Their ranch was surrounded by rich caoba forests where *hacheros* (woodcutters) and *boyeros* (drovers) suffered endlessly under the coercion of the *capataces* (foremen). The life of these unfortunates is also described by the Danish archaeologist Frans Blom in his work *La Selva Lancandona*. One particularly cruel *capataz*, Maximiliano, was said to cut off the feet of workers who tried to escape. All this is described by Traven in his books. It should be remembered that in those days there were no tractors or chainsaws to make the work easier (and on the other hand to accelerate the clearance of the forests).

In 1913, during the Mexican Revolution, a small brigade of revolutionaries marched south of Tenosique to liberate the workers held captive in the *monterías.* Although they destroyed some of them, they did not find them all, and Casa Romano continued operating in the southern Selva Lacandona until 1933. (De Vos 1988:228; quoted in Nations 200:128).

But now for the more beautiful side of mahogany! It is an interesting fact that 296 of the total 577 works painted by Rembrandt (1606–1669) were on wood panels. In most cases, of course, the wood used was oak. This was followed by walnut, poplar, beech (!) and, in six cases, mahogany (Bauch & Eckstein 1981 and personal communication). (In his mature period Rembrandt, like other painters, turned increasingly to canvas).

Mahogany or ***puuna' (äh)*** played an essential role in Lacandon material culture, e.g. in house construction, for various artefacts, as an indicator species in the agricultural round, its bark as a fish poison and for red dye (quoted in Cook 2016:229). The juice of the boiled fruit is drunk to relieve toothaches and fever (Kashanipour and McGee 2004:62).

7.6 Xylotomy and properties

The woods of *Swietenia macrophylla* King and *Swietenia mahagoni* (L.) Jacq. have vessels with exclusively or predominantly simple perforations, minute intervascular pitting, coloured or white deposits of gum or other substances in vessels in heartwood, traumatic axial (vertical) intercellular canals, i.e. canals of the "gummosis" type formed in response to injury to the tree, septate fibres, rays commonly 10 cells wide, heterogenous ray tissue type II, heterogenous ray issue type III, storeyed rays, small pits to vessels, terminal or initial parenchyma, diffuse, i.e. single apotracheal parenchyma strands or cells, predominantly paratracheal parenchyma, vasicentric parenchyma, axial vertical elements are storeyed, rhomboidal crystals in ordinary cells of rays, growth rings are sufficiently distinct and regular to indicate regular seasonal growth (Brazier and Franklin 1961).

The timbers of the species of *Swietenia* cannot be distinguished with certainty, but generally the wood of caoba / big-leaf mahogany, Central American mahogany (*S. macrophylla*) is less dense than that of Cuban or Spanish mahogany (S. *mahagoni*), having a density about 545 kg/m^3 in dry air conditions as compared to the 640–800 kg/m^3 of the finer-textured Cuban mahogany (Jane 1970:372; cf. Brazier and Franklin, 1961).

The woods of the *Swietenia, Khaya and Cedrela* genera are difficult to distinguish xylotomically because of their close evolutionary or botanical kinship. Unlike the *Khaya* genus, the Swietenia genus has axial (vertical) elements, i.e. storeyed axial parenchyma and vessel elements (storeyed rays not always present), while the *Cedrela* genus differs macroscopically from the Swietenia genus in terms of vessels visible to the unaided eye (mean tangential diameter more than 200 micrometres and (consequently) lower density and an absence of storeyed structures (cf. Brazier and Franklin 1961). American and African mahoganies, if we are going to use these commercial names, differ most in terms of texture and figure, density and natural durability, while there are no major differences in physical, mechanical properties, except those that can be explained by density (US Forest Products Laboratory). Even the differences, we can see with a lens, are quite small and based above all on vessel size, the presence, visibility and distribution of axial parenchyma ("soft tissue") and rays, the distinctness of growth rings and, of course, colour (cf. Identification of hardwoods – A lens key 1970).

Catesby (1743, quoted in Keay 1996) described "Island mahogany" (*S. mahagoni*) and its wood as follows:

> The tree increases to a stupendous size in few years, it being a quick grower. . . . The excellency of this wood for all domestic uses is now sufficiently known in England; and at the Bahama Islands, and other countries, where it grows naturally, it is in no less esteem for ship-building, having properties for that use exceling oak and all other wood, *viz*. durableness, resisting gunshots and burying the shot without splintering.

Generally the density and its variation is the most important single wood property indicating roughly the range in variation of physical, mechanical and technological properties as well as anatomical structure, especially the proportion of thick-walled fibres and thin-walled parenchyma. Lamb (1966: 22,23):

> *S. mahagoni* tends to be finer in texture, harder, darker in colour, and denser than *S. macrophylla*. However, the wood of West Indies when grown on rich, alluvial soils, supplied with abundant moisture the year round may approach Central American mahogany in its characteristics, and Central American mahogany tees on dry, exposed sites may produce dense wood approaching the characteristics of West Indies mahogany. *S. humilis*, growing on dry, exposed sites produces wood similar to *S. mahagoni*, but on most sites the wood resembles *S. macrophylla*. The woods of *S. mahagoni* and *S. macrophylla* when grown together in plantations in Java show only minor differences in wood characteristics.

The maximum range in density ρ_0 of the mahoganies is generally between 340 and 900 kg/m^3 (Dixon 1918; Koehler 1922). The density of *Swietenia macrophylla* is 430 to 610 kg/m^3 and the density of *S. mahagoni* 630 to 820 kg/m^3. In terms of density their strength is relatively high, while impact strength and cleavage strength are relatively low.

The colour of heartwood varies from reddish- or yellowish-brown to dark reddish-brown, with high natural lustre. The heavier material is generally darker in colour. Grain tends to be interlocked (double spiral grain), but there is a fair proportion of plain, straight-grained timber. Irregularities of grain produce a variety of figures: fiddleback, blister, stripe or roe, curl, mottle, etc. Texture is moderately coarse, but generally finer than African mahogany (*Khaya*) (Handbook of hardwoods 1972). There are also various forms of figure arising from grain patterns that diverge markedly from the straight-grained condition. Certain of these are clearly visible from outside, for example crotch figures, associated with the departure of major branches from the trunk, which are especially prized (Wilson and White 1986:185-6) Particularly notable and precious examples include “feather crotch figure”, produced when a cut passes through the centre of the crotch at the point where the trunk divides into two equal (codominant) trunks. If the cut does not pass through the centre of the crotch, this results in a “swirl crotch figure”. If the twisted growth layers in the crotch are very wide (“open-grained”), this results in an effect known as “moonshine crotch figure”. Plain-sawn boards can produce marvellous “flame-figured” wood (large U-shaped patterns of grain).

The wood is very easy to work. It saws, planes and moulds easily in both green and dry condition. It finishes to an exceptionally smooth, lustrous surface, but a woolly surface may occur on bands of reaction wood or interlocked grain.

The wood takes an excellent polish, gluing and nailing properties are good, but discoloration in contact with iron, copper and brass may occur under humid conditions.

Mahogany can be divided for convenience into four main categories (Buttler, 1985: 35,36):

> Jamaican wood (*S. mahagoni*) of which the earliest mahogany furniture was made, is very dark and heavy. When freshly cut wood ha san almost purple hue, with characteristic white flecks in the grain. When observed on an unrestored piece, it usually accumulates a greenish, ray-black surface almost resembling bronze where it is not polished regularly. It has little figure and an account of its density and the closeness of the grain is well suited to mouldings and carvings, which remain very crisp. It is said that this early mahogany, seldom seen after 1745, grew only by the coast and that the supply was used up quickly as it was easier to take wood from coastal areas than to cut inland through dense tropical forest.
>
> When stocks of the very dense Jamaican wood were exhausted, importers turned to the less desirable Cuban wood (*S. mahagoni*). This varies little in colour except when subjected to prolonged sunlight and is within a few shades of a reddish tan. Cuban mahogany weighs about half to two-thirds as much as Jamaican wood, but compensates for its lack of density by a considerable range of figure. The most common Cuban figure is the flame figure, while more unusual and therefore more sought after figures are plum pudding, roe, fiddleback and splash.
>
> San Domingo mahogany (*Swietenia mahagoni*) is also called Spanish mahogany, as it originally came from the Spanish colonies of the West Indies. It was considered to be of better quality than Cuban wood and is denser and of a slightly darker hue. It exhibits fewer figures but is often somewhat “stripey” or “cloudy”. The grain tends to be straighter thab in Cuban wood and

is consequently stronger, making this type of mahogany more suitable for use in fine quality legs and other structural parts. Many experts find the difference between Cuban and San Domingo mahoganies very difficult to perceive.

Honduras mahogany or caoba (*Swietenia macrophylla*) cut from trees on the South American mainland away from the coast, was also known as baywood. It is inferior to other mahoganies, being considerably lighter in colour and density. It has few figures, but during the last quarter of the eighteenth century was considered adequate for drawer linings and other non-visible and utilitarian parts of furniture. Cheaper furniture was made entirely of baywood, which was much used after about 1870, when many of the finer woods were exhausted.

Thanks to its remarkably homogeneous structure, mahogany also has outstanding technological characteristics (workability, stripping, cutting, nailing, see also Chapter Four). Once again I should emphasise in particular its drying or seasoning. The wood dries well, without much checking or distortion, and kiln-dries satisfactorily. Drying wood without juvenile wood and tension wood is entirely unproblematic and can even be carried out under the burning tropical sun (given the high relative air humidity): free, without restraint and without spacer strips (known as stickers) (Figure 2). Its dimensional stability is remarkable. Table 1 shows the percentage of shrinkage from green condition to the equilibrium moisture content in a "normal" climate (EMC 21 °C/65% rel. humidity, DIN 50014, 1985; DIN/EN 310, 1993) and the indicators for evaluation of dimensional stability: differential swelling *q* and swelling coefficient *h.* Differential swelling *q* and swelling coefficient *h* give the radial or tangential change in wood dimension in the case of a 1% change in wood moisture content or relative air humidity in the quasi-linear region of the sorption isotherm. Differences and quotients of differential swelling and swelling coefficients in the tangential and radial directions are also given. These give transverse swelling anisotropy and thus the shape stability of wood. For comparison purposes, values are given for "problematic" European beech wood (*Fagus silvatica L.*) and teak (*Tectona grandis L.f.*), an excellent wood for shipbuilding that is likewise distinguished by outstanding natural durability, dimensional stability and a decorative appearance, especially the colour and lustre of the heartwood (see Chapter Four for more information).

TABLE 7. 2. The caoba/large-leaved mahogany (*Swietenia macrophylla*). Seasoning shrinkage β_N and indicators of dimensional stability in comparison with beech (*Fagus silvatica*), teak (*Tectona grandis*) and Norway spruce (*Picea abies*) (Torelli 1982, Torelli and Gorišek 1995 a, b, c).

Species	ρ_o [kg/m3]	β_N rad [%]	β_N tang. [%]	q_T [%/%]	ρ_T-ρ_R [%/%]	ρ_T/ρ_R [%/%]	h_T [%/%]	$h_T - h_R$ [%/%]	$h_{T/}h_R$ [%/%]
Swietenia macrophylla	600	2.0	3.0	0.27	0.10	1.59	0.041	0.015	1.58
Fagus silvatica	660	4.0	8.0	0.41	0.21	2.05	0.065	0.033	1.91
Tectona grandis	650	1.5	2.5	0.26	0.10	1.63	0.035	0.013	1.63
Picea abies	450	2.0	4.0	0.36	0.17	1.90	0.070	0.033	1.89

Thanks to its outstanding qualities and usefulness as an all-purpose wood, mahogany is rightly classified among precious woods. Its properties are generally excellent: the movement is small, drying and working characteristics very good and the durability of the heartwood high; for details and comparison with other woods, see Property sheets). Unfortunately, fast growth in young trees, and especially in plantation trees, is associated with a high amount of technologically problematic juvenile and tension wood, resulting in fuzzy grain and an abnormally high axial shrinkage, causing warping and checking during drying.

Today the most precious of the mahoganies, namely West Indian/Spanish mahogany, can only be seen in the form of panelling and fine furniture in baroque palaces and churches, parliament chambers, courtrooms, libraries (e.g. El Escorial near Madrid) and concert halls. With the disappearance of natural forests on the American continent, caoba wood is also becoming increasingly rare, while plantation wood frequently lacks the equivalent qualities, both structurally and decoratively.

The coffin of the former italian prime minister Silvio Berlusconi, who died 12 June 2023, was made of very precious »Honduran mahogany« i.e. Swietenia macrophylla, caoba, a choice, that persuasively confirms the exceptional beauty of this wood. From Honduran mahogany or caoba there are also some quitars by Jimi Hendrix (942-1970). He is widely regarded as one of the most influential quitaist in the history of popular music, and one of the most celebrated musician of the 20th century.

8. Wood species

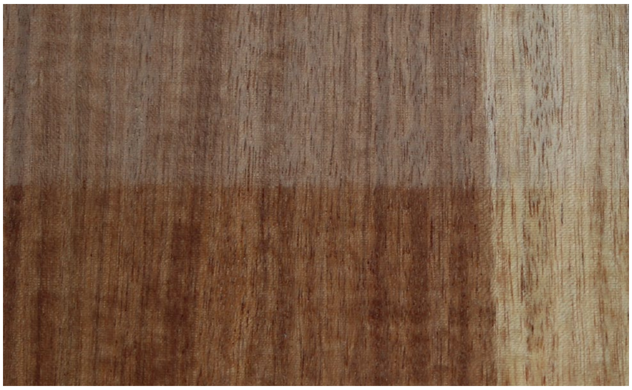
property sheets (43 species)

Acosmium panamense (Benth.) Yakovlev

sin.: ***Sweetia panamensis* Benth.**

Fabaceae | Common name: **Chakté** | Lacandon name: **/**

Use: Exterior construction, interior construction, flooring, sleepers, decorative face veneer



Radial section in actual size.
Upper half of the sample sanded and unfinished,
the lower half oil finish.

cross section *radial section* *tangential section*

500 µm

Tree, wood - Key Characteristics

Height	up to 40 m	
Diameter	up to 90 cm	
Bole	straight clear for 30 m	
Heartwood and sapwood (Munsell color chart)	heartwood clearly differentiated from sapwood	
Condition	Sapwood	Heartwood
Green	5 Y HUE / 5 Y 8.5/10	2.5 YR HUE / 2.5 YR 6/8
Air dried	2.5 Y HUE / 2.5 Y 9/2	7.5 YR HUE / 2.5 YR 6/4
Grain	slightly interlocked	
Texture	fine to medium	

Moisture content and density

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 2/4.

Density	ρ_0	S	775	...	**864**	...	955	kg/m³
		H	801	...	**872**	...	942	kg/m³
Moisture content (MC) green		S	46	...	**52**	...	58	%
		H	51	...	**54**	...	57	%
EMC(21 °C/65%)		S			**14**			%
		H			**12**			%

Dimensional stability

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 2/4.

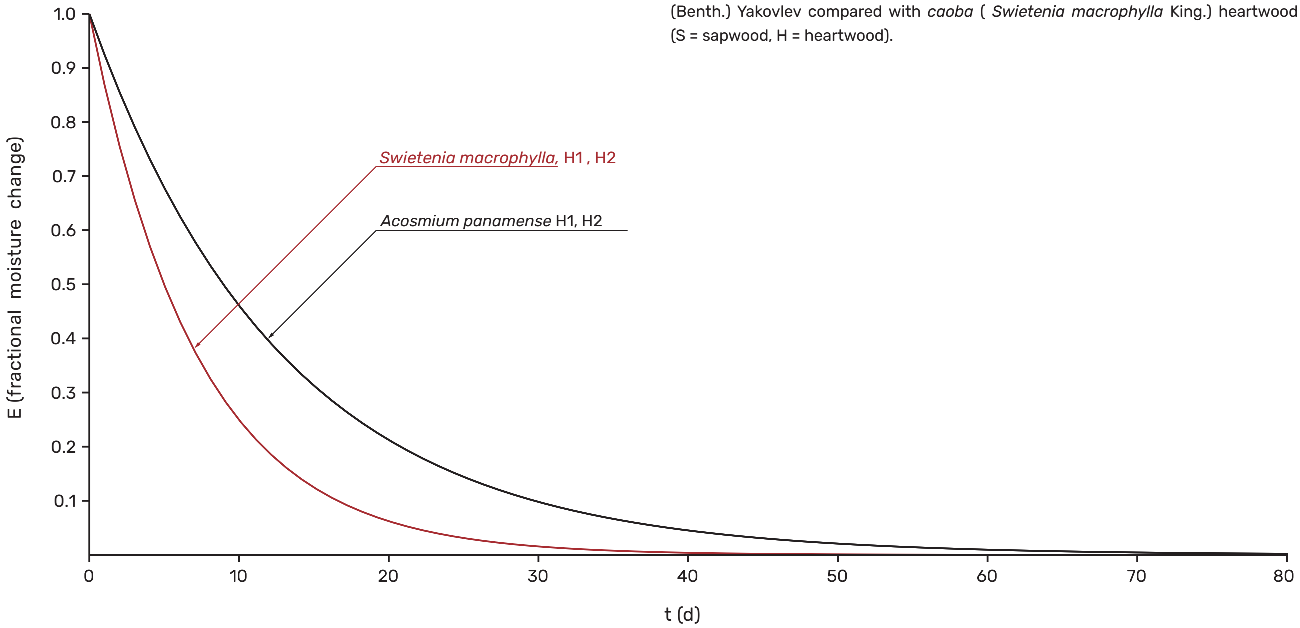
Density	ρ_0	S	775	...	**864**	...	955	kg / m³	
		H	801	...	**872**	...	942	kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.38	...	**0.40**	...	0.43	% / %	normal
	q_{tang}	H	0.35	...	**0.38**	...	0.4	% / %	normal
	q_{rad}	S	0.23	...	**0.24**	...	0.26	% / %	
	q_{rad}	H	0.2	...	**0.24**	...	0.27	% / %	
	q_{tang} / q_{rad}	S	1.46	...	**1.64**	...	1.87		normal
	q_{tang} / q_{rad}	H	1.48	...	**1.61**	...	1.75		normal
	$q_{tang} - q_{rad}$	S	0.12	...	**0.16**	...	0.20	% / %	normal
	$q_{tang} - q_{rad}$	H	0.13	...	**0.14**	...	0.15	% / %	normal
Swelling coefficient and anisotropy	h_{tang}	S	0.059	...	**0.062**	...	0.065	% / %	normal
	h_{tang}	H	0.047	...	**0.050**	...	0.052	% / %	normal
	h_{rad}	S	0.036	...	**0.038**	...	0.041	% / %	
	h_{rad}	H	0.026	...	**0.031**	...	0.036	% / %	
	h_{tang} / h_{rad}	S	1.46	...	**1.63**	...	1.81		normal
	h_{tang} / h_{rad}	H	1.44	...	**1.63**	...	1.81		normal
	$h_{tang} - h_{rad}$	S	0.019	...	**0.024**	...	0.029	% / %	normal
	$h_{tang} - h_{rad}$	H	0.016	...	**0.019**	...	0.021	% / %	favourable
Sorption coefficient	S	S	0.15	...	**0.16**	...	0.16	% / %	normal
	S	H	0.13	...	**0.13**	...	0.13	% / %	very favourable

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	872
	Seasoning time	days	112
	Initial moisture content	%	67
	Final moisture content	%	17
	Checking		115
	Warping		9
	Seasoning degrade		2
	$t_{eq0.5}$ days	H1:9, H2:9	9
	t_{eq} days	H1:57, H2:56	57
Recommended drying schedule	Drying gradient		1.8
	T_1	°C	50
	T_2	°C	70

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

1. *Acosmium panamense* (Benth.) Yakovlev



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
Sapwood	38/1S		4.9		
	38/2S		5.0		
Heartwood	38/1H	835	4.3	0.14	0.0002
	38/2H	967	4.9	0.11	0.0001

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			2 / 5	2 / 5
Weight loss	average	%	1	0
	minimum	%	0	0
	maximum	%	1	1
Resistance to decay			very resistant	very resistant
Proportion of samples in each class	1	%	100	100
	2	%	0	0
	3	%	0	0
	4	%	0	0

Mechanical properties in green condition

Number of test trees				2	
Basic density ρ_b			kg/m³	800	very high
	Stress at proportional limit		MPa	82.3	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	151.1	very high
	Stiffness	Modulus of elasticity	GPa	17.9	very high
Compression	Maximal compression strength parallel to grain		MPa	68.4	very high
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	61.2	exceptionally high
		Rad.	kN	10.56	exceptionally high
Janka hardness	Resistance to identation	Tang.	kN	10.37	exceptionally high
		End	kN	11.42	exceptionally high

Machining and related properties

Number of test trees				1
Number of test samples				10
Moisture content	Min - max		%	12.0 - 14.0
Planing	Defect free samples		%	70

		Angle		
		30°	20°	15°
Speed	7.6 m/min	30 %	70 %	70 %
	13.1 m/min	40 %	40 %	-

Shaping	Good to excellent samples	%	100
Turning	Fair to excellent samples	%	100
Nailing	Samples free from complete splits	%	5
Screwing	Samples free from complete splits	%	95

Slicing, sliced veneer - Assessment of relevant properties

Heating temperature	80-90 °C
Flich degrade due to thermal treatment	light to moderate
Ease of cutting	moderately easy to cut to difficult to cut
Drying degrade	some/little wrinkling and checking
Finishing quality	good

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

	not tested
Heating temperature	
Log degrade due to hydrothermal treatment	
Ease of peeling	
Gluing	
Mechanical properties of plywood	

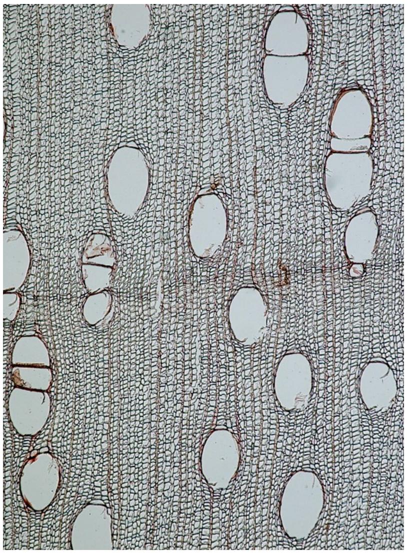
Alchornea latifolia Sw.

sin.: /

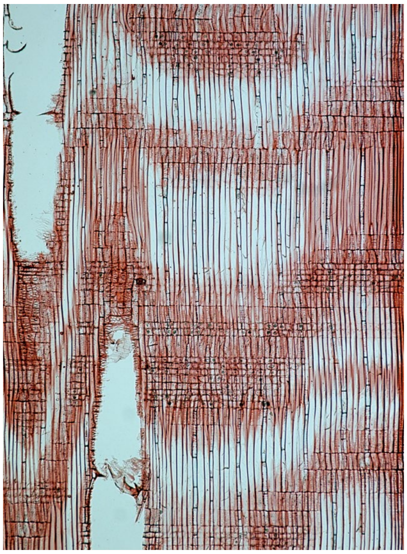
Euphorbiaceae | Common name: **cotón de caribe** | Lacandon name: **muxan che'**

Use: interior construction, framework, peeled veneer, decorative sliced veneer, packaging, paper pulp, particle board, core and crossband veneer, container veneer and plywood

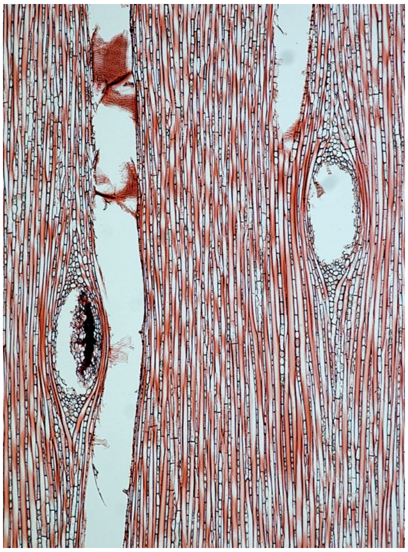
Radial section in actual size.
Upper half of the sample sanded and unfinished, the lower half oil finish.



cross section



radial section



tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 28 m
Diameter	about 60 cm, but can be larger
Bole	straight, cylindrycal, clear for 17 m, with horizontal branches, the crown irregular
Heartwood and sapwood (Munsell color chart)	colored heartwood not present, wound initiated discoloured wood possible

Condition	Sapwood		Heartwood
Green	2.5 Y HUE / 2.5 8.5/6		
Air dried	2.5 YR HUE / 2.5 YR 6/10	10 YR HUE / 10 YR 9/2	

Grain	generally straight, sometimes slightly interlocked
Texture	coarse

Moisture content and density

No. of test trees / samples: Sapwood (S) 1/2 ; Heartwood (H) 0/0.

Density	ρ_0	S	400	...	**402**	...	404	kg/m³
		H						
Moisture content (MC) green		S	114	...	**116**	...	118	%
		H						
EMC(21 °C/65%)		S			**13**			%
		H						

Dimensional stability

No. of test trees / samples: Sapwood (S) 1/2 ; Heartwood (H) 0/0.

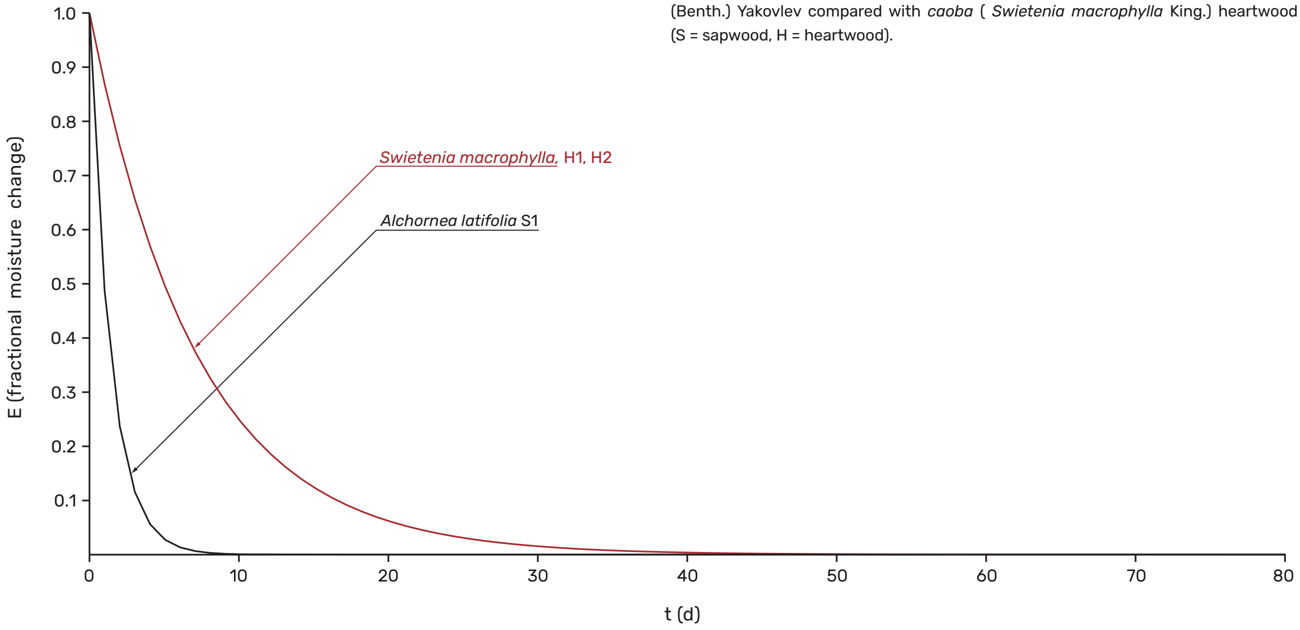
Density	ρ_0	S	400	...	**402**	...	404	kg / m³	
		H		...		...		kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.31	...	**0.32**	...	0.33	% / %	normal
	q_{tang}	H		...		...		% / %	
	q_{rad}	S	0.13	...	**0.13**	...	0.13	% / %	
	q_{rad}	H		...		...		% / %	
	q_{tang} / q_{rad}	S	2.39	...	**2.47**	...	2.54		unfavourable
	q_{tang} / q_{rad}	H		...		...			
	$q_{tang} - q_{rad}$	S	0.18	...	**0.19**	...	0.20	% / %	normal
	$q_{tang} - q_{rad}$	H		...		...		% / %	
Swelling coefficient and anisotropy	h_{tang}	S	0.050	...	**0.051**	...	0.052	% / %	normal
	h_{tang}	H		...		...		% / %	
	h_{rad}	S	0.020	...	**0.020**	...	0.020	% / %	
	h_{rad}	H		...		...		% / %	
	h_{tang} / h_{rad}	S	2.50	...	**2.55**	...	2.60		unfavourable
	h_{tang} / h_{rad}	H		...		...			
	$h_{tang} - h_{rad}$	S	0.030	...	**0.031**	...	0.032	% / %	normal
	$h_{tang} - h_{rad}$	H		...		...		% / %	
Sorption coefficient	s	S	0.16	...	**0.16**	...	0.16	% / %	normal
	s	H		...		...		% / %	

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	402
	Seasoning time	days	112
	Initial moisture content	%	89
	Final moisture content	%	18
	Checking		99
	Warping		1
	Seasoning degrade		1
	$t_{eq0.5}$ days		1
	t_{eq} days	S1:1	5
Recommended drying schedule	Drying gradient	S1:5	3.1
	T_1	°C	70
	T_2	°C	80

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

2. *Alchornea latifolia* Sw.



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density ρ_0 kg/m3	pH - value	Ash content %	Silica content %
Sapwood	1/1S	399	5.4	1.22	0.0008
Heartwood					

Mechanical properties in green condition

Number of test trees				1	
Basic density ρ_b			kg/m³	390	medium
Static bending-centre loading	Stress at proportional limit		MPa	18.6	
	Maximum bending strength	Modulus of rupture	MPa	46.9	low
	Stiffness	Modulus of elasticity	GPa	8.9	low
Compression	Maximal compression strength parallel to grain		MPa	18.6	low
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	12.9	very low
Janka hardness	Resistance to identation	Rad.	kN	1.37	very low
		Tang.	kN	1.59	very low
		End	kN	2.01	very low

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			1 / 4	1 / 4
Weight loss	average	%	40	23
	minimum	%	13	1
	maximum	%	61	39
Resistance to decay			moderately resistant	resistant
Proportion of samples in each class	1	%	0	25
	2	%	25	25
	3	%	25	50
	4	%	50	0

Machining and related properties

Number of test trees				1
Number of test samples				10
Moisture content	Min - max		%	12.0 - 15.0
Planing	Defect free samples		%	100

		Angle		
		30°	20°	15°
Speed	7.6 m/min	100	60	-
	13.1 m/min	70	50	-

Shaping	Good to excellent samples	%	30
Turning	Fair to excellent samples	%	40
Nailing	Samples free from complete splits	%	90
Screwing	Samples free from complete splits	%	100

Slicing, sliced veneer - Assessment of relevant properties

	not tested
Heating temperature	
Flich degrade due to thermal treatment	
Ease of cutting	
Drying degrade	
Finishing quality	

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

Heating temperature	20-50°C
Log degrade due to hydrothermal treatment	moderate
Ease of peeling	easy to peel
Gluing	good
Mechanical properties of plywood	satisfactory

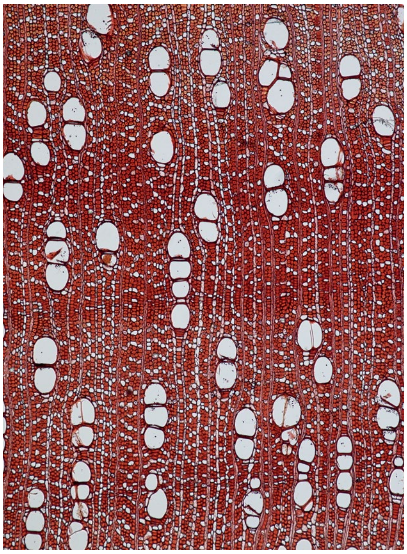
Ampelocera hottlei (Standl.) Standl.

sin.: /

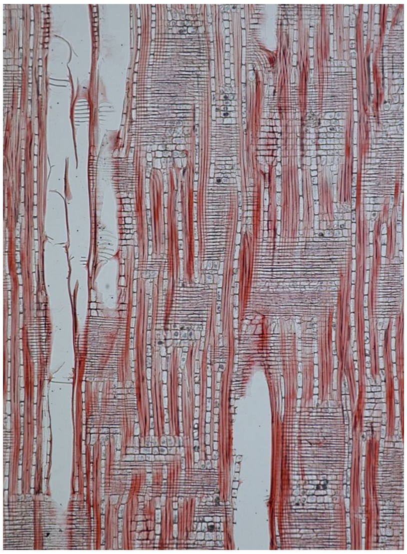
Cannabaceae | Common name: **luín** | Lacandon name: **luwin**

Use: interior construction, exterior construction, furniture, flooring, rail sleepers, possibly for decorative sliced veneer and particle board

Radial section in actual size.
Upper half of the sample sanded and unfinished, the lower half oil finish.



cross section



radial section

tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 35 m
Diameter	up to 60 cm
Bole	well formed, straight, clear for 15 m with small butresses
Heartwood and sapwood (Munsell color chart)	sapwood distinguished from heartwood

Condition	Sapwood	Heartwood
Green	7.5 YR HUE / 7.5 YR 8/10	5 YR HUE / 5 YR 4/2
Air dried	10 YR HUE / 10 YR 9/4	10 YR HUE / 10 YR 6/6

Grain	generally straight, locally shallowly interlocked
Texture	medium to fine

Moisture content and density

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 0/0.

Density	ρ_0	S	803	...	**812**	...	823	kg/m³
		H						
Moisture content (MC) green		S	56	...	**63**	...	70	%
		H						
EMC(21 °C/65%)		S			**15**			%
		H						

Dimensional stability

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 0/0.

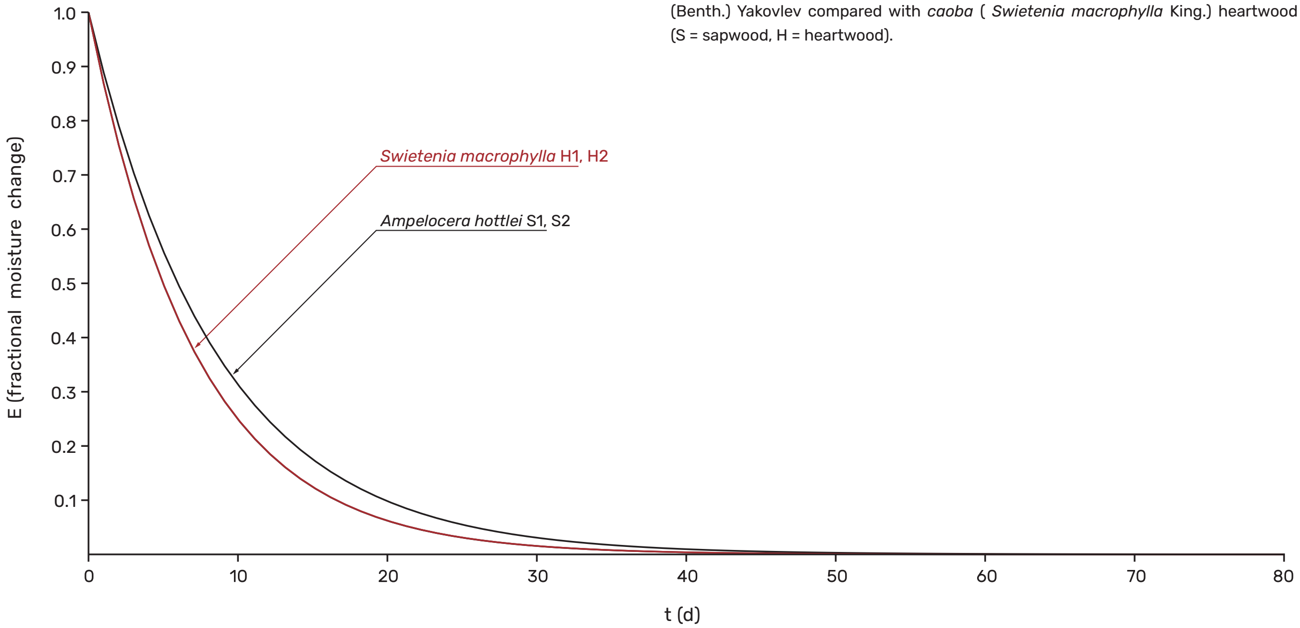
Density	ρ_0	S	803	...	**812**	...	823	kg / m³	
		H		...		...		kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.45	...	**0.47**	...	0.48	% / %	unfavourable
	q_{tang}	H		...		...		% / %	
	q_{rad}	S	0.24	...	**0.25**	...	0.26	% / %	
	q_{rad}	H		...		...		% / %	
	q_{tang} / q_{rad}	S	1.73	...	**1.87**	...	2.00		normal
	q_{tang} / q_{rad}	H		...		...			
	$q_{tang} - q_{rad}$	S	0.19	...	**0.22**	...	0.24	% / %	unfavourable
	$q_{tang} - q_{rad}$	H		...		...		% / %	
Swelling coefficient and anisotropy	h_{tang}	S	0.073	...	**0.074**	...	0.076	% / %	unfavourable
	h_{tang}	H		...		...		% / %	
	h_{rad}	S	0.038	...	**0.040**	...	0.042	% / %	
	h_{rad}	H		...		...		% / %	
	h_{tang} / h_{rad}	S	1.74	...	**1.86**	...	2.00		normal
	h_{tang} / h_{rad}	H		...		...			
	$h_{tang} - h_{rad}$	S	0.031	...	**0.034**	...	0.038	% / %	normal
	$h_{tang} - h_{rad}$	H		...		...		% / %	
Sorption coefficient	S	S	0.16	...	**0.16**	...	0.16	% / %	normal
	S	H		...		...		% / %	

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	690
	Seasoning time	days	112
	Initial moisture content	%	62
	Final moisture content	%	20
	Checking		6
	Warping		5
	Seasoning degrade		1-2
	$t_{eq0.5}$ days	S1:5, S2:6	6
	t_{eq} days	S1:35, S2:39	38
Recommended drying schedule	Drying gradient		2.1
	T_1	°C	50
	T_2	°C	80

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

3. *Ampelocera hottlei* (Standl.) Standl.



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
	44/1S	796	5.8	1.68	0.0003
Sapwood	44/2S	834	6.8	2.52	0.001
Heartwood					

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			2 / 5	2 / 5
Weight loss	average	%	18	33
	minimum	%	3	15
	maximum	%	38	47
Resistance to decay			resistant	moderately resistant
Proportion of samples in each class	1	%	40	0
	2	%	20	40
	3	%	40	20
	4	%	0	40

Mechanical properties in green condition

Number of test trees				2	
Basic density ρ_b			kg/m³	690	high
	Stress at proportional limit		MPa	47.7	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	107.6	high
	Stiffness	Modulus of elasticity	GPa	14.2	high
Compression	Maximal compression strength parallel to grain		MPa	42.1	high
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	40.8	high
		Rad.	kN	5.67	high
Janka hardness	Resistance to identation	Tang.	kN	5.67	high
		End	kN	6.46	high

Machining and related properties

Number of test trees					1
Number of test samples					10
Moisture content	Min - max			%	14.0 - 14.5
Planing	Defect free samples			%	30
		Angle			
		30°	20°		15°
Speed	7.6 m/min	30	20		10
	13.1 m/min	0	0		10
Shaping	Good to excellent samples			%	100
Turning	Fair to excellent samples			%	100
Nailing	Samples free from complete splits			%	0
Screwing	Samples free from complete splits			%	17

Slicing, sliced veneer - Assessment of relevant properties

Heating temperature	80-90 °C
Flich degrade due to thermal treatment	light
Ease of cutting	difficult to cut
Drying degrade	some/little wrinkling and checking
Finishing quality	good, poliester neg.

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

	not tested
Heating temperature	
Log degrade due to hydrothermal treatment	
Ease of peeling	
Gluing	
Mechanical properties of plywood	

Aspidosperma megalocarpon Muell. Arg.

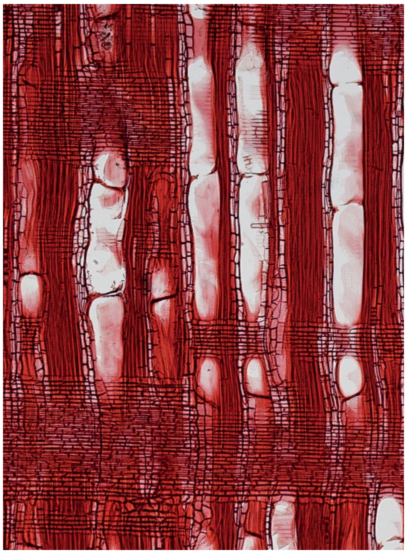
sin.: /

Apocynaceae | Common name: **bayo** | Lacandon name: **sayok (ah)**

Use: interior construction, exterior construction, framework, furniture, decorative sliced veneer, flooring, interior coverings, exterior coverings, hydraulic works, sleepers

Radial section in actual size.
Upper half of the sample sanded and unfinished, the lower half oil finish.

cross section



radial section

tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 40 m	
Diameter	up to 80 cm	
Bole	very straight, cylindrical clear for 30 m with horizontal branches	
Heartwood and sapwood (Munsell color chart)	heartwood clearly differentiated from the sapwood	
Condition	Sapwood	Heartwood
Green	2.5 Y HUE / 2.5 8.5/6	10 R HUE / 10 R 4/10
Air dried	7.5 YR HUE / 7.5 YR 8/4	10 R HUE / 10 R 7/6
Grain	straight to shallowly interlocked	
Texture	fine to medium	

Moisture content and density

No. of test trees / samples: Sapwood (S) 3/6 ; Heartwood (H) 3/6.

Density	ρ_0	S	749	...	**798**	...	841	kg/m³
		H	710	...	**771**	...	821	kg/m³
Moisture content (MC) green		S	52	...	**55**	...	59	%
		H	59	...	**66**	...	70	%
EMC(21 °C/65%)		S			**14**			%
		H			**13**			%

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

Dimensional stability

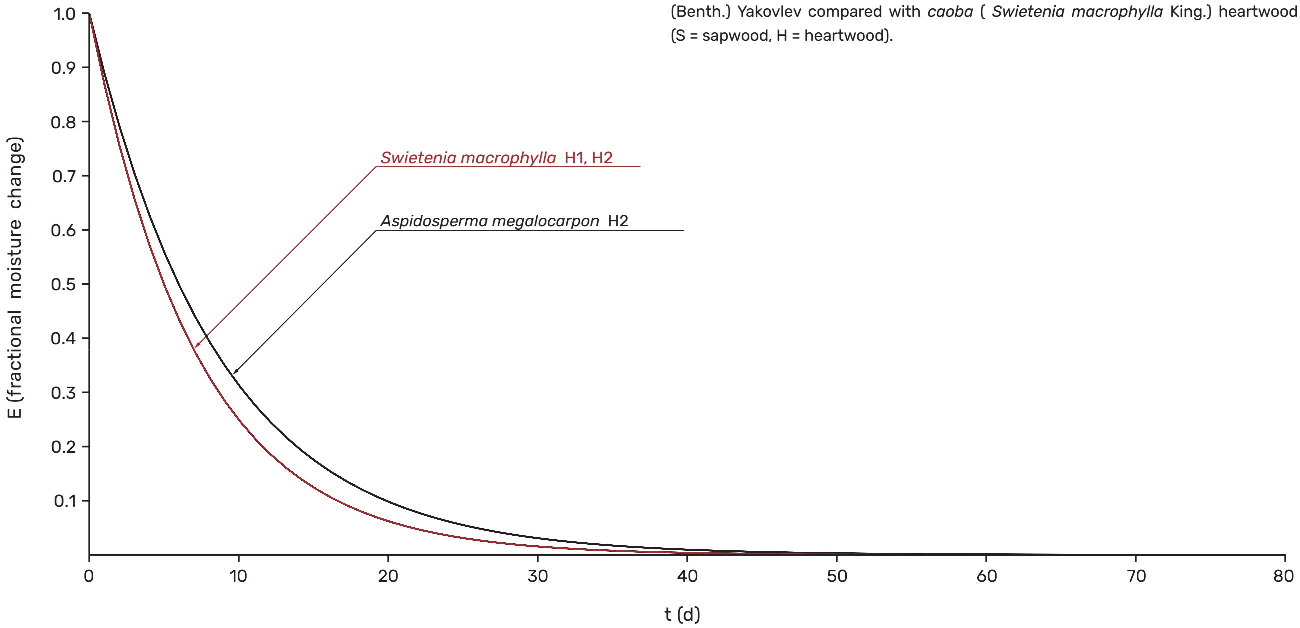
No. of test trees / samples: Sapwood (S) 3/6 ; Heartwood (H) 3/6.

Density	ρ_0	S	749	...	**798**	...	841	kg / m³	
		H	710	...	**771**	...	821	kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.43	...	**0.46**	...	0.51	% / %	unfavourable
	q_{tang}	H	0.40	...	**0.44**	...	0.47	% / %	unfavourable
	q_{rad}	S	0.26	...	**0.27**	...	0.29	% / %	
	q_{rad}	H	0.25	...	**0.27**	...	0.28	% / %	
	q_{tang} / q_{rad}	S	1.57	...	**1.67**	...	1.78		normal
	q_{tang} / q_{rad}	H	1.58	...	**1.65**	...	1.74		normal
	$q_{tang} - q_{rad}$	S	0.16	...	**0.18**	...	0.22	% / %	normal
	$q_{tang} - q_{rad}$	H	0.15	...	**0.17**	...	0.20	% / %	normal
Swelling coefficient and anisotropy	h_{tang}	S	0.067	...	**0.073**	...	0.079	% / %	unfavourable
	h_{tang}	H	0.061	...	**0.066**	...	0.070	% / %	unfavourable
	h_{rad}	S	0.041	...	**0.044**	...	0.046	% / %	
	h_{rad}	H	0.038	...	**0.040**	...	0.042	% / %	
	h_{tang} / h_{rad}	S	1.60	...	**1.66**	...	1.76		normal
	h_{tang} / h_{rad}	H	1.59	...	**1.66**	...	1.73		normal
	$h_{tang} - h_{rad}$	S	0.026	...	**0.029**	...	0.034	% / %	normal
	$h_{tang} - h_{rad}$	H	0.023	...	**0.026**	...	0.029	% / %	normal
Sorption coefficient	S	S	0.15	...	**0.16**	...	0.16	% / %	normal
	S	H	0.15	...	**0.15**	...	0.15	% / %	favourable

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	771
	Seasoning time	days	91
	Initial moisture content	%	71
	Final moisture content	%	19
	Checking		34
	Warping		0
	Seasoning degrade		1
	$t_{eq0.5}$ days	H2:6	5
	t_{eq} days	H2:41	38
Recommended drying schedule	Drying gradient		2.1
	T_1	°C	60
	T_2	°C	80

4. *Aspidosperma megalocarpon* Muell. Arg



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
	3/1S	771	5.1		
Sapwood	3/2S	852	5.0		
	3/3S	814	4.8		
	3/1H	751	4.8	0.15	0.0003
Heartwood	3/2H	829	4.7	0.15	0.0007
	3/3H	770	4.9	0.41	0.0004

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			3 / 5	3 / 5
Weight loss	average	%	10	1
	minimum	%	3	0
	maximum	%	33	1
Resistance to decay			very resistant	very resistant
Proportion of samples in each class	1	%	80	100
	2	%	0	0
	3	%	20	0
	4	%	0	0

Mechanical properties in green condition

Number of test trees				3	
Basic density ρ_b			kg/m³	670	high
	Stress at proportional limit		MPa	61.6	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	112.2	very high
	Stiffness	Modulus of elasticity	GPa	16.4	very high
Compression	Maximal compression strength parallel to grain		MPa	44.2	high
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	36.5	high
		Rad.	kN	4.46	high
Janka hardness	Resistance to identation	Tang.	kN	4.87	high
		End	kN	5.81	high

Machining and related properties

Number of test trees				1
Number of test samples				12
Moisture content	Min - max		%	13.5 - 14.5
Planing	Defect free samples		%	100
		Angle		
		30°	20°	15°
Speed	7.6 m/min	100	100	-
	13.1 m/min	92	100	-
Shaping	Good to excellent samples		%	100
Turning	Fair to excellent samples		%	100
Nailing	Samples free from complete splits		%	0
Screwing	Samples free from complete splits		%	84

Slicing, sliced veneer - Assessment of relevant properties

Heating temperature	80-90 °C
Flich degrade due to thermal treatment	none
Ease of cutting	moderately easy to cut
Drying degrade	without checking and wrinkling
Finishing quality	good

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

	not tested
Heating temperature	
Log degrade due to hydrothermal treatment	
Ease of peeling	
Gluing	
Mechanical properties of plywood	

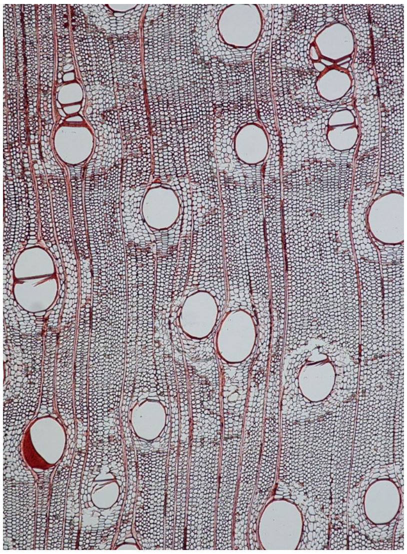
Balizia leucocalyx (Britton & Rose) Barneby & J.W.

sin.: ***Pithecellobium leucocalyx*** **(Britton & Rose) Standl.**

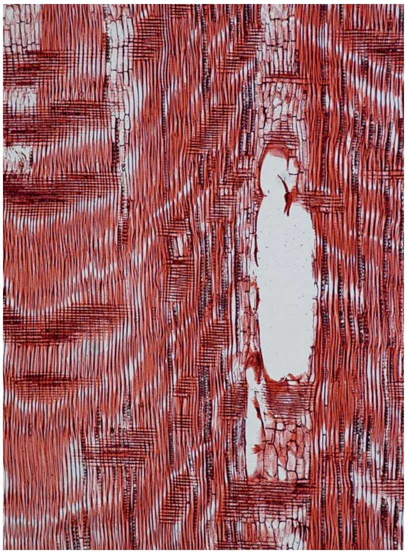
Fabaceae | Common name: **guacibán** | Lacandon name: **/**

Use: interior construction, exterior construction, framework, packaging, cellulose products, particle board, paper pulp, construction plywood, container veneer and plywood, flooring, hydraulic works, boat building

Radial section in actual size.
Upper half of the sample sanded and unfinished,
the lower half oil finish.



cross section



radial section

tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 40 m	
Diameter	up to 120 cm	
Bole	regular, up to 20 m	
Heartwood and sapwood (Munsell color chart)	heartwood only slightly demarcated from sapwood	
Condition	Sapwood	Heartwood
Green	2.5 Y HUE / 2.5 Y 8.5/6	10 R HUE / 10 R 6/8
Air dried	10 YR HUE / 10 YR 9/2	7.5 YR HUE / 7.5 YR 8/4
Grain	Interlocked or steeply narrowly interlocked	
Texture	Coarse or medium to coarse	

Moisture content and density

No. of test trees / samples: Sapwood (S) 1/2 ; Heartwood (H) 1/2.

Density	ρ_0	S	498	...	**505**	...	512	kg/m³
		H	503	...	**505**	...	506	kg/m³
Moisture content (MC) green		S	82	...	**83**	...	83	%
		H	93	...	**94**	...	95	%
EMC(21 °C/65%)		S			**13**			%
		H			**13**			%

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

Dimensional stability

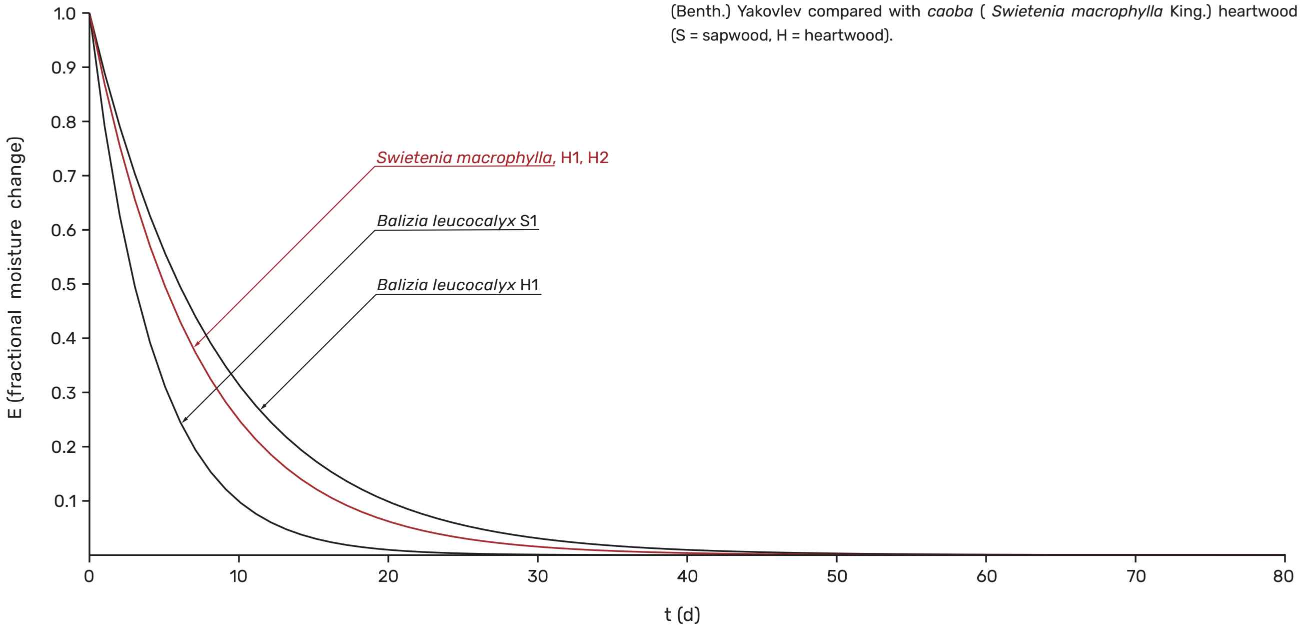
No. of test trees / samples: Sapwood (S) 1/2 ; Heartwood (H) 1/2.

Density	ρ_0	S	498	...	**505**	...	512	kg / m³	
		H	503	...	**505**	...	506	kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.27	...	**0.28**	...	0.28	% / %	favourable
	q_{tang}	H	0.28	...	**0.29**	...	0.29	% / %	favourable
	q_{rad}	S	0.14	...	**0.15**	...	0.15	% / %	
	q_{rad}	H	0.15	...	**0.16**	...	0.16	% / %	
	q_{tang} / q_{rad}	S	1.80	...	**1.90**	...	2.00		normal
	q_{tang} / q_{rad}	H	1.75	...	**1.84**	...	1.93		normal
	$q_{tang} - q_{rad}$	S	0.12	...	**0.13**	...	0.14	% / %	normal
	$q_{tang} - q_{rad}$	H	0.12	...	**0.13**	...	0.14	% / %	normal
Swelling coefficient and anisotropy	h_{tang}	S	0.041	...	**0.042**	...	0.042	% / %	favourable
	h_{tang}	H	0.041	...	**0.042**	...	0.042	% / %	favourable
	h_{rad}	S	0.022	...	**0.022**	...	0.022	% / %	
	h_{rad}	H	0.022	...	**0.023**	...	0.023	% / %	
	h_{tang} / h_{rad}	S	1.86	...	**1.89**	...	1.91		normal
	h_{tang} / h_{rad}	H	1.78	...	**1.85**	...	1.91		normal
	$h_{tang} - h_{rad}$	S	0.019	...	**0.020**	...	0.020	% / %	normal
	$h_{tang} - h_{rad}$	H	0.018	...	**0.019**	...	0.020	% / %	favourable
Sorption coefficient	S	S	0.15	...	**0.15**	...	0.15	% / %	favourable
	S	H	0.14	...	**0.14**	...	0.14	% / %	favourable

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	505
	Seasoning time	days	77
	Initial moisture content	%	80
	Final moisture content	%	18
	Checking		10
	Warping		0
	Seasoning degrade		1
	$t_{eq0.5}$ days	S1:3, H1:6	6
	t_{eq} days	S1:24, H1:42	42
Recommended drying schedule	Drying gradient		3.1
	T_1	°C	70
	T_2	°C	90

5. *Balizia leucocalyx* (Britton & Rose) Barneby & J.W.



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
Sapwood	27/1S	522	5.8		
Heartwood	27/1H	488	5.4	1.25	0.001

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			1 / 4	1 / 4
Weight loss	average	%	5	3
	minimum	%	2	1
	maximum	%	6	7
Resistance to decay			very resistant	very resistant
Proportion of samples in each class	1	%	100	100
	2	%	0	0
	3	%	0	0
	4	%	0	0

Mechanical properties in green condition

Number of test trees				1	
Basic density ρ_b			kg/m³	520	medium
	Stress at proportional limit		MPa	19.0	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	50.0	medium
	Stiffness	Modulus of elasticity	GPa	8.3	low
Compression	Maximal compression strength parallel to grain		MPa	23.5	medium
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	24.7	low
		Rad.	kN	2.61	low
Janka hardness	Resistance to identation	Tang.	kN	2.79	low
		End	kN	2.87	low

Machining and related properties

Number of test trees				1	
Number of test samples				10	
Moisture content	Min - max		%	14.0 - 15.0	
Planing	Defect free samples		%	40	
		Angle			
		30°	20°	15°	
Speed	7.6 m/min	20	40	10	
	13.1 m/min	10	10	20	
Shaping	Good to excellent samples		%	60	
Turning	Fair to excellent samples		%	50	
Nailing	Samples free from complete splits		%	60	
Screwing	Samples free from complete splits		%	100	

Slicing, sliced veneer - Assessment of relevant properties

not tested	
Heating temperature	
Flich degrade due to thermal treatment	
Ease of cutting	
Drying degrade	
Finishing quality	

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

Heating temperature	60-70°C
Log degrade due to hydrothermal treatment	moderate to severe
Ease of peeling	easy to peel
Gluing	satisfactory
Mechanical properties of plywood	satisfactory

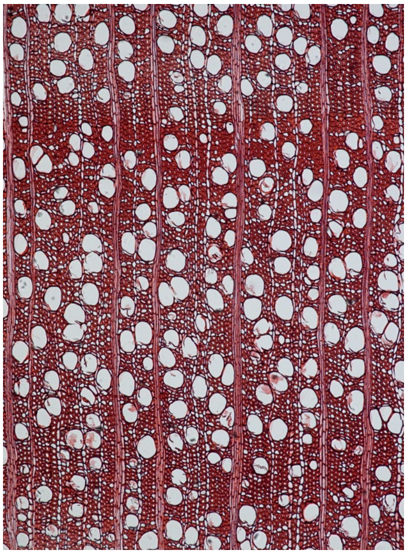
Blepharidium guatemalense Standl.

sin.: ***Blepharidium mexicanum*** **Standl.**

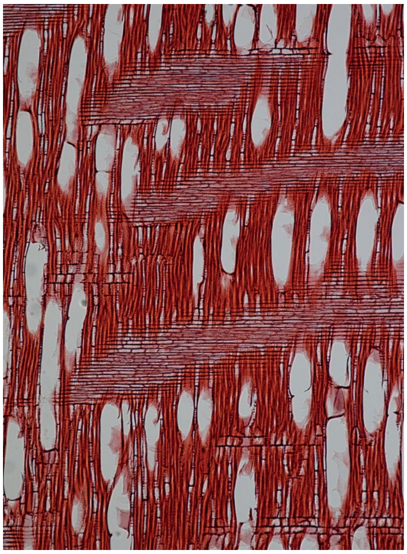
Rubiaceae | Common name: **popiste** | Lacandon name: **säkyuuhche' (äh)**

Use: interior construction, exterior construction, furniture, decorative sliced veneer, particle board, container veneer and plywood, covering interior

Radial section in actual size.
Upper half of the sample sanded and unfinished,
the lower half oil finish.



cross section



radial section

tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 25 m
Diameter	about 70 cm
Bole	straight, regular, up to 15 m
Heartwood and sapwood (Munsell color chart)	little distinction between the sapwood and heartwood

Condition	Sapwood	Heartwood
Green	2.5 Y HUE / 2.5 Y 8.5/8	7.5 YR HUE / 7.5 YR 6/14
Air dried	2.5 Y HUE / 2.5 y 8/6	

Grain	Straight
Texture	Fine

Moisture content and density

No. of test trees / samples: Sapwood (S) 1/2 ; Heartwood (H) 1/2.

Density	ρ_0	S	625	...	**626**	...	626	kg/m³
		H	638	...	**646**	...	653	kg/m³
Moisture content (MC) green		S	74	...	**75**	...	75	%
		H	70	...	**71**	...	72	%
EMC(21 °C/65%)		S			**14**			%
		H			**14**			%

Dimensional stability

No. of test trees / samples: Sapwood (S) 1/2 ; Heartwood (H) 1/2.

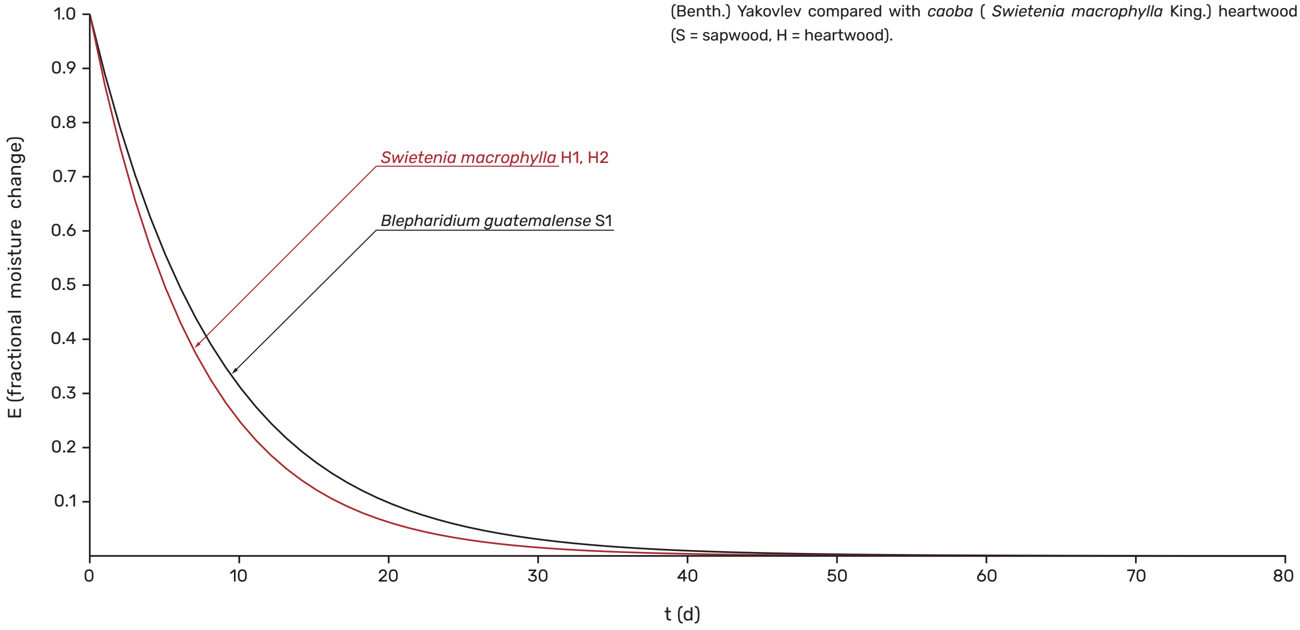
Density	ρ_0	S	625	...	**626**	...	626	kg / m³	
		H	638	...	**646**	...	653	kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.39	...	**0.41**	...	0.43	% / %	unfavourable
	q_{tang}	H	0.44	...	**0.45**	...	0.45	% / %	unfavourable
	q_{rad}	S	0.18	...	**0.18**	...	0.18	% / %	
	q_{rad}	H	0.21	...	**0.22**	...	0.22	% / %	
	q_{tang} / q_{rad}	S	2.17	...	**2.28**	...	2.39		unfavourable
	q_{tang} / q_{rad}	H	2.05	...	**2.08**	...	2.10		unfavourable
	$q_{tang} - q_{rad}$	S	0.21	...	**0.23**	...	0.25	% / %	unfavourable
	$q_{tang} - q_{rad}$	H	0.23	...	**0.23**	...	0.23	% / %	unfavourable
Swelling coefficient and anisotropy	h_{tang}	S	0.062	...	**0.065**	...	0.067	% / %	normal
	h_{tang}	H	0.069	...	**0.070**	...	0.07	% / %	unfavourable
	h_{rad}	S	0.028	...	**0.028**	...	0.029	% / %	
	h_{rad}	H	0.033	...	**0.034**	...	0.034	% / %	
	h_{tang} / h_{rad}	S	2.14	...	**2.27**	...	2.39		unfavourable
	h_{tang} / h_{rad}	H	2.06	...	**2.08**	...	2.09		unfavourable
	$h_{tang} - h_{rad}$	S	0.033	...	**0.036**	...	0.039	% / %	unfavourable
	$h_{tang} - h_{rad}$	H	0.036	...	**0.036**	...	0.036	% / %	unfavourable
Sorption coefficient	S	S	0.16	...	**0.16**	...	0.16	% / %	normal
	S	H	0.15	...	**0.16**	...	0.16	% / %	normal

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	646
	Seasoning time	days	154
	Initial moisture content	%	73
	Final moisture content	%	19
	Checking		157
	Warping		8
	Seasoning degrade		2-3
	$t_{eq0.5}$ days	S1:6	6
	t_{eq} days	S1:39	43
Recommended drying schedule	Drying gradient		1.8
	T_1	°C	35
	T_2	°C	65

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

6. *Blepharidium guatemalense* Standl.



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density ρ_0 kg/m3	pH - value	Ash content %	Silica content %
Sapwood	46/1S	620	5.6		
Heartwood	46/1H		5.6	1.19	0.0008

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			1 / 4	1 / 4
Weight loss	average	%	9	4
	minimum	%	3	1
	maximum	%	14	11
Resistance to decay			very resistant	very resistant
Proportion of samples in each class	1	%	75	75
	2	%	25	25
	3	%	0	0
	4	%	0	0

Mechanical properties in green condition

Number of test trees				1	
Basic density ρ_b			kg/m³	600	high
	Stress at proportional limit		MPa	31.9	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	72.0	medium
	Stiffness	Modulus of elasticity	GPa	9.4	low
Compression	Maximal compression strength parallel to grain		MPa	30.4	medium
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	25.9	medium
		Rad.	kN	4.00	medium
Janka hardness	Resistance to identation	Tang.	kN	3.14	low
		End	kN	5.03	high

Machining and related properties

Number of test trees				1
Number of test samples				10
Moisture content	Min - max		%	13.0 - 14.0
Planing	Defect free samples		%	100

		Angle		
		30°	20°	15°
Speed	7.6 m/min	100	100	-
	13.1 m/min	90	100	-

Shaping	Good to excellent samples	%	100
Turning	Fair to excellent samples	%	100
Nailing	Samples free from complete splits	%	40
Screwing	Samples free from complete splits	%	100

Slicing, sliced veneer - Assessment of relevant properties

	not tested
Heating temperature	
Flich degrade due to thermal treatment	
Ease of cutting	
Drying degrade	
Finishing quality	

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

Heating temperature	60-70°C
Log degrade due to hydrothermal treatment	moderate
Ease of peeling	moderately easy to peel
Gluing	satisfactory
Mechanical properties of plywood	satisfactory

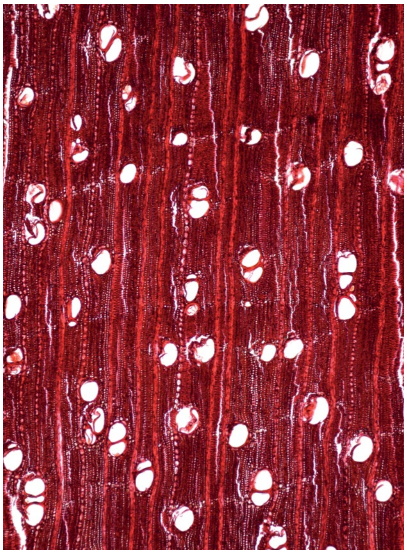
Brosimum alicastrum Sw.

sin.: /

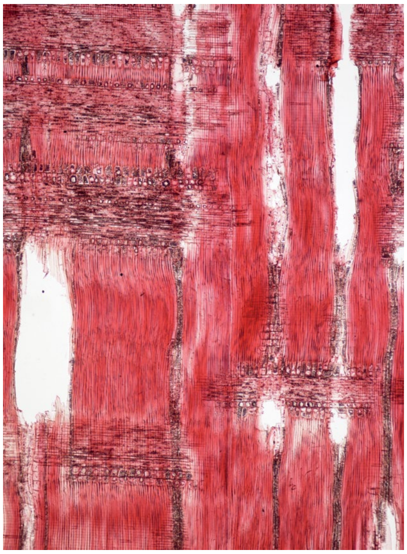
Moraceae | Common name: **ramón** | Lacandon name: **hach ,oox, k'än ,oox, ya'ax ,oox**

Use: interior construction, exterior construction, coverings interior, furniture, decorative sliced veneer, flooring, framework, with preservative treatment can be used for exterior construction and rail sleepers,

Radial section in actual size.
Upper half of the sample sanded and unfinished,
the lower half oil finish.



cross section



radial section

tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 40 m
Diameter	up to 130 cm
Bole	straight, regular, clear for 25 m
Heartwood and sapwood (Munsell color chart)	heartwood clearly differentiated from sapwood

Condition	Sapwood	Heartwood
Green	10 YR HUE / 10 YR 8/6	
Air dried	2.5 Y HUE / 2.2 y 9/4	

Grain	Lightly or broadly shallowly interlocked
Texture	medium to coarse

Moisture content and density

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 0/0.

Density	ρ_0	S	862	...	**865**	...	866	kg/m³
		H						
Moisture content (MC) green		S	46	...	**49**	...	53	%
		H						
EMC(21 °C/65%)		S			**14**			%
		H						

Dimensional stability

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 0/0.

Density	ρ_0	S	862	...	**865**	...	866	kg / m³	
		H		...		...		kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.38	...	**0.39**	...	0.39	% / %	normal
	q_{tang}	H		...		...		% / %	
	q_{rad}	S	0.25	...	**0.27**	...	0.28	% / %	
	q_{rad}	H		...		...		% / %	
	q_{tang} / q_{rad}	S	1.39	...	**1.46**	...	1.52		favourable
	q_{tang} / q_{rad}	H		...		...			
	$q_{tang} - q_{rad}$	S	0.11	...	**0.12**	...	0.13	% / %	normal
	$q_{tang} - q_{rad}$	H		...		...		% / %	
Swelling coefficient and anisotropy	h_{tang}	S	0.059	...	**0.060**	...	0.061	% / %	normal
	h_{tang}	H		...		...		% / %	
	h_{rad}	S	0.039	...	**0.041**	...	0.043	% / %	
	h_{rad}	H		...		...		% / %	
	h_{tang} / h_{rad}	S	1.42	...	**1.47**	...	1.54		favourable
	h_{tang} / h_{rad}	H		...		...			
	$h_{tang} - h_{rad}$	S	0.018	...	**0.019**	...	0.021	% / %	favourable
	$h_{tang} - h_{rad}$	H		...		...		% / %	
Sorption coefficient	S	S	0.15	...	**0.16**	...	0.16	% / %	normal
	S	H		...		...		% / %	

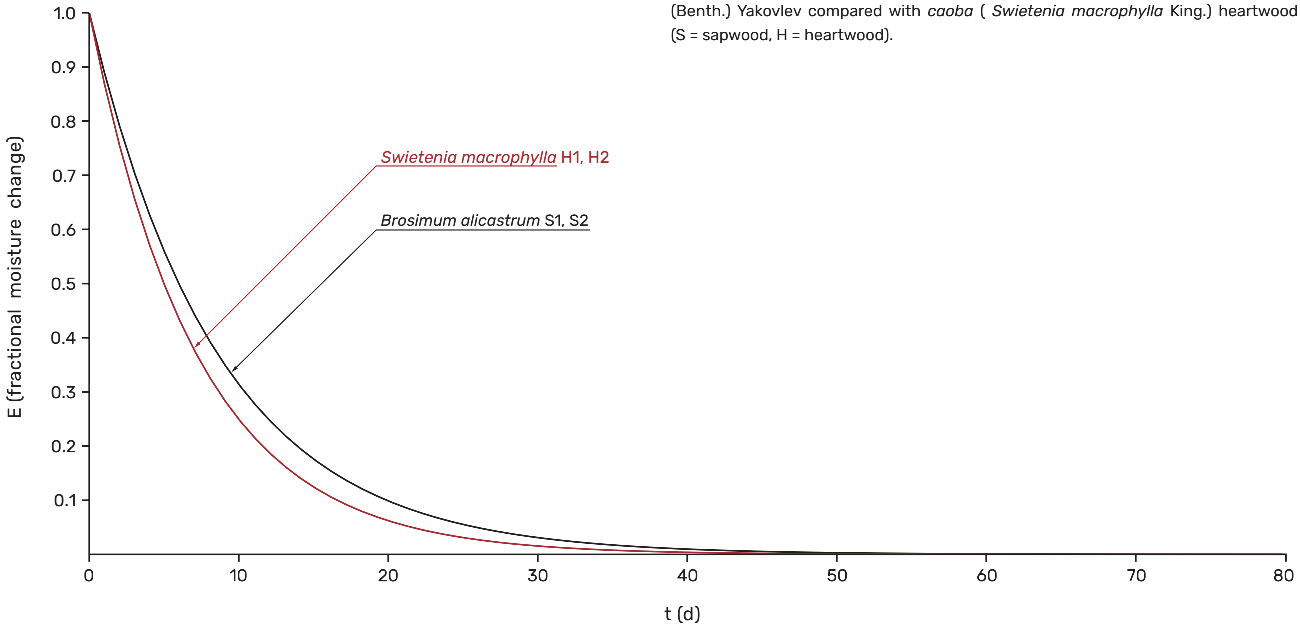
Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	865
	Seasoning time	days	105
	Initial moisture content	%	66
	Final moisture content	%	20
	Checking		42
	Warping		9
	Seasoning degrade		2
	$t_{eq0.5}$ days	S1:6, S2:6	6
	t_{eq} days	S1:43, S2:42	42
Recommended drying schedule	Drying gradient		2.1
	T_1	°C	50
	T_2	°C	80

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

7. ***Brosimum alicastrum*** Sw.

Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).



pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
	6/1S	875	5.6	1.73	0.0003
Sapwood	6/2S	874	5.7	1.87	0.0006
Heartwood					

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			2 / 5	2 / 5
Weight loss	average	%	27	28
	minimum	%	17	22
	maximum	%	34	37
Resistance to decay			very resistant	very resistant
Proportion of samples in each class	1	%	0	0
	2	%	40	40
	3	%	60	60
	4	%	0	0

Mechanical properties in green condition

Number of test trees				2	
Basic density ρ_b			kg/m³	730	very high
	Stress at proportional limit		MPa	62.6	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	117.0	very high
	Stiffness	Modulus of elasticity	GPa	13.5	high
Compression	Maximal compression strength parallel to grain		MPa	50.5	high
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	54.1	very high
		Rad.	kN	7.51	very high
Janka hardness	Resistance to identation	Tang.	kN	7.98	very high
		End	kN	8.83	very high

Machining and related properties

Number of test trees					1
Number of test samples					12
Moisture content	Min - max			%	13.0 - 14.5
Planing	Defect free samples			%	100
		Angle			
		30°	20°	15°	
Speed	7.6 m/min	100	100	-	
	13.1 m/min	58	58	-	
Shaping	Good to excellent samples			%	92
Turning	Fair to excellent samples			%	100
Nailing	Samples free from complete splits			%	67
Screwing	Samples free from complete splits			%	90

Slicing, sliced veneer - Assessment of relevant properties

	not tested
Heating temperature	
Flich degrade due to thermal treatment	
Ease of cutting	
Drying degrade	
Finishing quality	

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

	not tested
Heating temperature	
Log degrade due to hydrothermal treatment	
Ease of peeling	
Gluing	
Mechanical properties of plywood	

Bursera simaruba (L.) Sarg.

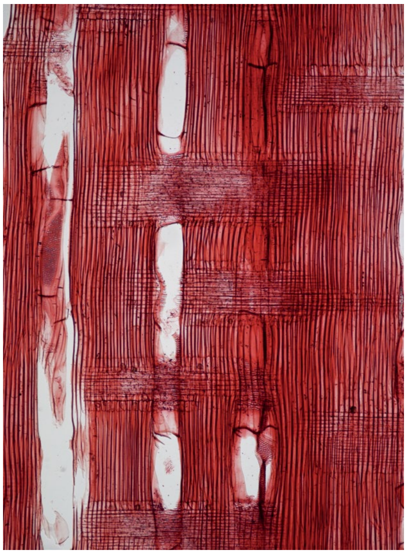
sin.: /

Burseraceae | Common name: **palo mulato** | Lacandon name: **chäklah**

Use: interior construction, decorative sliced veneer, packaging, cellulose products, particle board, pulp & paper, core and crossband veneer, container veneer and plywood, possibly for framework and peeled veneer, construction plywood

Radial section in actual size.
Upper half of the sample sanded and unfinished, the lower half oil finish.

cross section



radial section

tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 40 m	
Diameter	up to 100 cm	
Bole	straight, regular, clear for 25 m	
Heartwood and sapwood (Munsell color chart)	without colored heartwood	
Condition	Sapwood	Heartwood
Green	2.5 y HUE / 2.5 8.5/6	
Air dried	10 YR HUE / 10 YR 9/1	
Grain	straight	
Texture	fine to medium	

Moisture content and density

No. of test trees / samples: Sapwood (S) 3/6 ; Heartwood (H) 0/0.

Density	ρ_0	S	380	...	**452**	...	532	kg/m³
		H						
Moisture content (MC) green		S	108	...	**114**	...	124	%
		H						
EMC(21 °C/65%)		S			**14**			%
		H						

Dimensional stability

No. of test trees / samples: Sapwood (S) 3/6 ; Heartwood (H) 0/0.

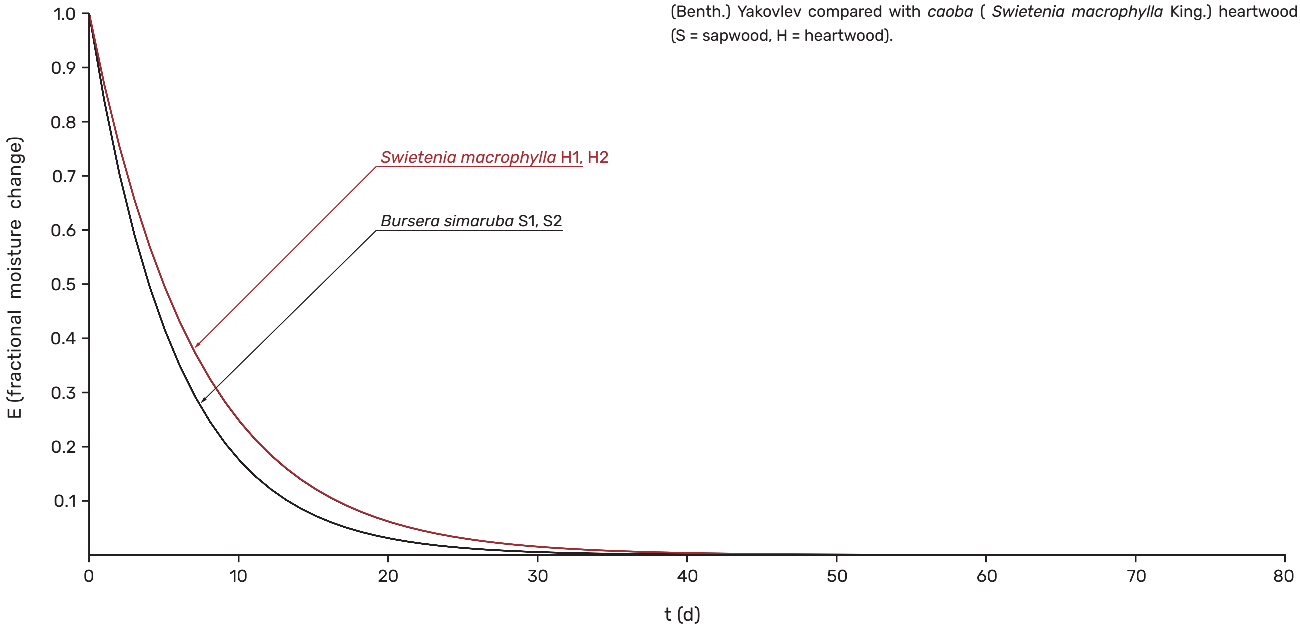
Density	ρ_0	S	357	...	**452**	...	532	kg / m³	
		H		...		...		kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.19	...	**0.21**	...	0.22	% / %	favourable
	q_{tang}	H		...		...		% / %	
	q_{rad}	S	0.12	...	**0.12**	...	0.13	% / %	
	q_{rad}	H		...		...		% / %	
	q_{tang} / q_{rad}	S	1.58	...	**1.66**	...	1.83		normal
	q_{tang} / q_{rad}	H		...		...			
	$q_{tang} - q_{rad}$	S	0.07	...	**0.08**	...	0.10	% / %	favourable
	$q_{tang} - q_{rad}$	H		...		...		% / %	
Swelling coefficient and anisotropy	h_{tang}	S	0.031	...	**0.037**	...	0.043	% / %	favourable
	h_{tang}	H		...		...		% / %	
	h_{rad}	S	0.019	...	**0.020**	...	0.022	% / %	
	h_{rad}	H		...		...		% / %	
	h_{tang} / h_{rad}	S	1.59	...	**1.69**	...	1.84		normal
	h_{tang} / h_{rad}	H		...		...			
	$h_{tang} - h_{rad}$	S	0.012	...	**0.014**	...	0.016	% / %	favourable
	$h_{tang} - h_{rad}$	H		...		...		% / %	
Sorption coefficient	S	S	0.16	...	**0.16**	...	0.17	% / %	normal
	S	H		...		...		% / %	

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	452
	Seasoning time	days	126
	Initial moisture content	%	138
	Final moisture content	%	19
	Checking		160
	Warping		14
	Seasoning degrade		4
	$t_{eq0.5}$ days	S1:4, S2:4	4
	t_{eq} days	S1:32, S2:32	32
Recommended drying schedule	Drying gradient		2.1
	T_1	°C	50
	T_2	°C	70

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

8. *Bursera simaruba* (L.) Sarg.



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density ρ_0 kg/m3	pH - value	Ash content %	Silica content %
Sapwood	8/1S	384	5.5	1.44	0.005
	8/2S	513	5.9	1.06	0.003
	8/3S	458	5.9	1.29	0.003
Heartwood					

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			3 / 5	3 / 5
Weight loss	average	%	55	53
	minimum	%	15	48
	maximum	%	73	60
Resistance to decay			non-resistant	non-resistant
Proportion of samples in each class	1	%	0	0
	2	%	20	0
	3	%	0	0
	4	%	80	100

Mechanical properties in green condition

Number of test trees				3	
Basic density ρ_b			kg/m^3	430	medium
Static ben-ding-centre loading	Stress at propor-tional limit		MPa	21.4	
	Maximum bending strength	Modulus of rupture	MPa	46.0	low
	Stiffness	Modulus of elasticity	GPa	7.2	very low
Compression	Maximal compression strength parallel to grain		MPa	17.8	low
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	20.8	low
Janka hardness	Resistance to identation	Rad.	kN	1.97	very low
		Tang.	kN	2.26	very low
		End	kN	2.34	low

Machining and related properties

Number of test trees					1
Number of test samples					10
Moisture content	Min - max			%	14.0 - 16.5
Planing	Defect free samples			%	100
		Angle			
		30°	20°		15°
Speed	7.6 m/min	100	90		-
	13.1 m/min	100	100		-
Shaping	Good to excellent samples			%	0
Turning	Fair to excellent samples			%	50
Nailing	Samples free from complete splits			%	95
Screwing	Samples free from complete splits			%	100

Slicing, sliced veneer - Assessment of relevant properties

	not tested
Heating temperature	
Flich degrade due to thermal treatment	
Ease of cutting	
Drying degrade	
Finishing quality	

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

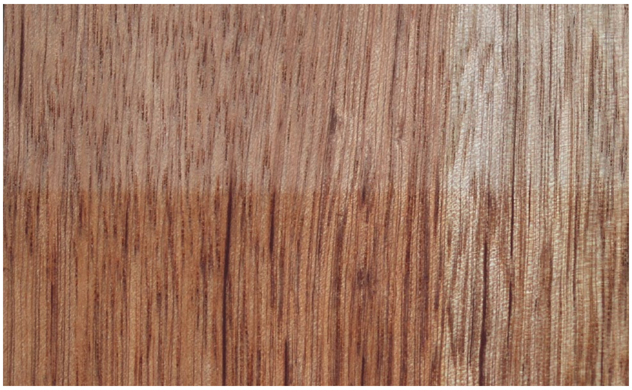
Heating temperature	25-50°C
Log degrade due to hydrothermal treatment	severe
Ease of peeling	
Gluing	satisfactory
Mechanical properties of plywood	satisfactory

Calophyllum brasiliense Camb.

sin.: /

Calophyllaceae | Common name: **barí** | Lacandon name: **babah**

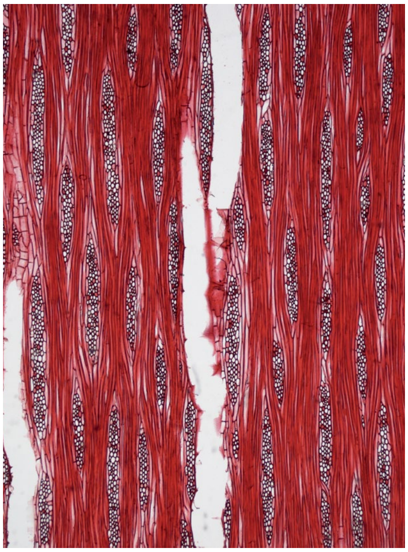
Use: interior construction, exterior construction, framework, furniture, peeled veneer, flooring, exterior coverings, interior coverings, boat building, construction plywood, particle board, possibly for decorative sliced veneer and rail sleepers, decorative race veneer



Radial section in actual size.
Upper half of the sample sanded and unfinished,
the lower half oil finish.

cross section

radial section



tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 40 m	
Diameter	up to 130 cm	
Bole	straight, regular, clear for 25 m	
Heartwood and sapwood (Munsell color chart)	colored heartwood, heartwood clearly differentiated from sapwood	
Condition	Sapwood	Heartwood
Green	5 YR HUE / 5 YR 8/4	10 R HUE / 10 R 7/8
Air dried	2.5 YR HUE / 2.5 YR 7/4	10 R HUE / 10 R 5/8
Grain	Lightly or broadly shallowly interlocked	
Texture	medium to coarse	

Moisture content and density

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 2/4.

Density	ρ_0	S	539	...	**575**	...	611	kg/m³
		H	587	...	**605**	...	621	kg/m³
Moisture content (MC) green		S	80	...	**85**	...	90	%
		H	70	...	**84**	...	97	%
EMC(21 °C/65%)		S			**14**			%
		H			**15**			%

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

Dimensional stability

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 2/4.

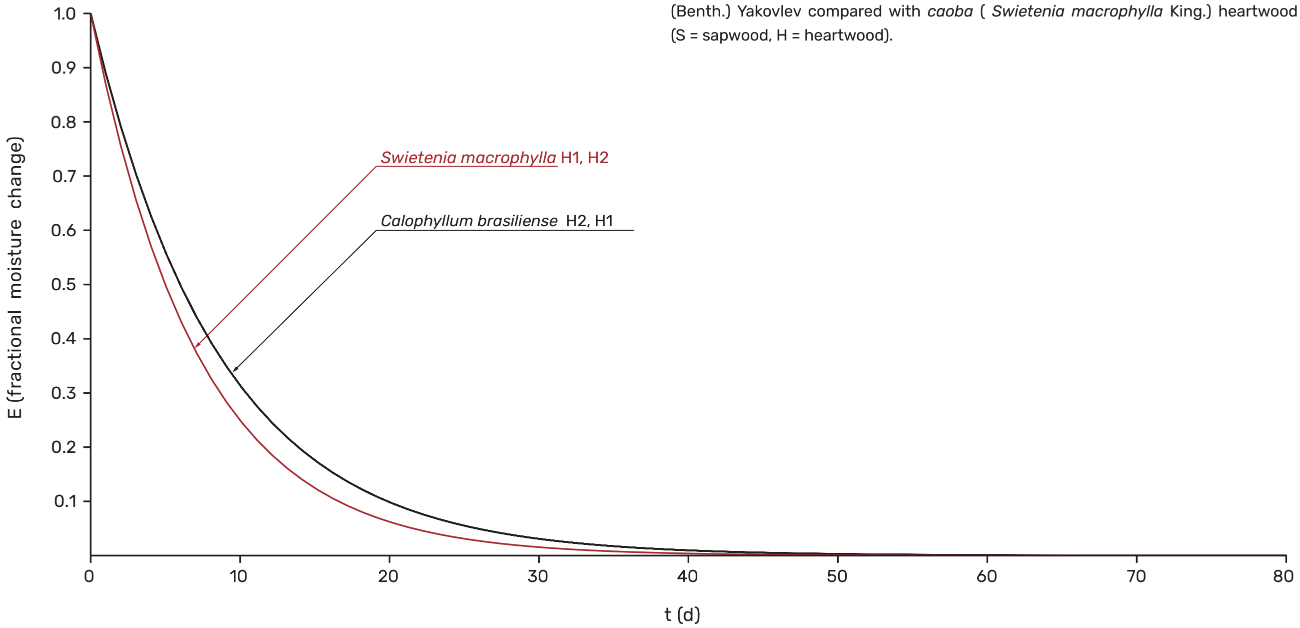
Density	ρ_0	S	539	...	**575**	...	611	kg / m³	
		H	587	...	**605**	...	621	kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.30	...	**0.31**	...	0.32	% / %	normal
	q_{tang}	H	0.33	...	**0.34**	...	0.34	% / %	normal
	q_{rad}	S	0.17	...	**0.20**	...	0.22	% / %	
	q_{rad}	H	0.18	...	**0.20**	...	0.22	% / %	
	q_{tang} / q_{rad}	S	1.45	...	**1.60**	...	1.76		normal
	q_{tang} / q_{rad}	H	1.55	...	**1.69**	...	1.83		normal
	$q_{tang} - q_{rad}$	S	0.10	...	**0.12**	...	0.13	% / %	normal
	$q_{tang} - q_{rad}$	H	0.12	...	**0.14**	...	0.15	% / %	normal
Swelling coefficient and anisotropy	h_{tang}	S	0.050	...	**0.053**	...	0.054	% / %	normal
	h_{tang}	H	0.053	...	**0.054**	...	0.054	% / %	normal
	h_{rad}	S	0.029	...	**0.034**	...	0.038	% / %	
	h_{rad}	H	0.029	...	**0.032**	...	0.036	% / %	
	h_{tang} / h_{rad}	S	1.42	...	**1.57**	...	1.73		favourable
	h_{tang} / h_{rad}	H	1.50	...	**1.68**	...	1.86		normal
	$h_{tang} - h_{rad}$	S	0.016	...	**0.019**	...	0.022	% / %	favourable
	$h_{tang} - h_{rad}$	H	0.018	...	**0.022**	...	0.025	% / %	normal
Sorption coefficient	*S*	S	0.17	...	**0.17**	...	0.17	% / %	unfavourable
	S	H	0.16	...	**0.16**	...	0.16	% / %	normal

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	605
	Seasoning time	days	147
	Initial moisture content	%	59
	Final moisture content	%	21
	Checking		43
	Warping		4
	Seasoning degrade		2
	$t_{eq0.5}$ days	H1:6, H2:6	6
	t_{eq} days	H1:42, H2:40	40
Recommended drying schedule	Drying gradient		1.9
	T_1	°C	35
	T_2	°C	65

9. ***Calophyllum brasiliense*** Camb.

Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).



pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
Sapwood	11/1S	637	5.1		
	11/2S		5.2		
Heartwood	11/1H	647	5.5	0.44	0.0007
	11/2H	584	5.3	0.45	0.0001

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			2 / 5	2 / 5
Weight loss	average	%	1	18
	minimum	%	0	13
	maximum	%	2	27
Resistance to decay			very resistant	resistant
Proportion of samples in each class	1	%	100	0
	2	%	0	80
	3	%	0	20
	4	%	0	0

Mechanical properties in green condition

Number of test trees				2	
Basic density ρ_b			kg/m³	520	medium
	Stress at proportional limit		MPa	34.3	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	78.3	high
	Stiffness	Modulus of elasticity	GPa	10.8	medium
Compression	Maximal compression strength parallel to grain		MPa	32.2	medium
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	52.6	very high
		Rad.	kN	3.21	low
Janka hardness	Resistance to identation	Tang.	kN	3.25	low
		End	kN	4.17	medium

Machining and related properties

Number of test trees				1
Number of test samples				10
Moisture content	Min - max		%	15.5 - 16.0
Planing	Defect free samples		%	60

		Angle		
		30°	20°	15°
Speed	7.6 m/min	60	30	30
	13.1 m/min	40	10	20

Shaping	Good to excellent samples	%	40
Turning	Fair to excellent samples	%	50
Nailing	Samples free from complete splits	%	15
Screwing	Samples free from complete splits	%	72

Slicing, sliced veneer - Assessment of relevant properties

not tested
Heating temperature
Flich degrade due to thermal treatment
Ease of cutting
Drying degrade
Finishing quality

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

not tested
Heating temperature
Log degrade due to hydrothermal treatment
Ease of peeling
Gluing
Mechanical properties of plywood

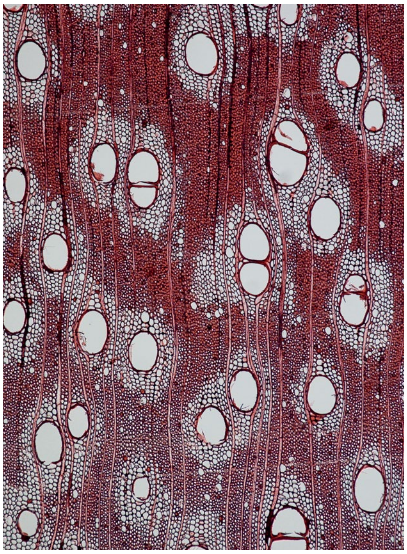
Cojoba arborea (L.) Britton & Rose

sin.: ***Pithecellobium arboreum*** **(L.) Urban**

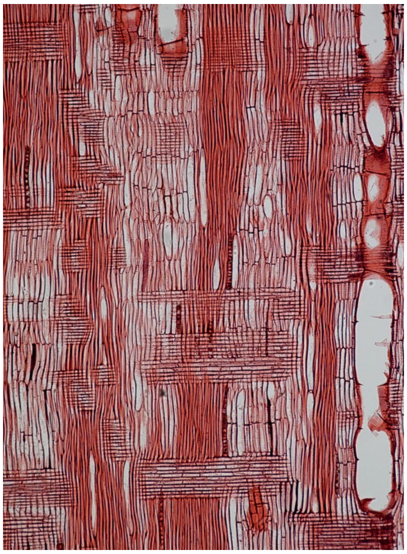
Fabaceae | Common name: **frijolillo** | Lacandon name: **/**

Use: interior construction, exterior construction, framework, furniture, decorative sliced veneer, flooring, container veneer and plywood, interior coverings, exterior coverings, hydraulic works, sleepers

Radial section in actual size.
Upper half of the sample sanded and unfinished,
the lower half oil finish.



cross section



radial section

tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 35 m	
Diameter	up to 100 cm	
Bole	Regular, straight clear for 20 m	
Heartwood and sapwood (Munsell color chart)	heartwood is clearly demarcated from sapwood	
Condition	Sapwood	Heartwood
Green	10 YR HUE / 10 YR 8/6	2.5 YR HUE / 2.5 YR 5/10
Air dried	5 YR HUE / 5 YR 8/2	10 R HUE / 10 R 5/6
Grain	typically inclined or narrowly interlocked	
Texture	Medium	

Moisture content and density

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 2/4.

Density	ρ_0	S	637	...	**700**	...	728	kg/m³
		H	613	...	**620**	...	632	kg/m³
Moisture content (MC) green		S	59	...	**65**	...	71	%
		H	94	...	**100**	...	105	%
EMC(21 °C/65%)		S			**14**			%
		H			**15**			%

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

Dimensional stability

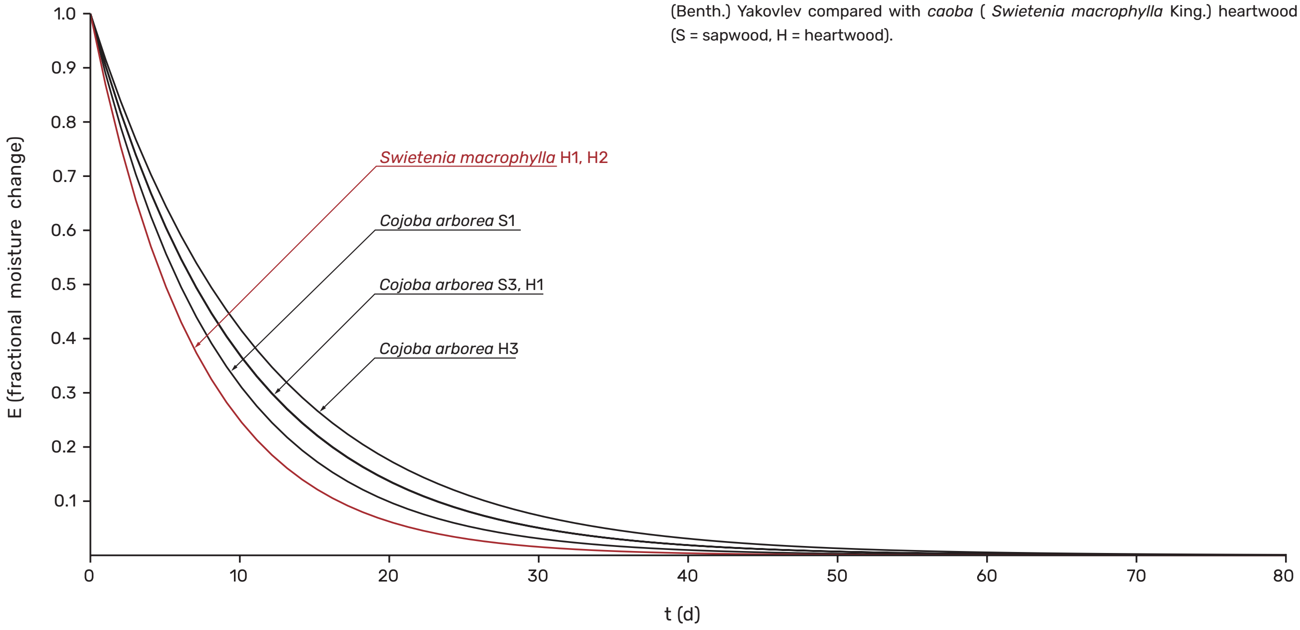
No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 2/4.

Density	ρ_0	S	673	...	**700**	...	728	kg / m³	
		H	613	...	**620**	...	632	kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.34	...	**0.35**	...	0.37	% / %	normal
	q_{tang}	H	0.31	...	**0.33**	...	0.36	% / %	normal
	q_{rad}	S	0.18	...	**0.18**	...	0.19	% / %	
	q_{rad}	H	0.17	...	**0.17**	...	0.17	% / %	
	q_{tang} / q_{rad}	S	1.89	...	**1.94**	...	2.06		normal
	q_{tang} / q_{rad}	H	1.82	...	**1.91**	...	2.12		normal
	$q_{tang} - q_{rad}$	S	0.16	...	**0.17**	...	0.19	% / %	normal
	$q_{tang} - q_{rad}$	H	0.14	...	**0.16**	...	0.19	% / %	normal
Swelling coefficient and anisotropy	h_{tang}	S	0.053	...	**0.056**	...	0.060	% / %	normal
	h_{tang}	H	0.048	...	**0.051**	...	0.055	% / %	normal
	h_{rad}	S	0.028	...	**0.029**	...	0.030	% / %	
	h_{rad}	H	0.026	...	**0.026**	...	0.026	% / %	
	h_{tang} / h_{rad}	S	1.86	...	**1.92**	...	2.00		normal
	h_{tang} / h_{rad}	H	1.85	...	**1.95**	...	2.12		normal
	$h_{tang} - h_{rad}$	S	0.025	...	**0.027**	...	0.030	% / %	normal
	$h_{tang} - h_{rad}$	H	0.022	...	**0.025**	...	0.029	% / %	normal
Sorption coefficient	s	S	0.16	...	**0.16**	...	0.16	% / %	normal
	s	H	0.15	...	**0.16**	...	0.16	% / %	normal

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³		700
	Seasoning time	days		112
	Initial moisture content	%		85
	Final moisture content	%		20
	Checking			29
	Warping			3
	Seasoning degrade			1-2
	$t_{eq0.5}$ days		S1:6, S3:7, H1:7, H3:8	8
	t_{eq} days		S1:42, S3:44, H1:48, H3:52	50
Recommended drying schedule	Drying gradient			2.1
	T_1	°C		50
	T_2	°C		80

10. ***Cojoba arborea*** **(L.) Britton & Rose**



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
Sapwood	26/1S	689	6.1		
	26/3S	728	5.6		
Heartwood	26/1H	617	5.2	0.90	0.0006
	26/3H	655	4.8	1.12	0.0003

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			3 / 5	3 / 5
Weight loss	average	%	2	6
	minimum	%	1	1
	maximum	%	2	9
Resistance to decay			very resistant	very resistant
Proportion of samples in each class	1	%	100	100
	2	%	0	0
	3	%	0	0
	4	%	0	0

Mechanical properties in green condition

Number of test trees				3	
Basic density ρ_b			kg/m³	650	high
	Stress at proportional limit		MPa	50.2	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	84.8	high
	Stiffness	Modulus of elasticity	GPa	10.8	medium
Compression	Maximal compression strength parallel to grain		MPa	44.0	high
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	27.1	medium
		Rad.	kN	5.34	high
Janka hardness	Resistance to identation	Tang.	kN	4.93	high
		End	kN	6.04	high

Machining and related properties

Number of test trees					1
Number of test samples					10
Moisture content	Min - max			%	13.0 - 15.0
Planing	Defect free samples			%	67
		Angle			
		30°	20°	15°	
Speed	7.6 m/min	50	67	67	
	13.1 m/min	42	8	0	
Shaping	Good to excellent samples			%	50
Turning	Fair to excellent samples			%	90
Nailing	Samples free from complete splits			%	58
Screwing	Samples free from complete splits			%	55

Slicing, sliced veneer - Assessment of relevant properties

Heating temperature	80-90 °C
Flich degrade due to thermal treatment	none
Ease of cutting	moderately easy to cut
Drying degrade	without checking and wrinkling to some/ little wrinkling and checking
Finishing quality	good

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

	not tested
Heating temperature	
Log degrade due to hydrothermal treatment	
Ease of peeling	
Gluing	
Mechanical properties of plywood	

Cordia alliodora (Ruiz & Pav.) Oken

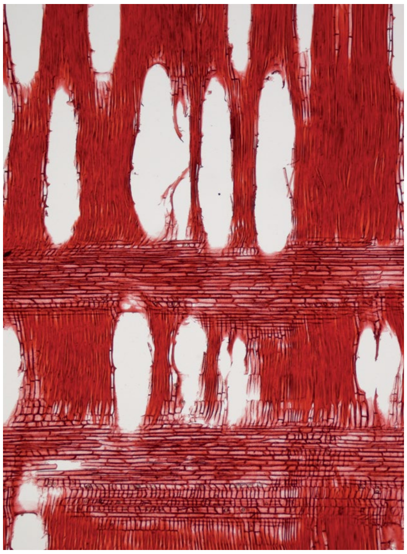
sin.: /

Boraginaceae | Common name: **bojón** | Lacandon name: **bahun che'**

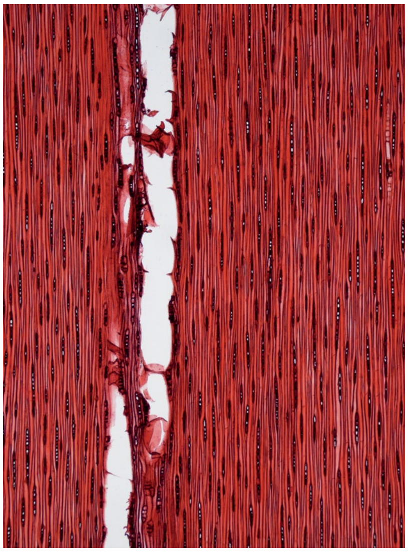
Use: interior construction, exterior construction, furniture, peeled veneer, flooring, particle board, decorative sliced veneer, container veneer and plywood, framework, interior coverings, exterior coverings, construction plywood

Radial section in actual size.
Upper half of the sample sanded and unfinished, the lower half oil finish.

cross section



radial section



tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 45 m	
Diameter	up to 50 cm	
Bole	Regular, 30m	
Heartwood and sapwood (Munsell color chart)	heartwood is clearly differentiated from the sapwood	
Condition	Sapwood	Heartwood
Green	7.5 YR HUE / 7.5 YR 8/8	5 YR HUE / 5 YR 4/2
Air dried	10 YR HUE / 10 YR 9/2	10 YR HUE / 10 YR 6/6
Grain	Straight, slightly or shalllowly interlocked	
Texture	Medium	

Dimensional stability

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 2/4.

Density	ρ_0	S	520	...	**552**	...	584	kg / m³	
		H	504	...	**536**	...	573	kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.34	...	**0.39**	...	0.43	% / %	normal
	q_{tang}	H	0.32	...	**0.36**	...	0.41	% / %	normal
	q_{rad}	S	0.17	...	**0.18**	...	0.19	% / %	
	q_{rad}	H	0.16	...	**0.17**	...	0.19	% / %	
	q_{tang} / q_{rad}	S	1.84	...	**2.17**	...	2.53		unfavourable
	q_{tang} / q_{rad}	H	1.68	...	**2.13**	...	2.56		unfavourable
	$q_{tang} - q_{rad}$	S	0.16	...	**0.21**	...	0.26	% / %	unfavourable
	$q_{tang} - q_{rad}$	H	0.13	...	**0.19**	...	0.25	% / %	normal
Swelling coefficient and anisotropy	h_{tang}	S	0.058	...	**0.064**	...	0.070	% / %	normal
	h_{tang}	H	0.047	...	**0.055**	...	0.062	% / %	normal
	h_{rad}	S	0.028	...	**0.030**	...	0.032	% / %	
	h_{rad}	H	0.024	...	**0.026**	...	0.028	% / %	
	h_{tang} / h_{rad}	S	1.81	...	**2.15**	...	2.50		unfavourable
	h_{tang} / h_{rad}	H	1.71	...	**2.14**	...	2.54		unfavourable
	$h_{tang} - h_{rad}$	S	0.026	...	**0.034**	...	0.042	% / %	normal
	$h_{tang} - h_{rad}$	H	0.020	...	**0.029**	...	0.037	% / %	normal
Sorption coefficient	S	S	0.16	...	**0.17**	...	0.17	% / %	unfavourable
	S	H	0.15	...	**0.15**	...	0.15	% / %	favourable

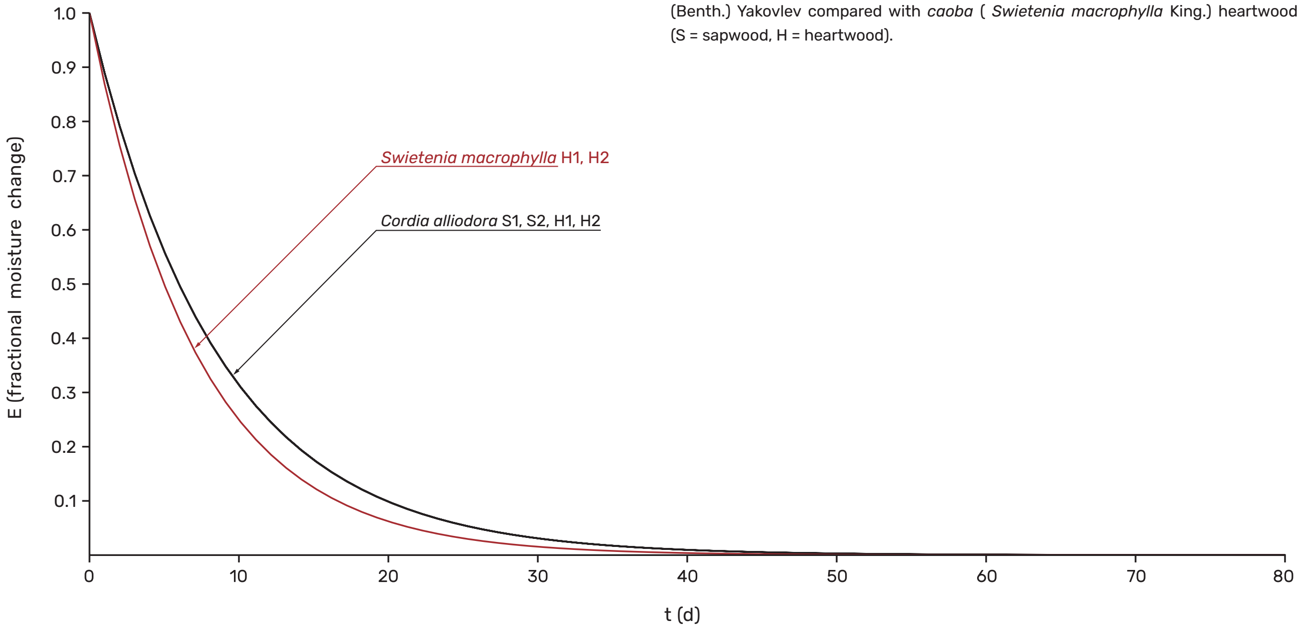
Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	536
	Seasoning time	days	154
	Initial moisture content	%	76
	Final moisture content	%	19
	Checking		98
	Warping		6
	Seasoning degrade		2
	$t_{eq0.5}$ days	S1, S2, H1, H2: 6	6
	t_{eq} days	S1, S2, H1, H2: 42	42
Recommended drying schedule	Drying gradient		3.1
	T_1	°C	60
	T_2	°C	80

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

11. *Cordia alliodora* (Ruiz & Pav.) Oken

Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).



pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
	12/1S	601	5.7		
Sapwood	12/2S	506	5.9		
	12/1H	510	5.5	0.63	0.0008
Heartwood	12/2H	498	5.6	0.81	0.0002

Mechanical properties in green condition

Number of test trees				2	
Basic density ρ_b			kg/m³	490	medium
	Stress at proportional limit		MPa	43.1	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	76.3	high
	Stiffness	Modulus of elasticity	GPa	9.8	medium
Compression	Maximal compression strength parallel to grain		MPa	33.5	medium
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	25.9	medium
		Rad.	kN	2.67	low
Janka hardness	Resistance to identation	Tang.	kN	2.99	low
		End	kN	3.66	medium

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			2 / 5	2 / 5
Weight loss	average	%	0	8
	minimum	%	0	2
	maximum	%	1	12
Resistance to decay			very resistant	very resistant
Proportion of samples in each class	1	%	100	80
	2	%	0	20
	3	%	0	0
	4	%	0	0

Machining and related properties

Number of test trees					1
Number of test samples					10
Moisture content	Min - max			%	12.5 - 14.5
Planing	Defect free samples			%	80
		Angle			
		30°	20°	15°	
Speed	7.6 m/min	80	60	-	
	13.1 m/min	60	0	-	
Shaping	Good to excellent samples			%	30
Turning	Fair to excellent samples			%	20
Nailing	Samples free from complete splits			%	70
Screwing	Samples free from complete splits			%	70

Slicing, sliced veneer - Assessment of relevant properties

Heating temperature	55-60 °C
Flich degrade due to thermal treatment	none
Ease of cutting	easy to cut
Drying degrade	without checking and wrinkling
Finishing quality	good

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

	not tested
Heating temperature	
Log degrade due to hydrothermal treatment	
Ease of peeling	
Gluing	
Mechanical properties of plywood	

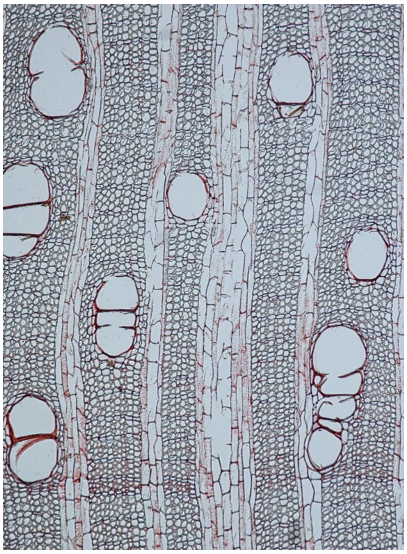
Cymbopetalum penduliflorum (Sessé & Moç. ex Dunal) Baill.

sin.: **/**

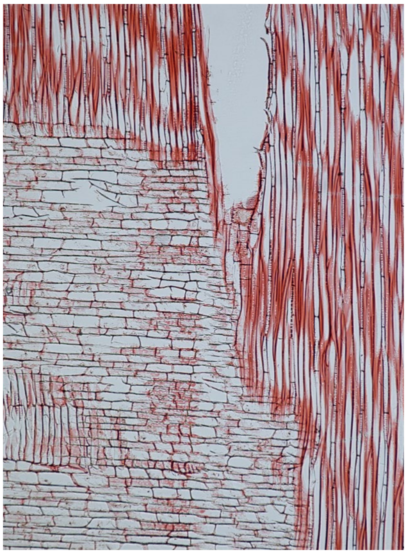
Annonaceae | Common name: **orejuelo** | Lacandon name: **ton ku'uk**

Use: peeled veneer, decorative sliced veneer, packaging, cellulose products, paper pulp, particle board, core and crossband veneer, container veneer and plywood, framework, interior construction

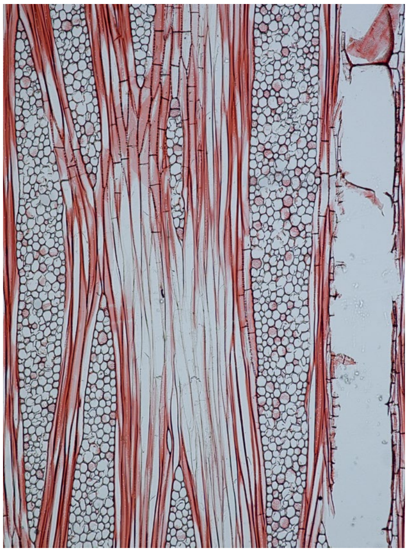
Radial section in actual size.
Upper half of the sample sanded and unfinished,
the lower half oil finish.



cross section



radial section



tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 25 m
Diameter	commonly about 50 cm
Bole	Up to 20m, regular
Heartwood and sapwood (Munsell color chart)	without colored heartwood

Condition	Sapwood	Heartwood
Green	10 YR HUE / 10 YR 9/2	
Air dried	2.5 Y HUE / 2.5 Y 8/4	

Grain	Straight
Texture	coarse

Moisture content and density

No. of test trees / samples: Sapwood (S) 1/2 ; Heartwood (H) 0/0.

Density	ρ_0	S	395	...	**395**	...	395	kg/m³
		H						
Moisture content (MC) green		S	132	...	**135**	...	138	%
		H						
EMC(21 °C/65%)		S			**14**			%
		H						

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ *days* – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} *days* – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

Dimensional stability

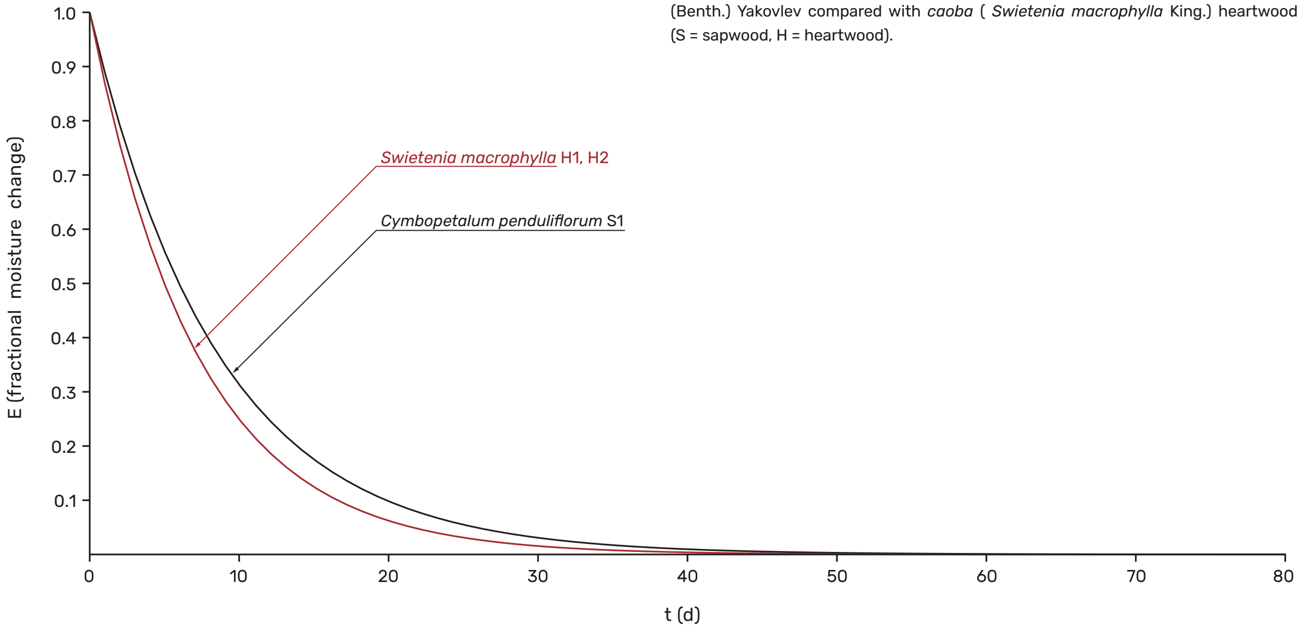
No. of test trees / samples: Sapwood (S) 1/2 ; Heartwood (H) 0/0.

Density	ρ_0	S	395	...	**395**	...	395	kg / m³	
		H		...		...		kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.35	...	**0.37**	...	0.38	% / %	normal
	q_{tang}	H		...		...		% / %	
	q_{rad}	S	0.16	...	**0.16**	...	0.16	% / %	
	q_{rad}	H		...		...		% / %	
	q_{tang} / q_{rad}	S	2.19	...	**2.29**	...	2.38		unfavourable
	q_{tang} / q_{rad}	H		...		...			
	$q_{tang} - q_{rad}$	S	0.19	...	**0.21**	...	0.22	% / %	unfavourable
	$q_{tang} - q_{rad}$	H		...		...		% / %	
Swelling coefficient and anisotropy	h_{tang}	S	0.055	...	**0.058**	...	0.060	% / %	normal
	h_{tang}	H		...		...		% / %	
	h_{rad}	S	0.025	...	**0.025**	...	0.025	% / %	
	h_{rad}	H		...		...		% / %	
	h_{tang} / h_{rad}	S	2.20	...	**2.30**	...	2.40		unfavourable
	h_{tang} / h_{rad}	H		...		...			
	$h_{tang} - h_{rad}$	S	0.030	...	**0.033**	...	0.035	% / %	normal
	$h_{tang} - h_{rad}$	H		...		...		% / %	
Sorption coefficient	S	S	0.16	...	**0.16**	...	0.16	% / %	normal
	S	H		...		...		% / %	

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	–
	Seasoning time	days	–
	Initial moisture content	%	–
	Final moisture content	%	–
	Checking		–
	Warping		–
	Seasoning degrade		–
	$t_{eq0.5}$ days	S1:6	–
	t_{eq} days	S:39	–
Recommended drying schedule	Drying gradient		–
	T_1	°C	–
	T_2	°C	–

12. *Cymbopetalum penduliflorum* (Sessé & Moç. ex Dunal) Baill.



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
Sapwood	47/1S	388	6.9	1.68	0.004
Heartwood					

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			1 / 3	1 / 4
Weight loss	average	%	23	34
	minimum	%	15	31
	maximum	%	29	50
Resistance to decay			resistant	moderately resistant
Proportion of samples in each class	1	%	0	0
	2	%	67	25
	3	%	33	50
	4	%	0	25

Mechanical properties in green condition

Number of test trees				1	
Basic density ρ_b			kg/m³	420	medium
	Stress at proportional limit		MPa	20.5	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	40.7	low
	Stiffness	Modulus of elasticity	GPa	6.0	very low
Compression	Maximal compression strength parallel to grain		MPa	17.9	low
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	9.8	very low
		Rad.	kN	1.32	very low
Janka hardness	Resistance to identation	Tang.	kN	1.84	very low
		End	kN	1.77	very low

Machining and related properties

Number of test trees				not tested	
Number of test samples					
Moisture content	Min - max	%		-	
Planing	Defect free samples	%			
			Angle		
		30°	20°	15°	
Speed	7.6 m/min				
	13.1 m/min				
Shaping	Good to excellent samples	%			
Turning	Fair to excellent samples	%			
Nailing	Samples free from complete splits	%			
Screwing	Samples free from complete splits	%			

Slicing, sliced veneer - Assessment of relevant properties

	not tested
Heating temperature	
Flich degrade due to thermal treatment	
Ease of cutting	
Drying degrade	
Finishing quality	

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

	not tested
Heating temperature	
Log degrade due to hydrothermal treatment	
Ease of peeling	
Gluing	
Mechanical properties of plywood	

Dendropanax arboreus (L.) Decne. & Planch.

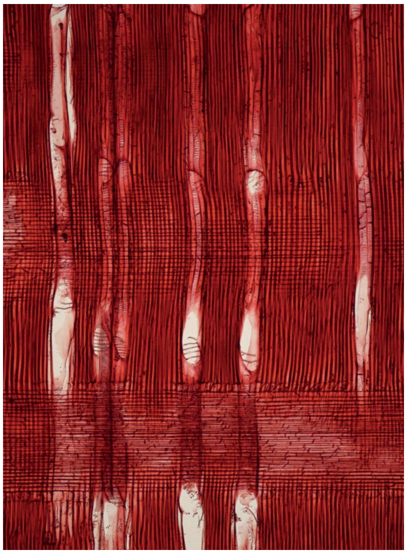
sin.: /

Araliaceae | Common name: **sac-chacáh** | Lacandon name: **sasakche'**

Use: interior construction, framework, peeled veneer, packaging, cellulose products, paper pulp, construction plywood, core and crossband veneer, container veneer and plywood

Radial section in actual size.
Upper half of the sample sanded and unfinished,
the lower half oil finish.

cross section



radial section

tangential section

500 µm

Tree, wood - Key Characteristics

Height	Up to 30m	
Diameter	Up to 70cm	
Bole	Up to 15m, regular	
Heartwood and sapwood (Munsell color chart)	Heartwood doesn't exist	
Condition	Sapwood	Heartwood
Green	2.5 y HUE / 2.5 Y 8.5/6	
Air dried	5 Y HUE / 5 Y 9/2	
Grain	Straight	
Texture	Coarse	

Moisture content and density

No. of test trees / samples: Sapwood (S) 3/6 ; Heartwood (H) 0/0.

Density	ρ_0	S	379	...	**421**	...	474	kg/m³
		H						
Moisture content (MC) green		S	122	...	**147**	...	170	%
		H						
EMC(21 °C/65%)		S			**14**			%
		H						

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

Dimensional stability

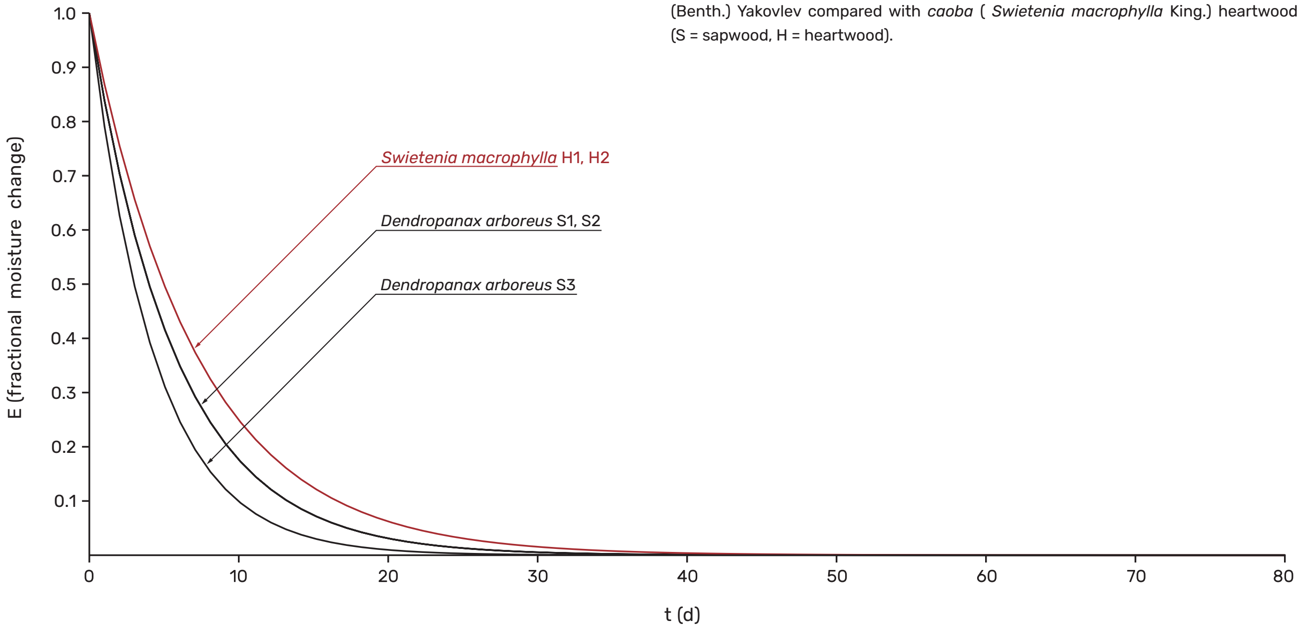
No. of test trees / samples: Sapwood (S) 3/6 ; Heartwood (H) 0/0.

Density	ρ_0	S	379	...	**421**	...	474	kg / m³	
		H		...		...		kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.26	...	**0.28**	...	0.31	% / %	favourable
	q_{tang}	H		...		...		% / %	
	q_{rad}	S	0.15	...	**0.17**	...	0.18	% / %	
	q_{rad}	H		...		...		% / %	
	q_{tang} / q_{rad}	S	1.39	...	**1.69**	...	1.88		normal
	q_{tang} / q_{rad}	H		...		...			
	$q_{tang} - q_{rad}$	S	0.07	...	**0.12**	...	0.14	% / %	normal
	$q_{tang} - q_{rad}$	H		...		...		% / %	
Swelling coefficient and anisotropy	h_{tang}	S	0.043	...	**0.048**	...	0.054	% / %	favourable
	h_{tang}	H		...		...		% / %	
	h_{rad}	S	0.025	...	**0.028**	...	0.030	% / %	
	h_{rad}	H		...		...		% / %	
	h_{tang} / h_{rad}	S	1.43	...	**1.72**	...	1.88		normal
	h_{tang} / h_{rad}	H		...		...			
	$h_{tang} - h_{rad}$	S	0.013	...	**0.020**	...	0.025	% / %	normal
	$h_{tang} - h_{rad}$	H		...		...		% / %	
Sorption coefficient	S	S	0.16	...	**0.17**	...	0.17	% / %	unfavourable
	S	H		...		...		% / %	

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	–
	Seasoning time	days	–
	Initial moisture content	%	–
	Final moisture content	%	–
	Checking		–
	Warping		–
	Seasoning degrade		–
	$t_{eq0.5}$ days	S1:4, S2:4, S3:3	–
	t_{eq} days	S1:29, S2:28, S3:26	–
Recommended drying schedule	Drying gradient		–
	T_1	°C	–
	T_2	°C	–

13. *Dendropanax arboreus* (L.) Decne. & Planch.



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
Sapwood	14/1S	475	6.1	1.00	0.001
	14/2S	417	6.2	1.02	0.002
	14/3S	384	6.1	1.08	0.002
Heartwood					

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			3 / 5	3 / 5
Weight loss	average	%	41	49
	minimum	%	34	41
	maximum	%	49	55
Resistance to decay			moderately resistant	non-resistant
Proportion of samples in each class	1	%	0	0
	2	%	0	0
	3	%	80	20
	4	%	20	80

Mechanical properties in green condition

Number of test trees				3	
Basic density ρ_b			kg/m³	400	medium
	Stress at proportional limit		MPa	25.6	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	48.1	low
	Stiffness	Modulus of elasticity	GPa	7.9	very low
Compression	Maximal compression strength parallel to grain		MPa	20.7	low
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	19.6	low
		Rad.	kN	2.24	very low
Janka hardness	Resistance to identation	Tang.	kN	2.19	very low
		End	kN	2.67	low

Machining and related properties

Number of test trees				not tested	
Number of test samples					
Moisture content	Min - max		%	-	
Planing	Defect free samples		%		
		Angle			
		30°	20°	15°	
Speed	7.6 m/min				
	13.1 m/min				
Shaping	Good to excellent samples		%		
Turning	Fair to excellent samples		%		
Nailing	Samples free from complete splits		%		
Screwing	Samples free from complete splits		%		

Slicing, sliced veneer - Assessment of relevant properties

	not tested
Heating temperature	
Flich degrade due to thermal treatment	
Ease of cutting	
Drying degrade	
Finishing quality	

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

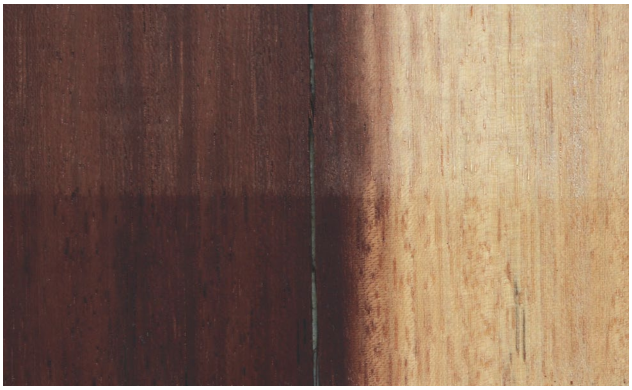
	not tested
Heating temperature	
Log degrade due to hydrothermal treatment	
Ease of peeling	
Gluing	
Mechanical properties of plywood	

Dialium guianense (Aubl.) Sandwith.

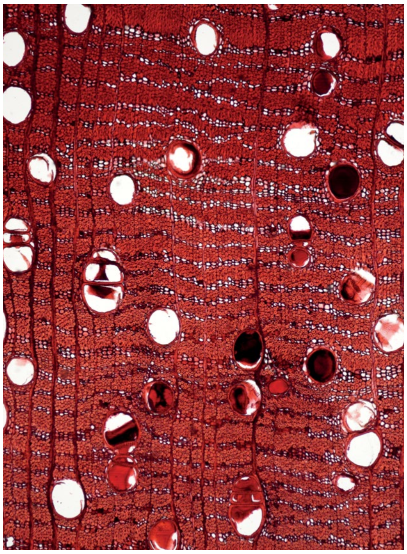
sin.: /

Fabaceae | Common name: **guapaque** | Lacandon name: **wäch'**

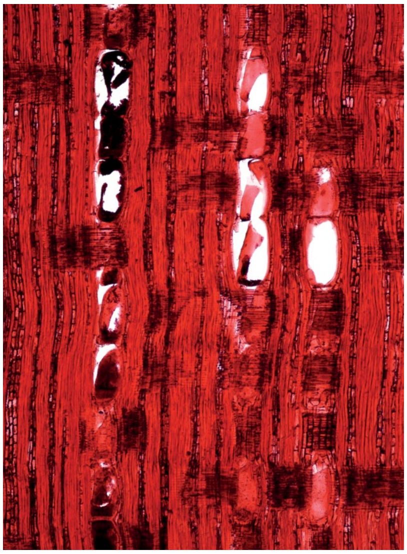
Use: exterior construction,rail sleepers, hydraulic works



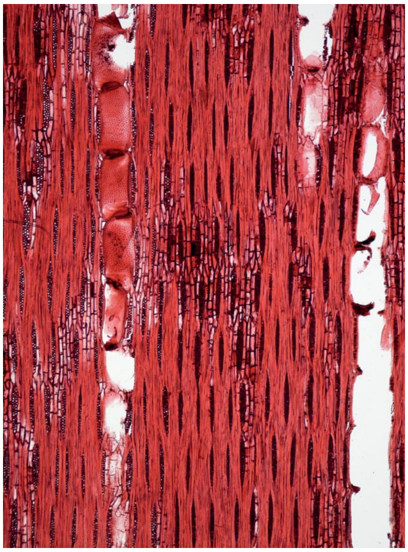
Radial section in actual size.
Upper half of the sample sanded and unfinished, the lower half oil finish.



cross section



radial section



tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 45 m	
Diameter	up to 150 cm	
Bole	Up to 30m, thin and tall butresses	
Heartwood and sapwood (Munsell color chart)	heartwood clearly differentiated from sapwood	
Condition	Sapwood	Heartwood
Green	2.5 Y HUE / 2.5 Y 8.5/6	7.5 R HUE / 7.5 R 5/6
Air dried	7.5 YR HUE / 7.5 YR 8/2	7.5 R HUE / 7.5 R. 5/4
Grain	slightly interlocked	
Texture	medium	

Moisture content and density

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 2/4.

Density	ρ_0	S	902	...	**917**	...	930	kg/m³
		H	952	...	**986**	...	1015	kg/m³
Moisture content (MC) green		S	53	...	**55**	...	57	%
		H	48	...	**52**	...	56	%
EMC(21 °C/65%)		S			**14**			%
		H			**14**			%

Dimensional stability

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 2/4.

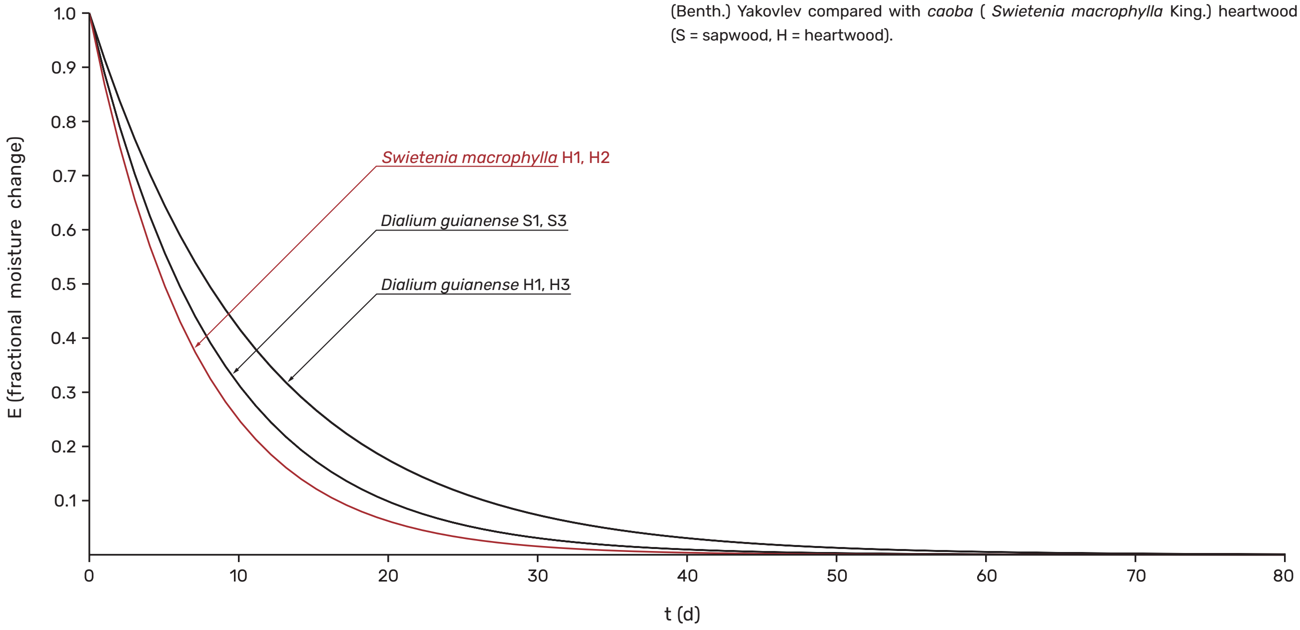
Density	ρ_0	S	902	...	**917**	...	930	kg / m³	
		H	952	...	**986**	...	1015	kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.46	...	**0.46**	...	0.47	% / %	unfavourable
	q_{tang}	H	0.46	...	**0.47**	...	0.47	% / %	unfavourable
	q_{rad}	S	0.20	...	**0.25**	...	0.28	% / %	
	q_{rad}	H	0.22	...	**0.24**	...	0.26	% / %	
	q_{tang} / q_{rad}	S	1.64	...	**1.91**	...	2.30		normal
	q_{tang} / q_{rad}	H	1.81	...	**1.95**	...	2.14		normal
	$q_{tang} - q_{rad}$	S	0.18	...	**0.22**	...	0.26	% / %	unfavourable
	$q_{tang} - q_{rad}$	H	0.16	...	**0.20**	...	0.25	% / %	normal
Swelling coefficient and anisotropy	h_{tang}	S	0.073	...	**0.074**	...	0.075	% / %	unfavourable
	h_{tang}	H	0.062	...	**0.065**	...	0.068	% / %	unfavourable
	h_{rad}	S	0.032	...	**0.040**	...	0.044	% / %	
	h_{rad}	H	0.031	...	**0.037**	...	0.041	% / %	
	h_{tang} / h_{rad}	S	1.65	...	**1.90**	...	2.31		normal
	h_{tang} / h_{rad}	H	1.54	...	**1.77**	...	2.16		normal
	$h_{tang} - h_{rad}$	S	0.029	...	**0.035**	...	0.042	% / %	normal
	$h_{tang} - h_{rad}$	H	0.022	...	**0.028**	...	0.036	% / %	normal
Sorption coefficient	s	S	0.16	...	**0.16**	...	0.16	% / %	normal
	s	H	0.13	...	**0.14**	...	0.14	% / %	favourable

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	986
	Seasoning time	days	112
	Initial moisture content	%	46
	Final moisture content	%	19
	Checking		8
	Warping		0
	Seasoning degrade		1
	$t_{eq0.5}$ days	S1:6, S3:6, H1:8, H3:8	8
	t_{eq} days	S1:40, S3:41, H1:50, H3:53	52
Recommended drying schedule	Drying gradient		2.1
	T_1	°C	50
	T_2	°C	80

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

14. *Dialium guianense* (Aubl.) Sandwith.



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
Sapwood	13/1S	922	4.9		
	13/3S	938	5.5		
Heartwood	13/1H	963	4.7	0.47	0.37
	13/3H	1008	4.9	1.58	1.40

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			3 / 5	3 / 5
Weight loss	average	%	0	1
	minimum	%	0	0
	maximum	%	0	3
Resistance to decay			very resistant	very resistant
Proportion of samples in each class	1	%	100	100
	2	%	0	0
	3	%	0	0
	4	%	0	0

Mechanical properties in green condition

Number of test trees				3	
Basic density ρ_b			kg/m³	800	very high
	Stress at proportional limit		MPa	65.7	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	124.5	very high
	Stiffness	Modulus of elasticity	GPa	18.4	very high
Compression	Maximal compression strength parallel to grain		MPa	55.5	very high
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	79.6	exceptionally high
		Rad.	kN	9.25	very high
Janka hardness	Resistance to identation	Tang.	kN	8.44	very high
		End	kN	9.23	very high

Machining and related properties

Number of test trees				not tested	
Number of test samples					
Moisture content	Min - max		%	-	
Planing	Defect free samples		%		
		Angle			
		30°	20°	15°	
Speed	7.6 m/min				
	13.1 m/min				
Shaping	Good to excellent samples		%		
Turning	Fair to excellent samples		%		
Nailing	Samples free from complete splits		%		
Screwing	Samples free from complete splits		%		

Slicing, sliced veneer - Assessment of relevant properties

	not tested
Heating temperature	
Flich degrade due to thermal treatment	
Ease of cutting	
Drying degrade	
Finishing quality	

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

	not tested
Heating temperature	
Log degrade due to hydrothermal treatment	
Ease of peeling	
Gluing	
Mechanical properties of plywood	

Guarea glabra Vahl

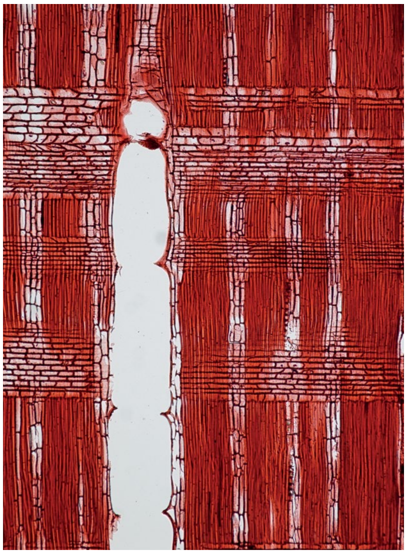
sin.: /

Meliaceae | Common name: **cedrillo** | Lacandon name: **säk bahche'**

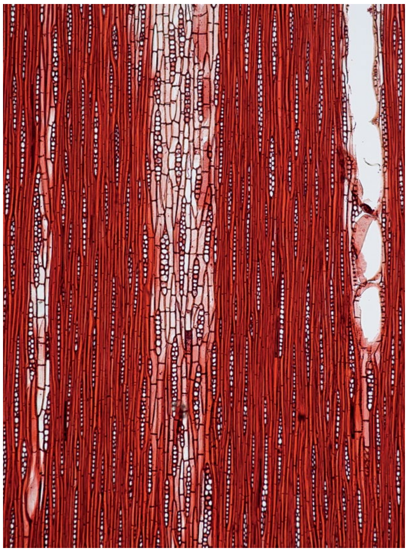
Use: interior construction, framework, furniture, peeled veneer, decorative sliced veneer, flooring, construction plywood, container veneer and plywood, exterior construction, exterior coverings, boat building, particle board

Radial section in actual size.
Upper half of the sample sanded and unfinished,
the lower half oil finish.

cross section



radial section



tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 35 m		
Diameter	up to 80 cm		
Bole	Up to 25m, regular with small buttresses		
Heartwood and sapwood (Munsell color chart)	heartwood demarcated from the sapwood		
Condition	Sapwood	Heartwood	
Green	5 YR HUE / 5 YR 7/8	10 R HUE / 10 R 6/8	2.5 YR HUE / 2.5 YR 5/12
Air dried	2.5 YR HUE / 2.5 YR 8/4	2.5 YR HUE / 2.5 YR 7/6	
Grain	straight or shallowly interlocked occasionally shallowly and narrowly interlocked		
Texture	medium		

Moisture content and density

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 2/4.

Density	ρ_0	S	561	...	**587**	...	612	kg/m³
		H	611	...	**623**	...	639	kg/m³
Moisture content (MC) green		S	77	...	**80**	...	82	%
		H	109	...	**112**	...	114	%
EMC(21 °C/65%)		S			**14**			%
		H			**14**			%

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

Dimensional stability

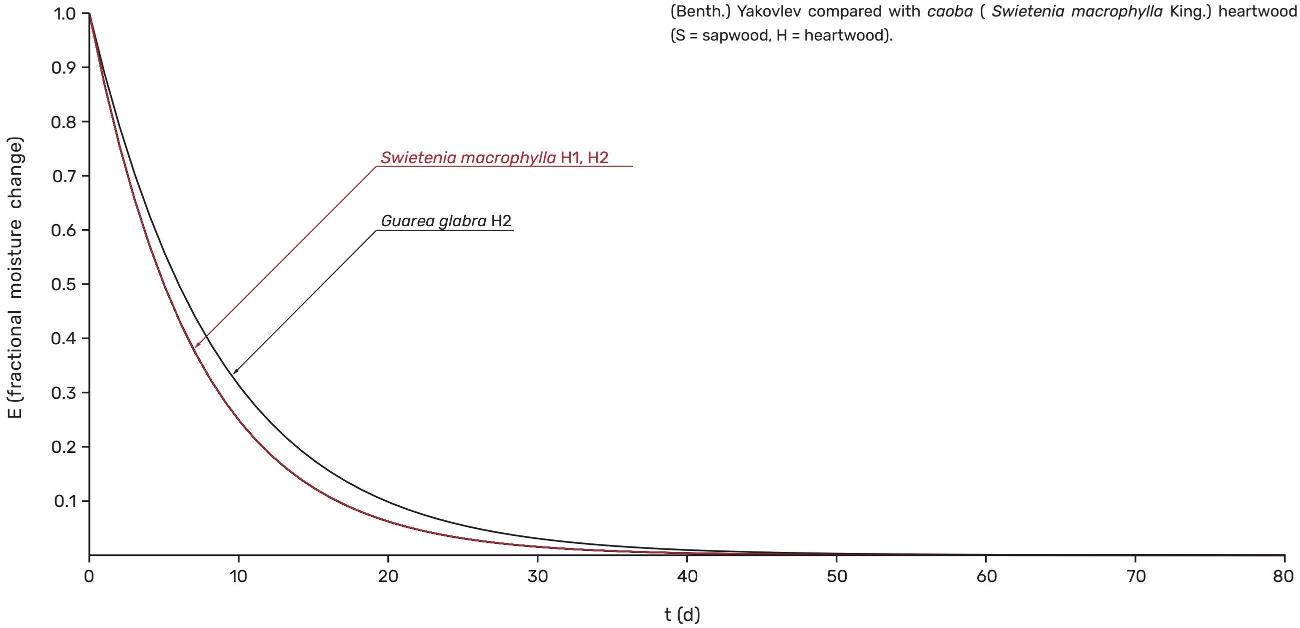
No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 2/4.

Density	ρ_0	S	561	...	**587**	...	612	kg / m³	
		H	611	...	**623**	...	639	kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.33	...	**0.34**	...	0.37	% / %	normal
	q_{tang}	H	0.34	...	**0.35**	...	0.36	% / %	normal
	q_{rad}	S	0.16	...	**0.17**	...	0.17	% / %	
	q_{rad}	H	0.17	...	**0.18**	...	0.19	% / %	
	q_{tang} / q_{rad}	S	2.06	...	**2.11**	...	2.18		unfavourable
	q_{tang} / q_{rad}	H	1.89	...	**1.95**	...	2.00		normal
	$q_{tang} - q_{rad}$	S	0.17	...	**0.18**	...	0.20	% / %	normal
	$q_{tang} - q_{rad}$	H	0.17	...	**0.17**	...	0.17	% / %	normal
Swelling coefficient and anisotropy	h_{tang}	S	0.053	...	**0.056**	...	0.058	% / %	normal
	h_{tang}	H	0.053	...	**0.055**	...	0.057	% / %	normal
	h_{rad}	S	0.025	...	**0.026**	...	0.027	% / %	
	h_{rad}	H	0.025	...	**0.028**	...	0.030	% / %	
	h_{tang} / h_{rad}	S	2.04	...	**2.12**	...	2.15		unfavourable
	h_{tang} / h_{rad}	H	1.87	...	**1.98**	...	2.12		normal
	$h_{tang} - h_{rad}$	S	0.027	...	**0.030**	...	0.031	% / %	normal
	$h_{tang} - h_{rad}$	H	0.026	...	**0.027**	...	0.028	% / %	normal
Sorption coefficient	S	S	0.16	...	**0.16**	...	0.16	% / %	normal
	S	H	0.15	...	**0.16**	...	0.16	% / %	normal

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	623
	Seasoning time	days	154
	Initial moisture content	%	119
	Final moisture content	%	20
	Checking		99
	Warping		3
	Seasoning degrade		1
	$t_{eq0.5}$ days	H2:6	6
	t_{eq} days	H2:39	38
Recommended drying schedule	Drying gradient		2.6
	T_1	°C	50
	T_2	°C	80

15. *Guarea glabra* Vahl



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
Sapwood	15/1S	578	5.4		
	15/2S	624	6.1		
Heartwood	15/1H	626	4.6	0.70	0.079
	15/2H	646	4.8	0.76	0.085

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			3 / 5	3 / 5
Weight loss	average	%	1	14
	minimum	%	0	9
	maximum	%	4	19
Resistance to decay			very resistant	resistant
Proportion of samples in each class	1	%	100	40
	2	%	0	60
	3	%	0	0
	4	%	0	0

Mechanical properties in green condition

Number of test trees				3	
Basic density ρ_b			kg/m³	560	high
Static bending-centre loading	Stress at proportional limit		MPa	44.9	
	Maximum bending strength	Modulus of rupture	MPa	88.2	high
	Stiffness	Modulus of elasticity	GPa	12.4	high
Compression	Maximal compression strength parallel to grain		MPa	37.5	high
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	28.2	medium
Janka hardness	Resistance to identation	Rad.	kN	4.29	medium
		Tang.	kN	3.88	medium
		End	kN	4.47	high

Machining and related properties

Number of test trees				1
Number of test samples				10
Moisture content	Min - max		%	14.5 - 15.5
Planing	Defect free samples		%	100

		Angle		
		30°	20°	15°
Speed	7.6 m/min	100	100	-
	13.1 m/min	60	80	-

Shaping	Good to excellent samples	%	90
Turning	Fair to excellent samples	%	80
Nailing	Samples free from complete splits	%	25
Screwing	Samples free from complete splits	%	78

Slicing, sliced veneer - Assessment of relevant properties

Heating temperature	70-80 °C
Flich degrade due to thermal treatment	none
Ease of cutting	easy to cut
Drying degrade	without checking and wrinkling
Finishing quality	good

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

	not tested
Heating temperature	
Log degrade due to hydrothermal treatment	
Ease of peeling	
Gluing	
Mechanical properties of plywood	

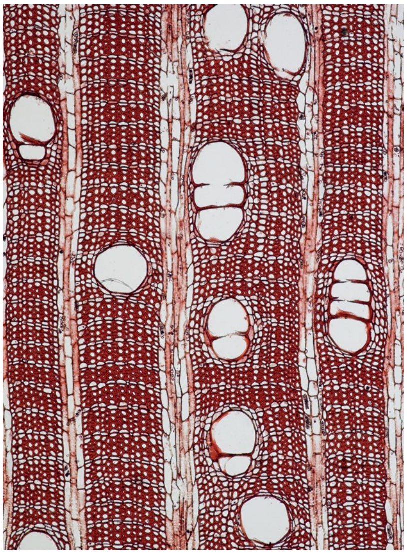
Guatteria anomala R. E. Fr.

sin.: /

Annonaceae | Common name: **zopo** | Lacandon name: **ek ‚bahche‘**

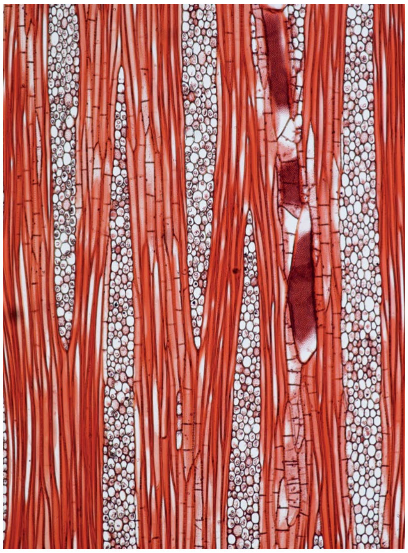
Use: interior construction, framework, packaging, cellulose products, paper pulp, particle board, core and crossband veneer, container veneer and plywood, possibly for furniture and decorative sliced veneer

Radial section in actual size.
Upper half of the sample sanded and unfinished, the lower half oil finish.



cross section

radial section



tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 60 m	
Diameter	up to 400 cm	
Bole	Irregular, occasionally butresses are up to the cup	
Heartwood and sapwood (Munsell color chart)	colored heartwood absent	
Condition	Sapwood	Heartwood
Green	2.5 Y HUE / 2.5 Y 8.5/6	
Air dried	2.5 Y HUE / 2.5 Y 9/4	
Grain	straight	
Texture	coarse	

Moisture content and density

No. of test trees / samples: Sapwood (S) 3/6 ; Heartwood (H) 0/0.

Density	ρ_0	S	326	...	**432**	...	506	kg/m³
		H						
Moisture content (MC) green		S	86	...	**105**	...	131	%
		H						
EMC(21 °C/65%)		S			**14**			%
		H						

Dimensional stability

No. of test trees / samples: Sapwood (S) 3/6 ; Heartwood (H) 0/0.

Density	ρ_0	S	326	...	**432**	...	506	kg / m³	
		H		...		...		kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.23	...	**0.27**	...	0.31	% / %	favourable
	q_{tang}	H		...		...		% / %	
	q_{rad}	S	0.14	...	**0.16**	...	0.19	% / %	
	q_{rad}	H		...		...		% / %	
	q_{tang} / q_{rad}	S	1.63	...	**1.73**	...	1.86		normal
	q_{tang} / q_{rad}	H		...		...			
	$q_{tang} - q_{rad}$	S	0.09	...	**0.11**	...	0.12	% / %	favourable
	$q_{tang} - q_{rad}$	H		...		...		% / %	
Swelling coefficient and anisotropy	h_{tang}	S	0.036	...	**0.042**	...	0.050	% / %	favourable
	h_{tang}	H		...		...		% / %	
	h_{rad}	S	0.021	...	**0.025**	...	0.031	% / %	
	h_{rad}	H		...		...		% / %	
	h_{tang} / h_{rad}	S	1.57	...	**1.69**	...	1.82		normal
	h_{tang} / h_{rad}	H		...		...			
	$h_{tang} - h_{rad}$	S	0.013	...	**0.017**	...	0.018	% / %	favourable
	$h_{tang} - h_{rad}$	H		...		...		% / %	
Sorption coefficient	S	S	0.15	...	**0.16**	...	0.16	% / %	normal
	S	H		...		...		% / %	

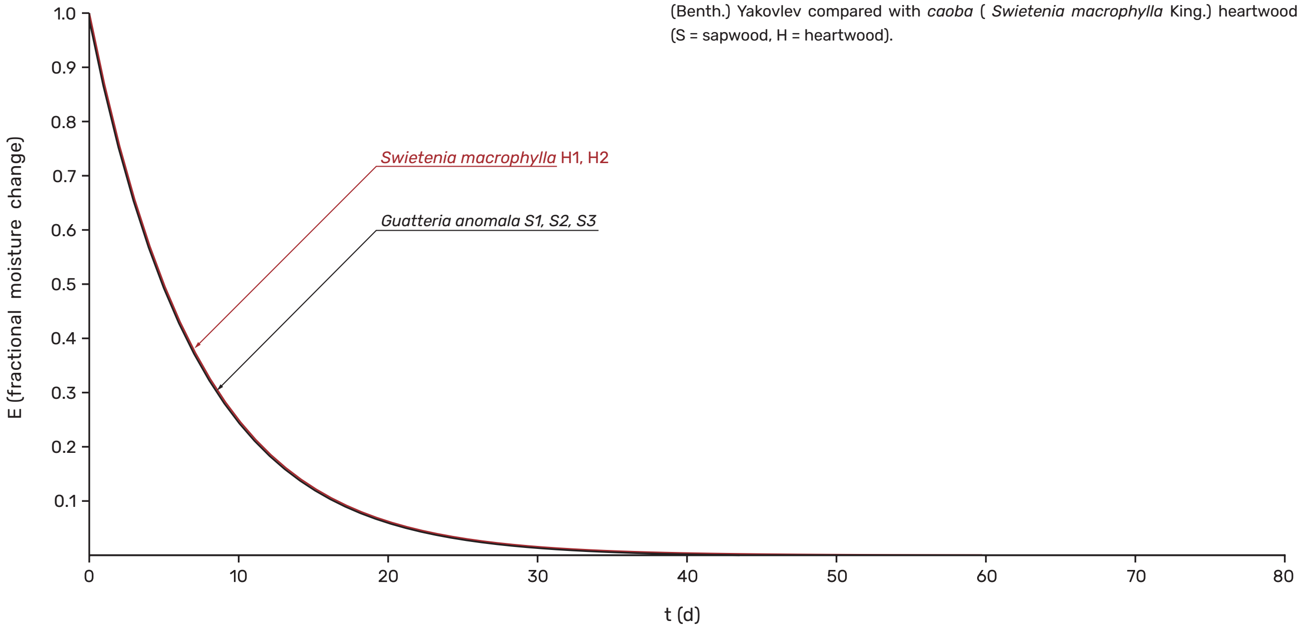
Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	432
	Seasoning time	days	98
	Initial moisture content	%	106
	Final moisture content	%	20
	Checking		149
	Warping		9
	Seasoning degrade		2
	$t_{eq0.5}$ days	S1, S2, S3: 5	5
	t_{eq} days	S1:37, S2:36, S3:37	37
Recommended drying schedule	Drying gradient		2.6
	T_1	°C	60
	T_2	°C	80

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

16. *Guatteria anomala* R. E. Fr.

Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).



pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
Sapwood	16/1S	542	6.3	0.92	0.004
	16/2S	477	6.3	0.86	0.001
	16/3S	359	6.6	1.51	0.005
Heartwood					

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			3 / 5	3 / 5
Weight loss	average	%	34	38
	minimum	%	18	23
	maximum	%	58	45
Resistance to decay			moderately resistant	moderately resistant
Proportion of samples in each class	1	%	0	0
	2	%	20	20
	3	%	60	60
	4	%	20	20

Mechanical properties in green condition

Number of test trees				3	
Basic density ρ_b			kg/m³	430	medium
	Stress at proportional limit		MPa	26.2	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	55.0	medium
	Stiffness	Modulus of elasticity	GPa	8.6	low
Compression	Maximal compression strength parallel to grain		MPa	26.0	medium
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	18.0	low
		Rad.	kN	2.01	very low
Janka hardness	Resistance to identation	Tang.	kN	2.39	low
		End	kN	2.63	low

Machining and related properties

Number of test trees				1
Number of test samples				10
Moisture content	Min - max		%	14.0 - 16.0
Planing	Defect free samples		%	100

		Angle		
		30°	20°	15°
Speed	7.6 m/min	100	100	-
	13.1 m/min	80	60	-

Shaping	Good to excellent samples	%	0
Turning	Fair to excellent samples	%	10
Nailing	Samples free from complete splits	%	85
Screwing	Samples free from complete splits	%	100

Slicing, sliced veneer - Assessment of relevant properties

not tested	
Heating temperature	
Flich degrade due to thermal treatment	
Ease of cutting	
Drying degrade	
Finishing quality	

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

Heating temperature	25-50°C
Log degrade due to hydrothermal treatment	moderate
Ease of peeling	easy to peel
Gluing	satisfactory
Mechanical properties of plywood	satisfactory

Licaria peckii (I. M. Johnston) Kosterm.

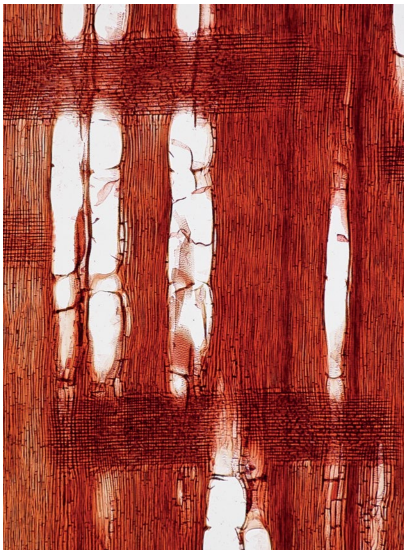
sin.: ***Misanteca peckii*** **I.M. Johnston**

Lauraceae | Common name: **pimientillo** | Lacandon name: **/**

Use: interior construction, framework, peeled veneer, particle board, possibly for furniture and decorative sliced veneer, container veneer and plywood

Radial section in actual size.
Upper half of the sample sanded and unfinished, the lower half oil finish.

cross section



radial section

tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 45 m		
Diameter	up to 70 cm		
Bole	straight clear for 25 m, regular		
Heartwood and sapwood (Munsell color chart)	Clearly different probably discolored wood		
Condition	Sapwood		Heartwood
Green	5 Y HUE / 5 Y 8/8	10 YR HUE / 10 YR 8/10	5 R HUE / 5 R 3/1
Air dried	10 YR HUE / 10 YR 7/4		10 YR HUE / 10 YR 6/6
Grain	Slightly or shallowly interlocked, locally straight		
Texture	Medium to fine		

Moisture content and density

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 2/4.

Density	ρ_0	S	610	...	**653**	...	682	kg/m³
		H	571	...	**613**	...	641	kg/m³
Moisture content (MC) green		S	58	...	**69**	...	79	%
		H	45	...	**49**	...	55	%
EMC(21 °C/65%)		S			**14**			%
		H			**14**			%

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ *days* – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} *days* – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

Dimensional stability

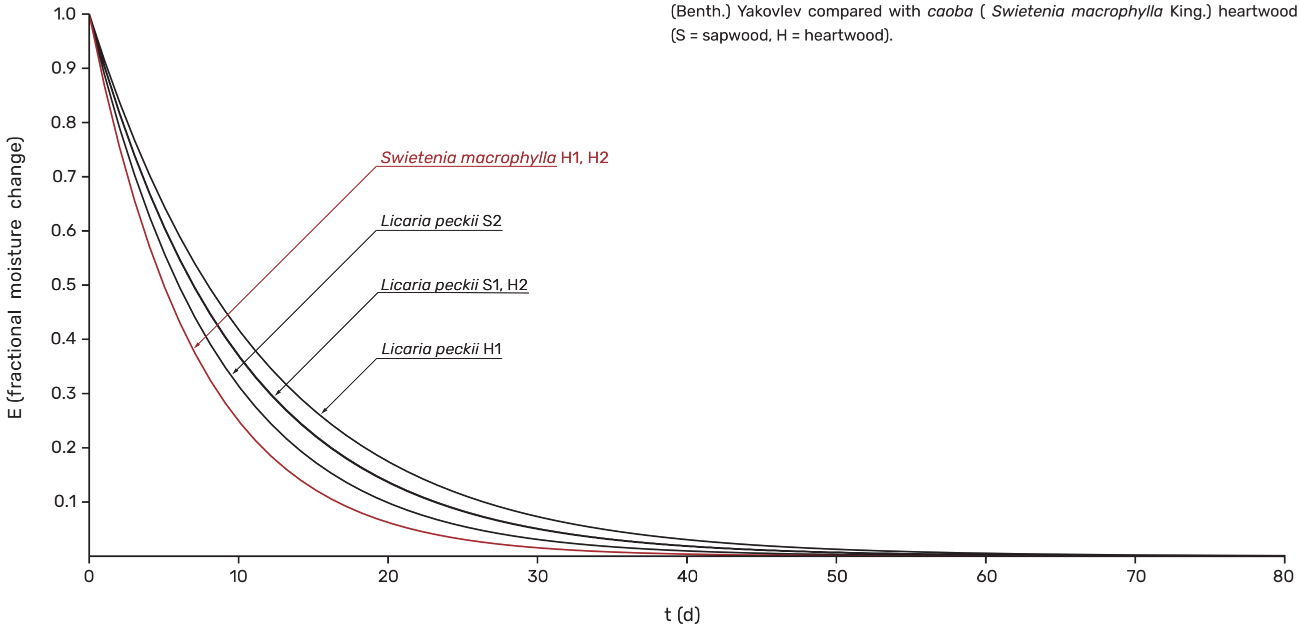
No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 2/4.

Density	ρ_0	S	610	...	**653**	...	682	kg / m³	
		H	571	...	**613**	...	641	kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.33	...	**0.35**	...	0.37	% / %	normal
	q_{tang}	H	0.31	...	**0.34**	...	0.38	% / %	normal
	q_{rad}	S	0.19	...	**0.23**	...	0.26	% / %	
	q_{rad}	H	0.18	...	**0.21**	...	0.24	% / %	
	q_{tang} / q_{rad}	S	1.27	...	**1.58**	...	1.89		favourable
	q_{tang} / q_{rad}	H	1.29	...	**1.64**	...	1.94		normal
	$q_{tang} - q_{rad}$	S	0.07	...	**0.12**	...	0.17	% / %	normal
	$q_{tang} - q_{rad}$	H	0.07	...	**0.13**	...	0.18	% / %	normal
Swelling coefficient and anisotropy	h_{tang}	S	0.052	...	**0.055**	...	0.058	% / %	normal
	h_{tang}	H	0.047	...	**0.051**	...	0.054	% / %	normal
	h_{rad}	S	0.029	...	**0.035**	...	0.040	% / %	
	h_{rad}	H	0.029	...	**0.032**	...	0.035	% / %	
	h_{tang} / h_{rad}	S	1.30	...	**1.60**	...	1.93		normal
	h_{tang} / h_{rad}	H	1.39	...	**1.63**	...	1.90		normal
	$h_{tang} - h_{rad}$	S	0.012	...	**0.020**	...	0.027	% / %	normal
	$h_{tang} - h_{rad}$	H	0.012	...	**0.020**	...	0.027	% / %	normal
Sorption coefficient	s	S	0.16	...	**0.16**	...	0.16	% / %	normal
	s	H	0.15	...	**0.15**	...	0.16	% / %	favourable

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³		613
	Seasoning time	days		112
	Initial moisture content	%		46
	Final moisture content	%		20
	Checking			4
	Warping			0
	Seasoning degrade			1
	$t_{eq0.5}$ days		S1:7 , S2:6, H1:8, H2:7	8
	t_{eq} days		S1:48 , S2:41, H1:49, H2:43	46
Recommended drying schedule	Drying gradient			2.1
	T_1	°C		60
	T_2	°C		80

17. *Licaria peckii* (I. M. Johnston) Kosterm.



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
	66/1S	700	4.9		
Sapwood	66/2S	646	5.0		
	66/1H	646	4.9	0.08	0.001
Heartwood	66/2H	574	4.9	0.11	0.0003

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			2 / 8	2 / 8
Weight loss	average	%	12	25
	minimum	%	9	2
	maximum	%	16	45
Resistance to decay			resistant	moderately resistant
Proportion of samples in each class	1	%	40	12
	2	%	60	38
	3	%	0	38
	4	%	0	12

Mechanical properties in green condition

Number of test trees				2	
Basic density ρ_b			kg/m³	600	high
	Stress at proportional limit		MPa	40.1	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	90.1	high
	Stiffness	Modulus of elasticity	GPa	13.3	high
Compression	Maximal compression strength parallel to grain		MPa	38.2	high
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	28.6	medium
		Rad.	kN	3.75	medium
Janka hardness	Resistance to identation	Tang.	kN	4.18	medium
		End	kN	4.85	high

Machining and related properties

Number of test trees				1
Number of test samples				10
Moisture content	Min - max		%	12.0 - 13.5
Planing	Defect free samples		%	70

		Angle		
		30°	20°	15°
Speed	7.6 m/min	40	60	70
	13.1 m/min	30	40	20

Shaping	Good to excellent samples	%	100
Turning	Fair to excellent samples	%	100
Nailing	Samples free from complete splits	%	35
Screwing	Samples free from complete splits	%	60

Slicing, sliced veneer - Assessment of relevant properties

not tested	
Heating temperature	
Flich degrade due to thermal treatment	
Ease of cutting	
Drying degrade	
Finishing quality	

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

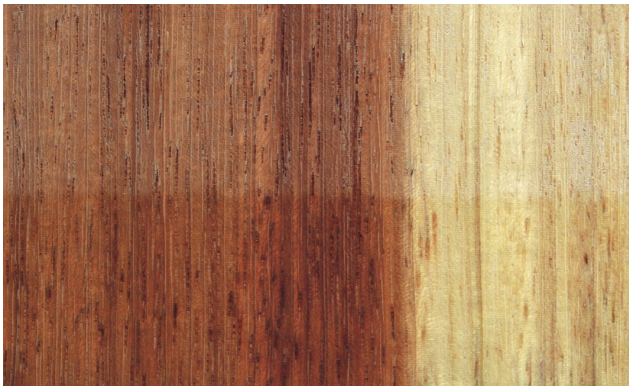
Heating temperature	60-70°C
Log degrade due to hydrothermal treatment	moderate to severe
Ease of peeling	moderately easy to peel
Gluing	satisfactory
Mechanical properties of plywood	satisfactory

Lonchocarpus castilloi Standl.

sin.: /

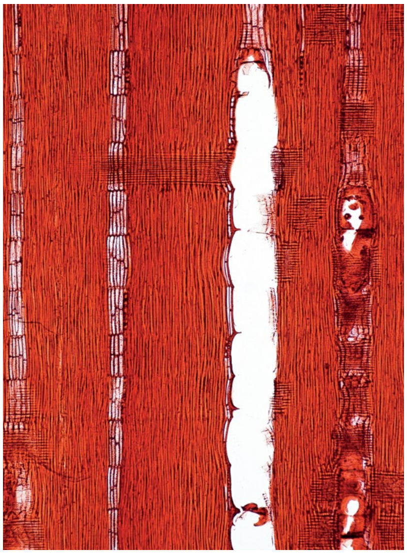
Fabaceae | Common name: **machiche** | Lacandon name: **hach balche'**

Use: interior construction, exterior construction, exterior coverings, decorative sliced veneer, flooring, rail sleepers, framework, hydraulic works, possibly for furniture



Radial section in actual size.
Upper half of the sample sanded and unfinished, the lower half oil finish.

cross section



radial section

tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 45 m		
Diameter	up to 70 cm		
Bole	Regular, straight clear for 25 m		
Heartwood and sapwood (Munsell color chart)	heartwood clearly differentiated from sapwood		
Condition	Sapwood	Heartwood	
Green	10 YR HUE / 10 YR 8/10	2.5 YR HUE / 2.5 YR 5/10	5 R HUE / 5 R 4/6
Air dried	5 Y HUE / 5 Y 9/4	2.5 YR HUE / 2.5 YR 5/6	
Grain	Typically narrowly interlocked		
Texture	medium to coarse		

Moisture content and density

No. of test trees / samples: Sapwood (S) 3/6 ; Heartwood (H) 3/6.

Density	ρ_0	S	809	...	**837**	...	855	kg/m³
		H	667	...	**806**	...	846	kg/m³
Moisture content (MC) green		S	45	...	**50**	...	55	%
		H	59	...	**62**	...	66	%
EMC(21 °C/65%)		S			**14**			%
		H			**13**			%

Dimensional stability

No. of test trees / samples: Sapwood (S) 3/6 ; Heartwood (H) 3/6.

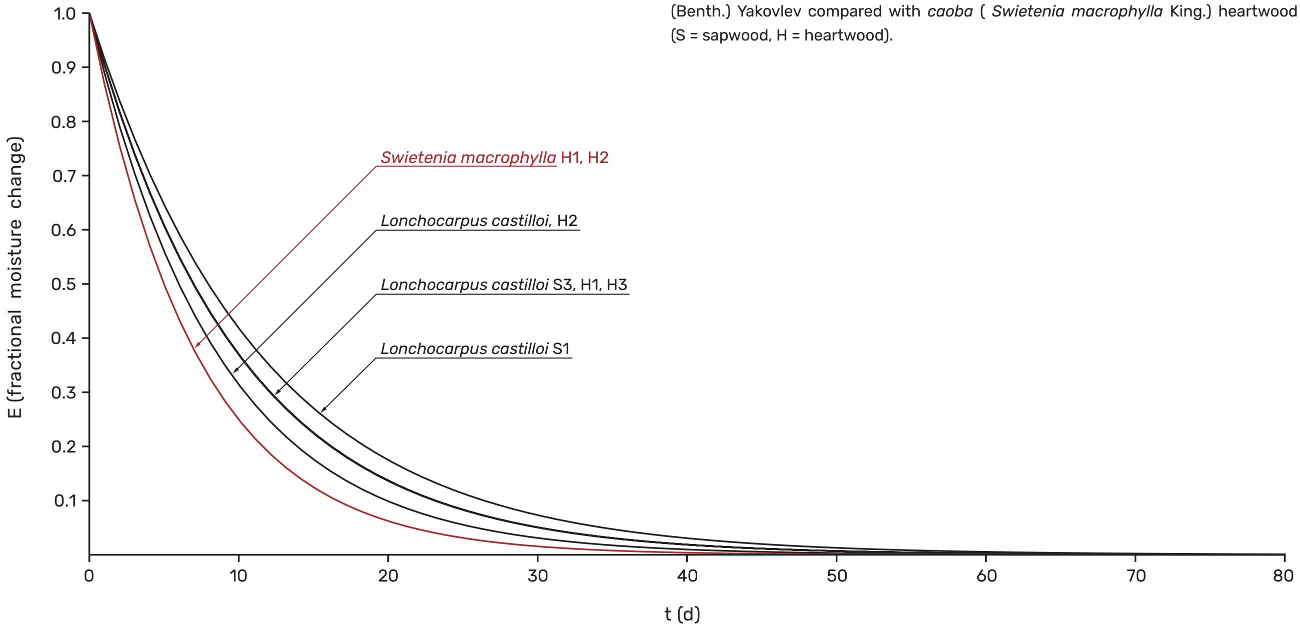
Density	ρ_0	S	809	...	**837**	...	855	kg / m³	
		H	667	...	**806**	...	846	kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.38	...	**0.42**	...	0.46	% / %	unfavourable
	q_{tang}	H	0.40	...	**0.42**	...	0.48	% / %	unfavourable
	q_{rad}	S	0.21	...	**0.24**	...	0.28	% / %	
	q_{rad}	H	0.21	...	**0.24**	...	0.31	% / %	
	q_{tang} / q_{rad}	S	1.41	...	**1.76**	...	1.95		normal
	q_{tang} / q_{rad}	H	1.55	...	**1.77**	...	1.95		normal
	$q_{tang} - q_{rad}$	S	0.11	...	**0.18**	...	0.22	% / %	normal
	$q_{tang} - q_{rad}$	H	0.15	...	**0.18**	...	0.20	% / %	normal
Swelling coefficient and anisotropy	h_{tang}	S	0.063	...	**0.066**	...	0.071	% / %	unfavourable
	h_{tang}	H	0.055	...	**0.057**	...	0.060	% / %	unfavourable
	h_{rad}	S	0.033	...	**0.038**	...	0.042	% / %	
	h_{rad}	H	0.029	...	**0.033**	...	0.039	% / %	
	h_{tang} / h_{rad}	S	1.52	...	**1.76**	...	1.91		normal
	h_{tang} / h_{rad}	H	1.54	...	**1.75**	...	1.93		normal
	$h_{tang} - h_{rad}$	S	0.022	...	**0.028**	...	0.033	% / %	normal
	$h_{tang} - h_{rad}$	H	0.021	...	**0.024**	...	0.027	% / %	normal
Sorption coefficient	S	S	0.14	...	**0.16**	...	0.16	% / %	normal
	S	H	0.13	...	**0.14**	...	0.14	% / %	favourable

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³		806
	Seasoning time	days		154
	Initial moisture content	%		62
	Final moisture content	%		18
	Checking			124
	Warping			16
	Seasoning degrade			2–3
	$t_{eq0.5}$ days		S1:8 , S3:7, H1:7, H3:7	8
	t_{eq} days		S1:50 , S3:46, H1:47, H3:43	48
Recommended drying schedule	Drying gradient			2.1
	T_1	°C		50
	T_2	°C		70

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

18. *Lonchocarpus castilloi* Standl.



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
	19/1S	859	6.0		
Sapwood	19/2S		5.9		
	19/3S	854	5.6		
	19/1H	843	6.0	0.33	0.0004
Heartwood	19/2H	837	5.2	0.50	0.00005
	19/3H	838	5.6	0.52	0.0009

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			3 / 4	3 / 4
Weight loss	average	%	1	1
	minimum	%	0	0
	maximum	%	1	1
Resistance to decay			very resistant	very resistant
Proportion of samples in each class	1	%	100	100
	2	%	0	0
	3	%	0	0
	4	%	0	0

Mechanical properties in green condition

Number of test trees				3	
Basic density ρ_b			kg/m³	740	very high
	Stress at proportional limit		MPa	62.8	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	117.2	very high
	Stiffness	Modulus of elasticity	GPa	17.7	very high
Compression	Maximal compression strength parallel to grain		MPa	54.6	very high
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	43.9	high
		Rad.	kN	7.35	very high
Janka hardness	Resistance to identation	Tang.	kN	7.40	very high
		End	kN	7.19	very high

Machining and related properties

Number of test trees				1
Number of test samples				9
Moisture content	Min - max		%	13.0 - 13.0
Planing	Defect free samples		%	89

		Angle		
		30°	20°	15°
Speed	7.6 m/min	78	89	11
	13.1 m/min	56	56	0

Shaping	Good to excellent samples	%	67
Turning	Fair to excellent samples	%	100
Nailing	Samples free from complete splits	%	50
Screwing	Samples free from complete splits	%	78

Slicing, sliced veneer - Assessment of relevant properties

Heating temperature	80-90 °C
Flich degrade due to thermal treatment	severe
Ease of cutting	moderately easy to cut
Drying degrade	some/little wrinkling and checking
Finishing quality	good

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

	not tested
Heating temperature	
Log degrade due to hydrothermal treatment	
Ease of peeling	
Gluing	
Mechanical properties of plywood	

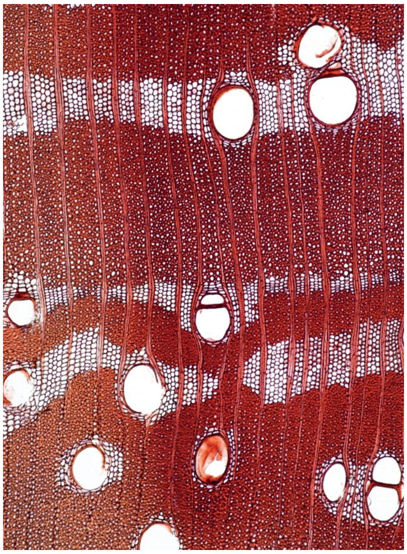
Lonchocarpus hondurensis Benth.

sin.: /

Fabaceae | Common name: **palo gusano** | Lacandon name: **balche', ya'ax balche'**

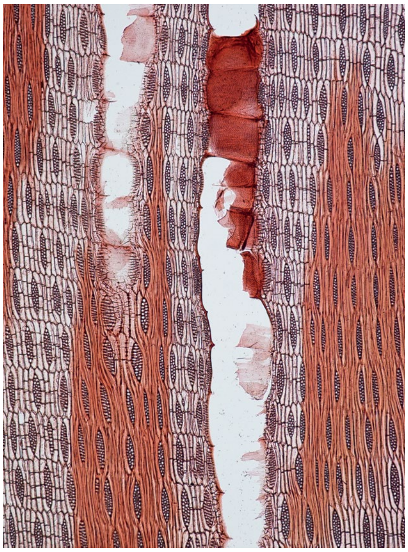
Use: interior construction, exterior construction, exterior coverings, decorative sliced veneer, flooring, rail sleepers, framework, hydraulic works, possibly for furniture

Radial section in actual size.
Upper half of the sample sanded and unfinished,
the lower half oil finish.



cross section

radial section



tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 40 m		
Diameter	up to 70 cm		
Bole	Regular, up to 25m		
Heartwood and sapwood (Munsell color chart)	Heartwood clearly differentiated from sapwood		
Condition	Sapwood	Heartwood	
Green	10 YR HUE / 10 YR 8/10	2.5 YR HUE / 2.5 YR 5/10	5 R HUE / 5 R 4/6
Air dried	5 Y HUE / 5 Y 9/4	2.5 YR HUE / 2.5 YR 5/6	
Grain	typically interlocked and irregular		
Texture	medium to coarse		

Moisture content and density

No. of test trees / samples: Sapwood (S) 1/2 ; Heartwood (H) 1/2.

Density	ρ_0	S	723	...	**729**	...	735	kg/m³
		H	730	...	**732**	...	733	kg/m³
Moisture content (MC) green		S	61	...	**62**	...	64	%
		H	71	...	**72**	...	73	%
EMC(21 °C/65%)		S			**13**			%
		H			**13**			%

Dimensional stability

No. of test trees / samples: Sapwood (S) 1/2 ; Heartwood (H) 1/2.

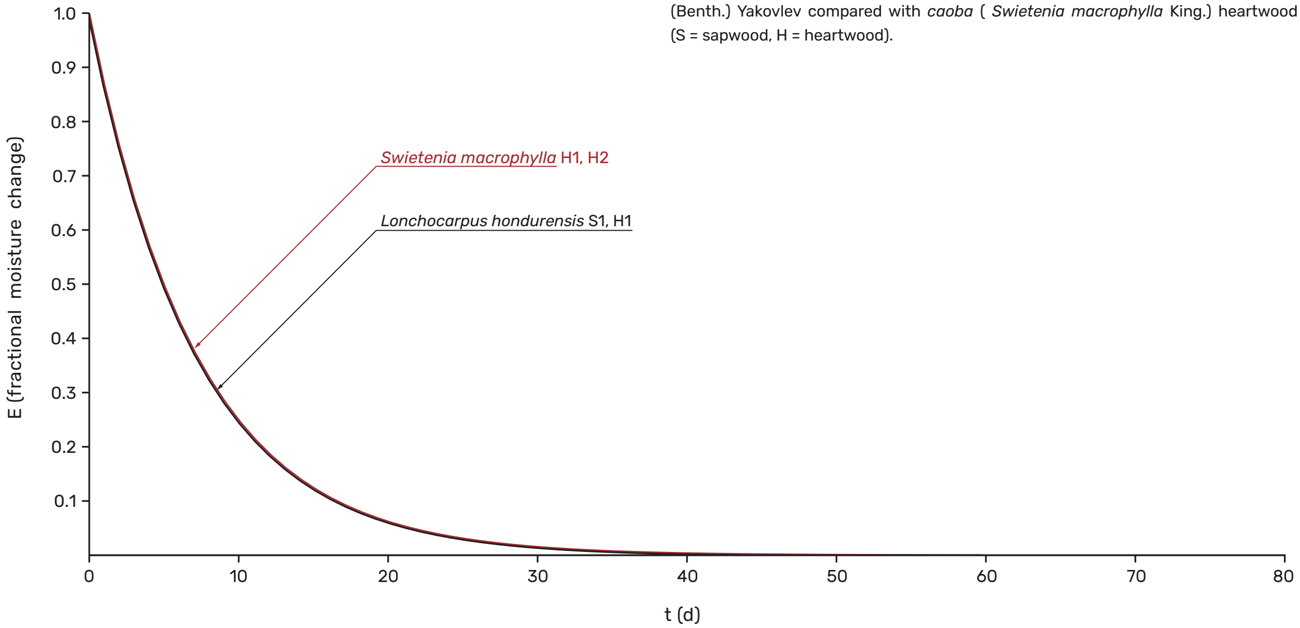
Density	ρ_0	S	723	...	**729**	...	735	kg / m³	
		H	730	...	**732**	...	733	kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.36	...	**0.40**	...	0.44	% / %	normal
	q_{tang}	H	0.36	...	**0.37**	...	0.37	% / %	normal
	q_{rad}	S	0.20	...	**0.20**	...	0.20	% / %	
	q_{rad}	H	0.23	...	**0.24**	...	0.24	% / %	
	q_{tang} / q_{rad}	S	1.80	...	**1.95**	...	2.20		normal
	q_{tang} / q_{rad}	H	1.54	...	**1.56**	...	1.57		favourable
	$q_{tang} - q_{rad}$	S	0.16	...	**0.20**	...	0.24	% / %	normal
	$q_{tang} - q_{rad}$	H	0.13	...	**0.13**	...	0.13	% / %	normal
Swelling coefficient and anisotropy	h_{tang}	S	0.059	...	**0.060**	...	0.060	% / %	normal
	h_{tang}	H	0.049	...	**0.050**	...	0.050	% / %	normal
	h_{rad}	S	0.033	...	**0.033**	...	0.033	% / %	
	h_{rad}	H	0.031	...	**0.032**	...	0.032	% / %	
	h_{tang} / h_{rad}	S	1.79	...	**1.81**	...	1.82		normal
	h_{tang} / h_{rad}	H	1.56	...	**1.57**	...	1.58		favourable
	$h_{tang} - h_{rad}$	S	0.026	...	**0.027**	...	0.027	% / %	normal
	$h_{tang} - h_{rad}$	H	0.018	...	**0.018**	...	0.018	% / %	favourable
Sorption coefficient	S	S	0.16	...	**0.16**	...	0.16	% / %	normal
	S	H	0.14	...	**0.14**	...	0.14	% / %	favourable

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	732
	Seasoning time	days	154
	Initial moisture content	%	68
	Final moisture content	%	18
	Checking		177
	Warping		10
	Seasoning degrade		2-3
	$t_{eq0.5}$ days	S1:5, H1:5	5
	t_{eq} days	S1:34, H1:37	37
Recommended drying schedule	Drying gradient		2.1
	T_1	°C	50
	T_2	°C	70

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

19. *Lonchocarpus hondurensis* Benth.



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
Sapwood	20/1S	776	6.0		
Heartwood	20/1H	758	5.9	0.24	0.001

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			1 / 4	1 / 4
Weight loss	average	%	3	4
	minimum	%	1	0
	maximum	%	6	8
Resistance to decay			very resistant	very resistant
Proportion of samples in each class	1	%	100	100
	2	%	0	0
	3	%	0	0
	4	%	0	0

Mechanical properties in green condition

Number of test trees				1	
Basic density ρ_b			kg/m³	670	high
	Stress at proportional limit		MPa	61.1	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	108.7	high
	Stiffness	Modulus of elasticity	GPa	15.3	high
Compression	Maximal compression strength parallel to grain		MPa	48.5	high
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	39.2	high
		Rad.	kN	5.23	high
Janka hardness	Resistance to identation	Tang.	kN	5.45	high
		End	kN	5.93	high

Machining and related properties

Number of test trees				1
Number of test samples				10
Moisture content	Min - max		%	13.0 - 14.5
Planing	Defect free samples		%	70

		Angle		
		30°	20°	15°
Speed	7.6 m/min	20	40	-
	13.1 m/min	10	20	-

Shaping	Good to excellent samples	%	60
Turning	Fair to excellent samples	%	100
Nailing	Samples free from complete splits	%	75
Screwing	Samples free from complete splits	%	100

Slicing, sliced veneer - Assessment of relevant properties

	not tested
Heating temperature	
Flich degrade due to thermal treatment	
Ease of cutting	
Drying degrade	
Finishing quality	

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

	not tested
Heating temperature	
Log degrade due to hydrothermal treatment	
Ease of peeling	
Gluing	
Mechanical properties of plywood	

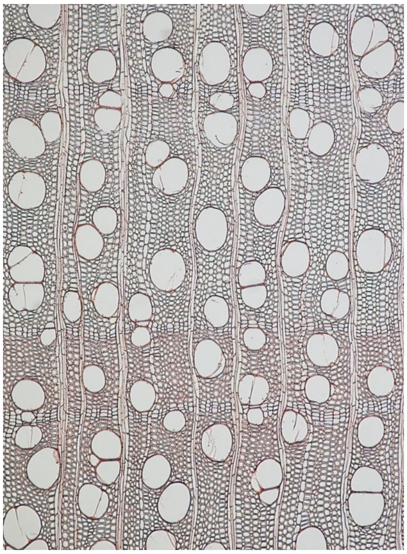
Magnolia mexicana DC.

sin.: ***Talauma mexicana*** **(DC.) G.Don**

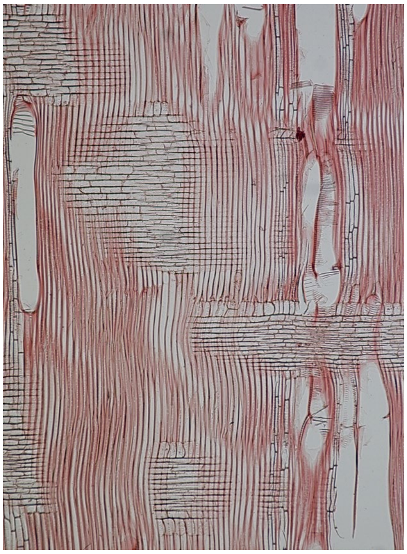
Magnoliaceae | Common name: **jolmashté** | Lacandon name: **kuti' kuti'il wits**

Use: interior construction, framework, peeled veneer, decorative sliced veneer, packaging, cellulose products, paper pulp, construction plywood, core and crossband veneer, container veneer and plywood, interior coverings, possibly for furniture, particle board

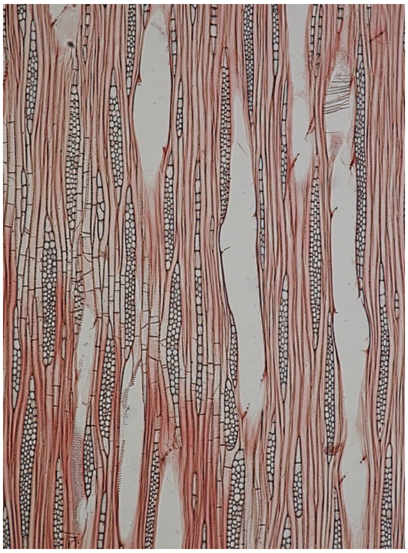
Radial section in actual size.
Upper half of the sample sanded and unfinished,
the lower half oil finish.



cross section



radial section



tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 45 m	
Diameter	up to 130 cm	
Bole	Regular, clear for 12 m	
Heartwood and sapwood (Munsell color chart)	Status of heartwood unknown, wound initiated discolored wood	
Condition	Sapwood	Heartwood
Green	5 Y HUE / 5 Y 8.5/6	7.5 YR HUE / 7.5 YR 5/4
Air dried	10 YR HUE / 10 YR 9/2	10 YR HUE / 10 YR 6/6
Grain	straight	
Texture	medium	

Moisture content and density

No. of test trees / samples: Sapwood (S) 3/6 ; Heartwood (H) 0/0.

Density	ρ_0	S	522	...	**551**	...	583	kg/m³
		H						
Moisture content (MC) green		S	50	...	**70**	...	85	%
		H						
EMC(21 °C/65%)		S			**14**			%
		H						

Dimensional stability

No. of test trees / samples: Sapwood (S) 3/6 ; Heartwood (H) 0/0.

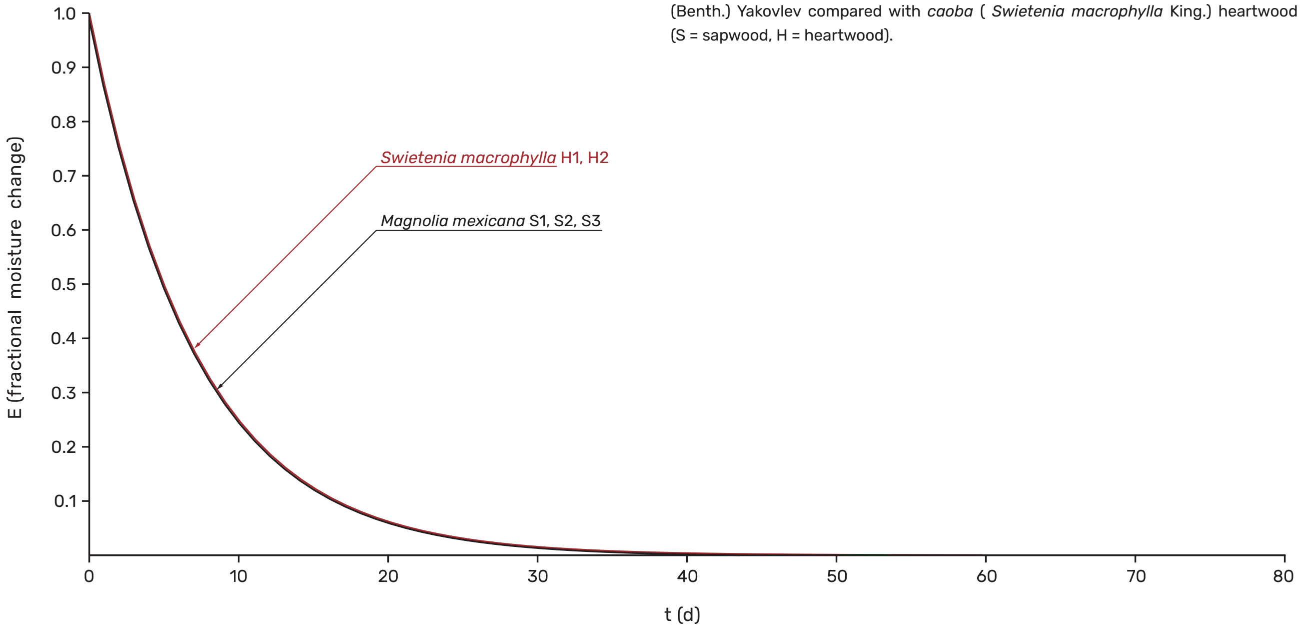
Density	ρ_0	S	522	...	**551**	...	583	kg / m³	
		H		...		...		kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.30	...	**0.32**	...	0.32	% / %	normal
	q_{tang}	H		...		...		% / %	
	q_{rad}	S	0.18	...	**0.18**	...	0.18	% / %	
	q_{rad}	H		...		...		% / %	
	q_{tang} / q_{rad}	S	1.67	...	**1.75**	...	1.78		normal
	q_{tang} / q_{rad}	H		...		...			
	$q_{tang} - q_{rad}$	S	0.12	...	**0.14**	...	0.14	% / %	normal
	$q_{tang} - q_{rad}$	H		...		...		% / %	
Swelling coefficient and anisotropy	h_{tang}	S	0.047	...	**0.049**	...	0.050	% / %	favourable
	h_{tang}	H		...		...		% / %	
	h_{rad}	S	0.028	...	**0.028**	...	0.028	% / %	
	h_{rad}	H		...		...		% / %	
	h_{tang} / h_{rad}	S	1.68	...	**1.75**	...	1.79		normal
	h_{tang} / h_{rad}	H		...		...			
	$h_{tang} - h_{rad}$	S	0.019	...	**0.021**	...	0.022	% / %	normal
	$h_{tang} - h_{rad}$	H		...		...		% / %	
Sorption coefficient	S	S	0.15	...	**0.16**	...	0.16	% / %	normal
	S	H		...		...		% / %	

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	551
	Seasoning time	days	112
	Initial moisture content	%	79
	Final moisture content	%	20
	Checking		8
	Warping		3
	Seasoning degrade		1
	$t_{eq0.5}$ days	S1:, S2, S3:5	5
	t_{eq} days	S1, S2:36, S3:38	37
Recommended drying schedule	Drying gradient		3.1
	T_1	°C	70
	T_2	°C	80

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

20. *Magnolia mexicana* DC.



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
Sapwood	40/1S	566	6.2	0.60	0.002
	40/2S	525	6.3	0.50	0.001
	40/3S	590	6.1	0.37	0.0006
Heartwood					

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			3 / 5	3 / 5
Weight loss	average	%	60	56
	minimum	%	38	52
	maximum	%	70	59
Resistance to decay			non-resistant	non-resistant
Proportion of samples in each class	1	%	0	0
	2	%	0	0
	3	%	20	0
	4	%	80	100

Mechanical properties in green condition

Number of test trees				2	
Basic density ρ_b			kg/m³	490	medium
	Stress at proportional limit		MPa	36.7	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	76.4	high
	Stiffness	Modulus of elasticity	GPa	12.0	high
Compression	Maximal compression strength parallel to grain		MPa	30.3	medium
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	23.5	low
		Rad.	kN	2.68	low
Janka hardness	Resistance to identation	Tang.	kN	2.87	low
		End	kN	3.25	low

Machining and related properties

Number of test trees				1
Number of test samples				12
Moisture content	Min - max		%	13.5 - 14.5
Planing	Defect free samples		%	100

		Angle		
		30°	20°	15°
Speed	7.6 m/min	100	83	-
	13.1 m/min	100	58	-

Shaping	Good to excellent samples	%	33
Turning	Fair to excellent samples	%	40
Nailing	Samples free from complete splits	%	87
Screwing	Samples free from complete splits	%	90

Slicing, sliced veneer - Assessment of relevant properties

not tested
Heating temperature
Flich degrade due to thermal treatment
Ease of cutting
Drying degrade
Finishing quality

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

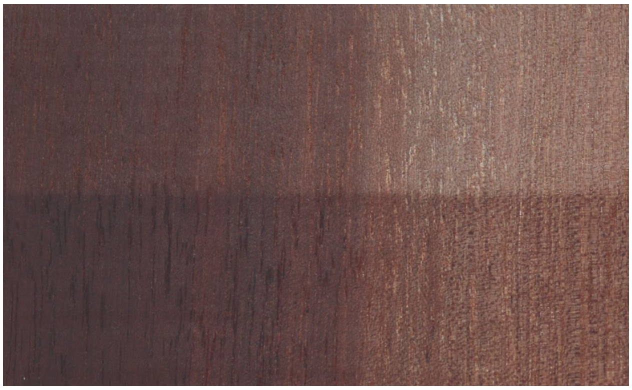
not tested
Heating temperature
Log degrade due to hydrothermal treatment
Ease of peeling
Gluing
Mechanical properties of plywood

Manilkara zapota (L.) P. Royen

sin.: /

Sapotaceae | Common name: **chicozapote** | Lacandon name: **chäk ya', hach ya', ya'**

Use: exterior construction, flooring, rail sleepers, possibly for furniture, framework, exterior coverings, hydraulic works



Radial section in actual size.
Upper half of the sample sanded and unfinished,
the lower half oil finish.

cross section

radial section

tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 45 m		
Diameter	up to 150 cm		
Bole	Regular, up to 30m		
Heartwood and sapwood (Munsell color chart)	heartwood clearly demarcated from sapwood		
Condition	Sapwood	Heartwood	
Green	3 R HUE / 3.75 R 6/12	7.5 R HUE / 7.5 R 3/10	5 R HUE / 5 R 3/8
Air dried	2.5 YR HUE / 2.5 YR 6/4	10 R HUE / 10 R 4/4	
Grain	generally straight		
Texture	fine		

Moisture content and density

No. of test trees / samples: Sapwood (S) 3/6 ; Heartwood (H) 3/6.

Density	ρ_0	S	895	...	**926**	...	967	kg/m³
		H	1008	...	**1043**	...	1065	kg/m³
Moisture content (MC) green		S	42	...	**46**	...	50	%
		H	41	...	**47**	...	49	%
EMC(21 °C/65%)		S			**15**			%
		H			**13**			%

Dimensional stability

No. of test trees / samples: Sapwood (S) 3/6 ; Heartwood (H) 3/6.

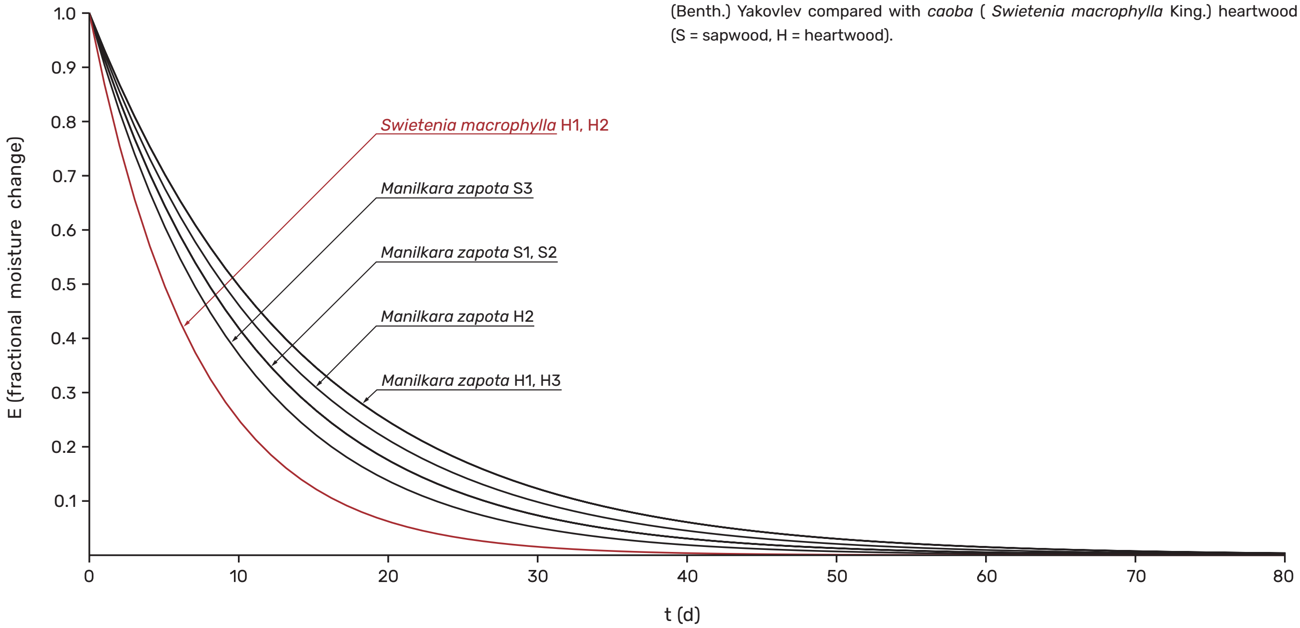
Density	ρ_0	S	895	...	**926**	...	967	kg / m³	
		H	1008	...	**1043**	...	1065	kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.41	...	**0.42**	...	0.44	% / %	unfavourable
	q_{tang}	H	0.41	...	**0.43**	...	0.45	% / %	unfavourable
	q_{rad}	S	0.26	...	**0.26**	...	0.27	% / %	
	q_{rad}	H	0.28	...	**0.28**	...	0.29	% / %	
	q_{tang} / q_{rad}	S	1.52	...	**1.61**	...	1.65		normal
	q_{tang} / q_{rad}	H	1.46	...	**1.52**	...	1.57		favourable
	$q_{tang} - q_{rad}$	S	0.14	...	**0.16**	...	0.17	% / %	normal
	$q_{tang} - q_{rad}$	H	0.13	...	**0.15**	...	0.16	% / %	normal
Swelling coefficient and anisotropy	h_{tang}	S	0.066	...	**0.067**	...	0.069	% / %	unfavourable
	h_{tang}	H	0.059	...	**0.063**	...	0.065	% / %	unfavourable
	h_{rad}	S	0.040	...	**0.041**	...	0.043	% / %	
	h_{rad}	H	0.040	...	**0.041**	...	0.042	% / %	
	h_{tang} / h_{rad}	S	1.54	...	**1.62**	...	1.68		normal
	h_{tang} / h_{rad}	H	1.45	...	**1.53**	...	1.59		favourable
	$h_{tang} - h_{rad}$	S	0.023	...	**0.026**	...	0.028	% / %	normal
	$h_{tang} - h_{rad}$	H	0.019	...	**0.022**	...	0.024	% / %	normal
Sorption coefficient	S	S	0.16	...	**0.16**	...	0.16	% / %	normal
	S	H	0.14	...	**0.14**	...	0.14	% / %	favourable

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³		1043
	Seasoning time	days		154
	Initial moisture content	%		54
	Final moisture content	%		19
	Checking			212
	Warping			3
	Seasoning degrade			2-3
	$t_{eq0.5}$ days		S1:8, S2:8, S3:7, H1:10, H2:9, H3:10	9
	t_{eq} days		S1:51, S2:52, S3:48, H1:59, H2:58, H3:59	59
Recommended drying schedule	Drying gradient			1.5
	T_1	°C		40
	T_2	°C		60

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

21. *Manilkara zapota* (L.) P. Royen



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
Sapwood	21/1S	929	4.9		
	21/2S	974	5.0		
	21/3S	906	4.9		
Heartwood	21/1H	1069	5.2	1.28	0.0004
	21/2H	1019	5.0	0.56	0.0002
	21/3H	1093	5.2	1.46	0.0003

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			3 / 5	3 / 5
Weight loss	average	%	1	0
	minimum	%	0	0
	maximum	%	1	0
Resistance to decay			very resistant	very resistant
Proportion of samples in each class	1	%	100	100
	2	%	0	0
	3	%	0	0
	4	%	0	0

Mechanical properties in green condition

Number of test trees				3	
Basic density ρ_b			kg/m³	900	exceptionally high
	Stress at proportional limit		MPa	71.8	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	129.1	very high
	Stiffness	Modulus of elasticity	GPa	16.0	high
Compression	Maximal compression strength parallel to grain		MPa	65.4	very high
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	72.6	exceptionally high
		Rad.	kN	9.26	very high
Janka hardness	Resistance to identation	Tang.	kN	8.85	very high
		End	kN	8.70	very high

Machining and related properties

Number of test trees				1
Number of test samples				10
Moisture content	Min - max		%	12.0 - 13.0
Planing	Defect free samples		%	90

		Angle		
		30°	20°	15°
Speed	7.6 m/min	90	80	-
	13.1 m/min	70	70	-

Shaping	Good to excellent samples	%	100
Turning	Fair to excellent samples	%	100
Nailing	Samples free from complete splits	%	0
Screwing	Samples free from complete splits	%	5

Slicing, sliced veneer - Assessment of relevant properties

	not tested
Heating temperature	
Flich degrade due to thermal treatment	
Ease of cutting	
Drying degrade	
Finishing quality	

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

	not tested
Heating temperature	
Log degrade due to hydrothermal treatment	
Ease of peeling	
Gluing	
Mechanical properties of plywood	

Nectandra sp.

sin.: /

Lauraceae | Common name: **laurel** | Lacandon name: **mehen ,oonte', nukuch ,oonte'**

Use: interior construction, framework, furniture, peeled veneer, decorative sliced veneer, packaging, cellulose products, particle board, paper pulp, construction plywood, core and crossband veneer, container veneer and plywood

Radial section in actual size.
Upper half of the sample sanded and unfinished, the lower half oil finish.

cross section

radial section

tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 40 m	
Diameter	up to 70 cm	
Bole	straight clear for 25 m, occasionally wih small buttresses	
Heartwood and sapwood (Munsell color chart)	without colored heartwood, possibly wound initiated discolored wood	
Condition	Sapwood	Heartwood
Green	10 YR HUE / 10 YR 8/10	
Air dried	5 Y HUE / 5 Y 9/4	
Grain	slightly interlocked, typically shallowly interlocked, sometimes straight	
Texture	Medium to fine	

Moisture content and density

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 0/0.

Density	ρ_0	S	475	...	**508**	...	541	kg/m³
		H						
Moisture content (MC) green		S	95	...	**108**	...	121	%
		H						
EMC(21 °C/65%)		S			**14**			%
		H						

Dimensional stability

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 0/0.

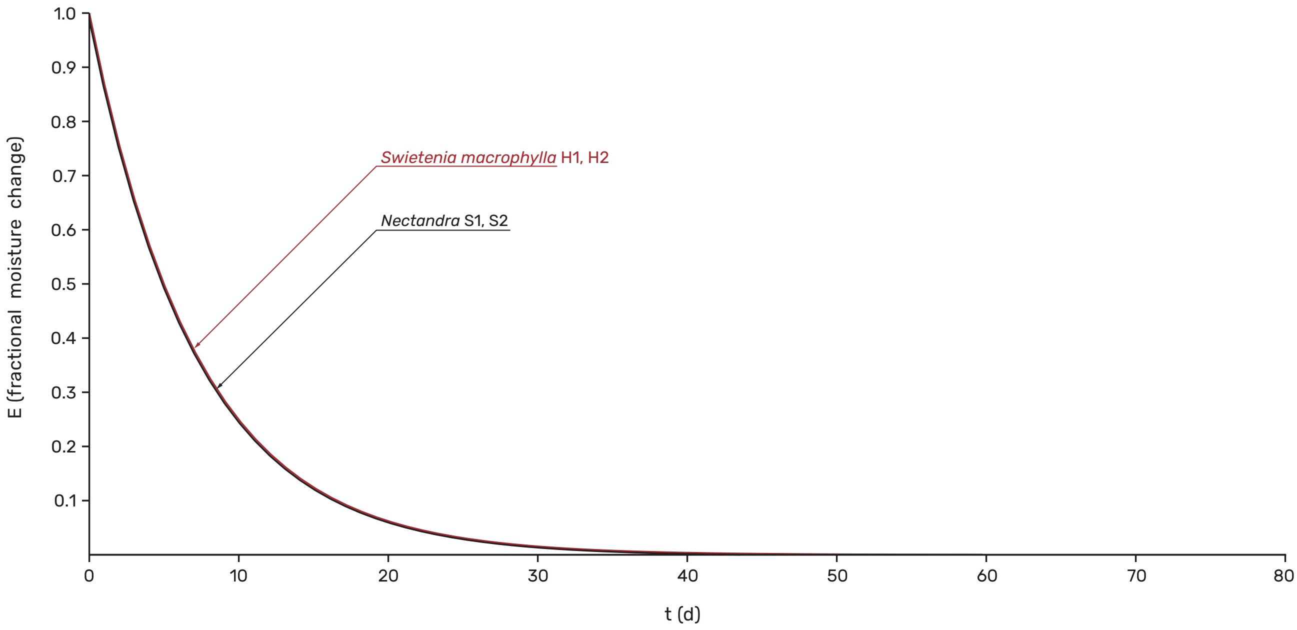
Density	ρ_0	S	475	...	**508**	...	541	kg / m³	
		H		...		...		kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.30	...	**0.34**	...	0.37	% / %	normal
	q_{tang}	H		...		...		% / %	
	q_{rad}	S	0.19	...	**0.21**	...	0.22	% / %	
	q_{rad}	H		...		...		% / %	
	q_{tang} / q_{rad}	S	1.50	...	**1.66**	...	1.76		normal
	q_{tang} / q_{rad}	H		...		...			
	$q_{tang} - q_{rad}$	S	0.10	...	**0.14**	...	0.16	% / %	normal
	$q_{tang} - q_{rad}$	H		...		...		% / %	
Swelling coefficient and anisotropy	h_{tang}	S	0.050	...	**0.056**	...	0.061	% / %	normal
	h_{tang}	H		...		...		% / %	
	h_{rad}	S	0.032	...	**0.034**	...	0.036	% / %	
	h_{rad}	H		...		...		% / %	
	h_{tang} / h_{rad}	S	1.52	...	**1.65**	...	1.74		normal
	h_{tang} / h_{rad}	H		...		...			
	$h_{tang} - h_{rad}$	S	0.017	...	**0.022**	...	0.026	% / %	normal
	$h_{tang} - h_{rad}$	H		...		...		% / %	
Sorption coefficient	S	S	0.16	...	**0.17**	...	0.17	% / %	unfavourable
	S	H		...		...		% / %	

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	508
	Seasoning time	days	91
	Initial moisture content	%	69
	Final moisture content	%	20
	Checking		110
	Warping		1
	Seasoning degrade		1-2
	$t_{eq0.5}$ days	S1, S2:5	5
	t_{eq} days	S1:36, S2:34	35
Recommended drying schedule	Drying gradient		3.1
	T_1	°C	60
	T_2	°C	80

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

22. *Nectandra* sp.



pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
	24/1S	471	5.5	0.41	0.0004
Sapwood	24/2S	543	5.4	0.67	0.0002
Heartwood					

Mechanical properties in green condition

Number of test trees				2	
Basic density ρ_b			kg/m³	460	medium
	Stress at proportional limit		MPa	27.1	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	54.3	medium
	Stiffness	Modulus of elasticity	GPa	10.8	medium
Compression	Maximal compression strength parallel to grain		MPa	23.4	medium
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	20.0	low
		Rad.	kN	2.22	very low
Janka hardness	Resistance to identation	Tang.	kN	2.22	very low
		End	kN	2.45	low

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			2 / 5	2 / 5
Weight loss	average	%	53	47
	minimum	%	34	41
	maximum	%	70	53
Resistance to decay			non-resistant	non-resistant
Proportion of samples in each class	1	%	0	0
	2	%	0	0
	3	%	40	40
	4	%	60	60

Machining and related properties

Number of test trees				1
Number of test samples				10
Moisture content	Min - max		%	13.5 - 14.0
Planing	Defect free samples		%	50

		Angle		
		30°	20°	15°
Speed	7.6 m/min	0	50	0
	13.1 m/min	0	0	0

Shaping	Good to excellent samples	%	80
Turning	Fair to excellent samples	%	90
Nailing	Samples free from complete splits	%	45
Screwing	Samples free from complete splits	%	89

Slicing, sliced veneer - Assessment of relevant properties

	not tested
Heating temperature	
Flich degrade due to thermal treatment	
Ease of cutting	
Drying degrade	
Finishing quality	

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

Heating temperature	50-60°C
Log degrade due to hydrothermal treatment	moderate
Ease of peeling	moderately easy to peel
Gluing	satisfactory
Mechanical properties of plywood	satisfactory

Pachira aquatica Aubl.

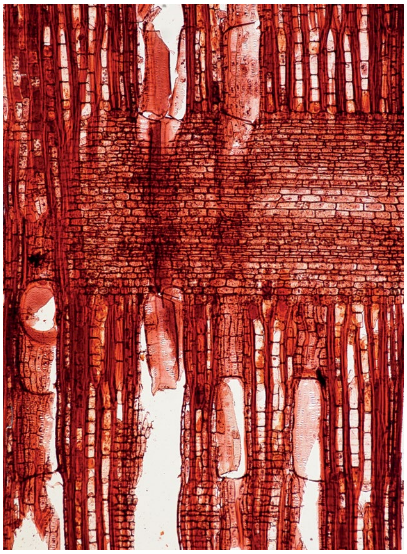
sin.: /

Malvaceae | Common name: **palo de agua** | Lacandon name: **kubuh (ah)**

Use: interior construction, decorative sliced veneer, packaging, cellulose products, particle board, paper pulp, core and crossband veneer, container veneer and plywood

Radial section in actual size.
Upper half of the sample sanded and unfinished,
the lower half oil finish.

cross section



radial section

tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 35 m	
Diameter	up to 60 cm	
Bole	Up to 20m, buttresses very well developed and frequently crooked	
Heartwood and sapwood (Munsell color chart)	no colored heartwood	
Condition	Sapwood	Heartwood
Green	2.5 Y HUE / 2.5 Y 8.5/6	
Air dried	7.5 YR HUE / 7.5 YR 8/4	
Grain	straight	
Texture	medium to coarse	

Moisture content and density

No. of test trees / samples: Sapwood (S) 3/6 ; Heartwood (H) 0/0.

Density	ρ_0	S	505	...	**526**	...	550	kg/m³
		H						
Moisture content (MC) green		S	92	...	**96**	...	98	%
		H						
EMC(21 °C/65%)		S			**14**			%
		H						

Dimensional stability

No. of test trees / samples: Sapwood (S) 3/6 ; Heartwood (H) 0/0.

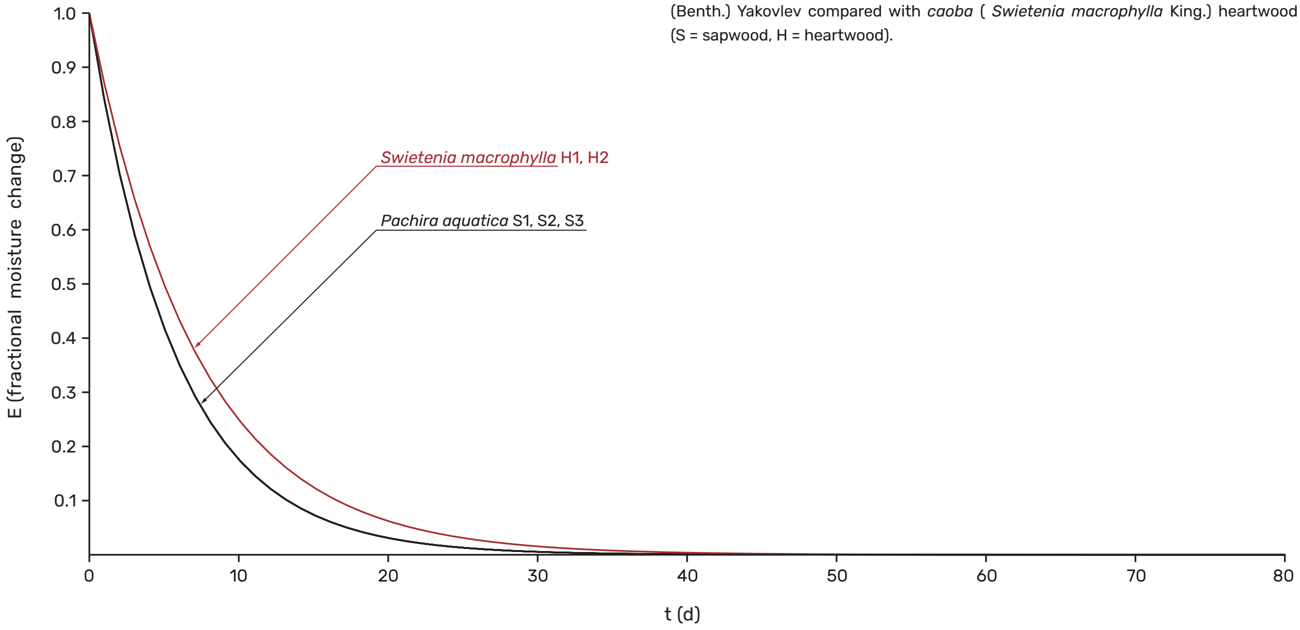
Density	ρ_0	S	505	...	**526**	...	550	kg / m³	
		H		...		...		kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.35	...	**0.36**	...	0.36	% / %	normal
	q_{tang}	H		...		...		% / %	
	q_{rad}	S	0.14	...	**0.15**	...	0.16	% / %	
	q_{rad}	H		...		...		% / %	
	q_{tang} / q_{rad}	S	2.19	...	**2.46**	...	2.57		unfavourable
	q_{tang} / q_{rad}	H		...		...			
	$q_{tang} - q_{rad}$	S	0.19	...	**0.21**	...	0.22	% / %	unfavourable
	$q_{tang} - q_{rad}$	H		...		...		% / %	
Swelling coefficient and anisotropy	h_{tang}	S	0.057	...	**0.058**	...	0.059	% / %	normal
	h_{tang}	H		...		...		% / %	
	h_{rad}	S	0.022	...	**0.023**	...	0.026	% / %	
	h_{rad}	H		...		...		% / %	
	h_{tang} / h_{rad}	S	2.23	...	**2.52**	...	2.68		unfavourable
	h_{tang} / h_{rad}	H		...		...			
	$h_{tang} - h_{rad}$	S	0.032	...	**0.035**	...	0.037	% / %	normal
	$h_{tang} - h_{rad}$	H		...		...		% / %	
Sorption coefficient	S	S	0.16	...	**0.16**	...	0.16	% / %	normal
	S	H		...		...		% / %	

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	526
	Seasoning time	days	98
	Initial moisture content	%	122
	Final moisture content	%	20
	Checking		202
	Warping		10
	Seasoning degrade		2
	$t_{eq0.5}$ days	S1, S2, S3:4	4
	t_{eq} days	S2:27, S2:28, S3:30	28
Recommended drying schedule	Drying gradient		2.6
	T_1	°C	60
	T_2	°C	80

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

23. *Pachira aquatica* Aubl.



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
Sapwood	53/1S	545	6.2	1.91	0.11
	53/2S	522	6.3	1.74	0.017
	53/3S	537	6.3	1.56	0.006
Heartwood					

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			3 / 5	3 / 5
Weight loss	average	%	18	46
	minimum	%	10	41
	maximum	%	22	49
Resistance to decay			resistant	non-resistant
Proportion of samples in each class	1	%	20	0
	2	%	80	0
	3	%	0	20
	4	%	0	80

Mechanical properties in green condition

Number of test trees				3	
Basic density ρ_b			kg/m³	500	medium
	Stress at propor-tional limit		MPa	19.2	
Static ben-ding-centre loading	Maximum bending strength	Modulus of rupture	MPa	45.2	low
	Stiffness	Modulus of elasticity	GPa	7.4	very low
Compression	Maximal compression strength parallel to grain		MPa	18.5	low
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	18.0	low
		Rad.	kN	1.95	very low
Janka hardness	Resistance to identation	Tang.	kN	2.14	very low
		End	kN	2.05	very low

Machining and related properties

Number of test trees					1
Number of test samples					10
Moisture content	Min - max			%	15.0 - 20.0
Planing	Defect free samples			%	90
		Angle			
		30°	20°	15°	
Speed	7.6 m/min	90	60	-	
	13.1 m/min	40	60	-	
Shaping	Good to excellent samples			%	10
Turning	Fair to excellent samples			%	80
Nailing	Samples free from complete splits			%	90
Screwing	Samples free from complete splits			%	95

Slicing, sliced veneer - Assessment of relevant properties

not tested
Heating temperature
Flich degrade due to thermal treatment
Ease of cutting
Drying degrade
Finishing quality

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

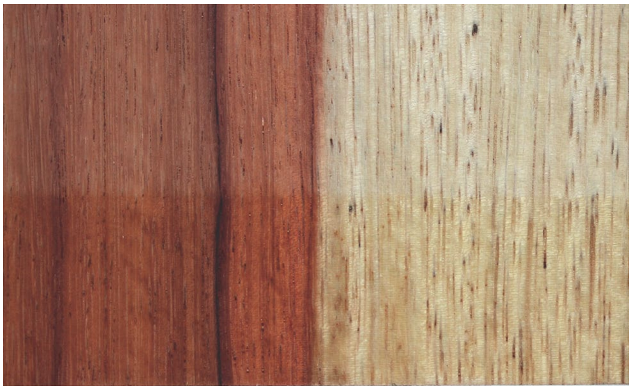
not tested
Heating temperature
Log degrade due to hydrothermal treatment
Ease of peeling
Gluing
Mechanical properties of plywood

Platymiscium yucatanum Standl.

sin.: ***Sweetia panamensis* Benth.**

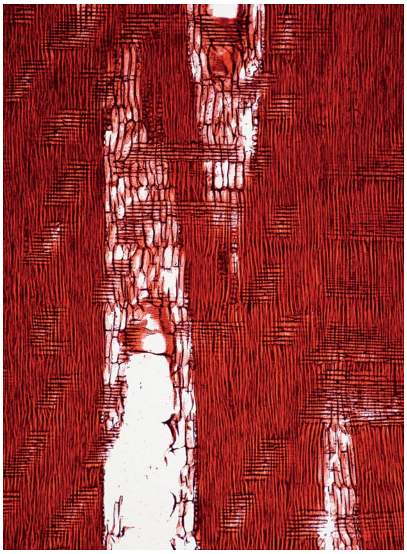
Fabaceae | Common name: **chulul** | Lacandon name: **säk chulul (äh)**

Use: interior construction, exterior construction, framework, furniture, decorative sliced veneer, flooring, container veneer and plywood, interior coverings, exterior coverings, hydraulic works, boat building, sleepers



Radial section in actual size.
Upper half of the sample sanded and unfinished,
the lower half oil finish.

cross section



radial section

tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 45 m	
Diameter	up to 80 cm	
Bole	Regular, straight clear for 25 m	
Heartwood and sapwood (Munsell color chart)	heartwood clearly differentiated from sapwood	
Condition	Sapwood	Heartwood
Green	2.5 Y HUE / 2.5 Y 8.5/6	2.5 YR HUE / 2.5 YR 5/12
Air dried	10 YR HUE / 10 YR 9/2	10 R HUE / 10 R 5/8
Grain	straight or slightly, narrowly shallowly interlocked	
Texture	Medium to coarse	

Moisture content and density

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 2/4.

Density	ρ_0	S	663	...	**727**	...	791	kg/m³
		H	668	...	**713**	...	760	kg/m³
Moisture content (MC) green		S	56	...	**60**	...	64	%
		H	71	...	**80**	...	88	%
EMC(21 °C/65%)		S			**14**			%
		H			**12**			%

Dimensional stability

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 2/4.

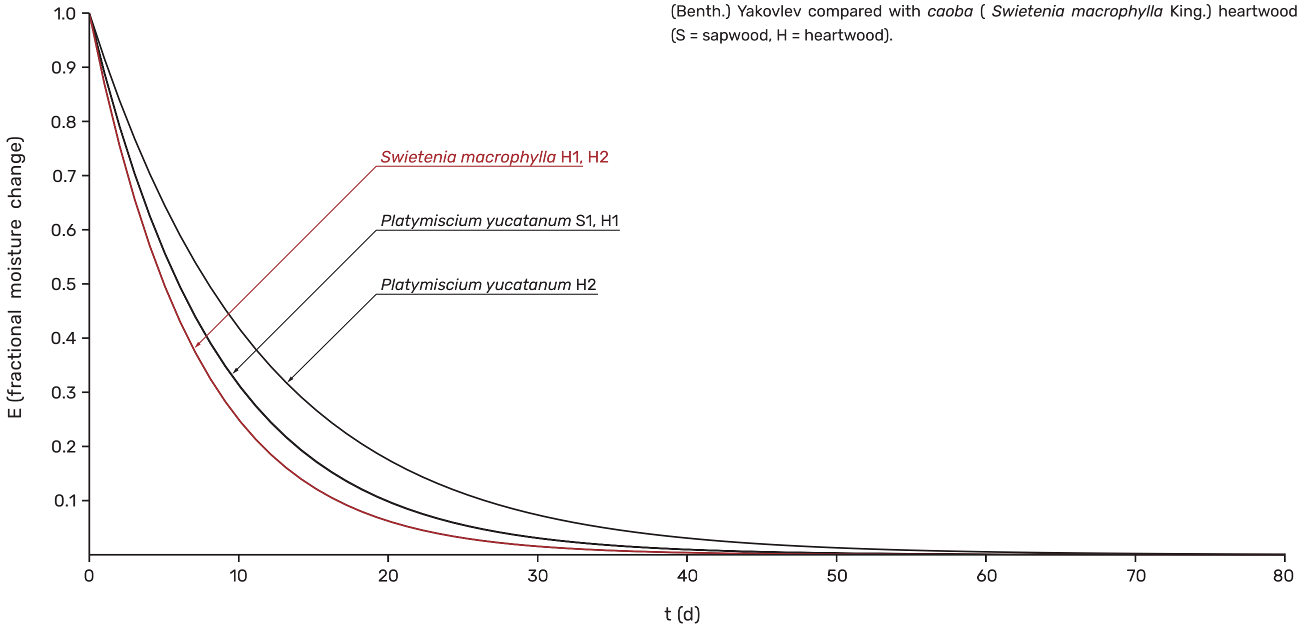
Density	ρ_0	S	663	...	**727**	...	791	kg / m³	
		H	668	...	**713**	...	760	kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.31	...	**0.34**	...	0.38	% / %	normal
	q_{tang}	H	0.31	...	**0.35**	...	0.38	% / %	normal
	q_{rad}	S	0.19	...	**0.20**	...	0.21	% / %	
	q_{rad}	H	0.19	...	**0.20**	...	0.21	% / %	
	q_{tang} / q_{rad}	S	1.55	...	**1.69**	...	1.81		normal
	q_{tang} / q_{rad}	H	1.63	...	**1.74**	...	1.90		normal
	$q_{tang} - q_{rad}$	S	0.11	...	**0.14**	...	0.16	% / %	normal
	$q_{tang} - q_{rad}$	H	0.12	...	**0.15**	...	0.18	% / %	normal
Swelling coefficient and anisotropy	h_{tang}	S	0.047	...	**0.053**	...	0.058	% / %	normal
	h_{tang}	H	0.036	...	**0.042**	...	0.048	% / %	normal
	h_{rad}	S	0.030	...	**0.032**	...	0.034	% / %	
	h_{rad}	H	0.022	...	**0.024**	...	0.027	% / %	
	h_{tang} / h_{rad}	S	1.57	...	**1.68**	...	1.82		normal
	h_{tang} / h_{rad}	H	1.64	...	**1.73**	...	1.85		normal
	$h_{tang} - h_{rad}$	S	0.017	...	**0.022**	...	0.027	% / %	normal
	$h_{tang} - h_{rad}$	H	0.014	...	**0.018**	...	0.022	% / %	favourable
Sorption coefficient	S	S	0.15	...	**0.16**	...	0.16	% / %	normal
	S	H	0.12	...	**0.13**	...	0.13	% / %	very favourable

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³		713
	Seasoning time	days		182
	Initial moisture content	%		74
	Final moisture content	%		15
	Checking			9
	Warping			3
	Seasoning degrade			1
	$t_{eq0.5}$ days		S1, H1:6, H2:8	7
	t_{eq} days		S1:38, H1:42, H2:52	47
Recommended drying schedule	Drying gradient			2.1
	T_1	°C		50
	T_2	°C		80

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

24. *Platymiscium yucatanum* Standl.



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
	54/1S	831	5.6		
Sapwood	54/2S	661	5.5		
	54/1H	746	4.4	0.67	0.0003
	54/2H	675	4.4	0.80	0.0005
Heartwood					

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			2 / 5	2 / 5
Weight loss	average	%	1	1
	minimum	%	0	0
	maximum	%	1	3
Resistance to decay			very resistant	very resistant
Proportion of samples in each class	1	%	100	100
	2	%	0	0
	3	%	0	0
	4	%	0	0

Mechanical properties in green condition

Number of test trees				2	
Basic density ρ_b			kg/m³	660	high
	Stress at proportional limit		MPa	59.2	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	97.7	high
	Stiffness	Modulus of elasticity	GPa	12.4	high
Compression	Maximal compression strength parallel to grain		MPa	51.8	high
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	28.2	medium
		Rad.	kN	5.54	high
Janka hardness	Resistance to identation	Tang.	kN	5.57	high
		End	kN	6.23	high

Machining and related properties

Number of test trees				1
Number of test samples				10
Moisture content	Min - max		%	13.0 - 15.0
Planing	Defect free samples		%	70

		Angle		
		30°	20°	15°
Speed	7.6 m/min	10	70	-
	13.1 m/min	10	50	-

Shaping	Good to excellent samples	%	90
Turning	Fair to excellent samples	%	100
Nailing	Samples free from complete splits	%	15
Screwing	Samples free from complete splits	%	65

Slicing, sliced veneer - Assessment of relevant properties

Heating temperature	80-90 °C
Flich degrade due to thermal treatment	none
Ease of cutting	moderately easy to cut
Drying degrade	without checking and wrinkling
Finishing quality	good

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

	not tested
Heating temperature	
Log degrade due to hydrothermal treatment	
Ease of peeling	
Gluing	
Mechanical properties of plywood	

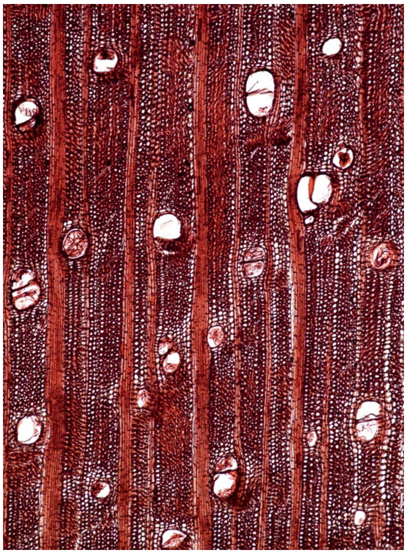
Poulsenia armata (Miq.) Standl.

sin.: /

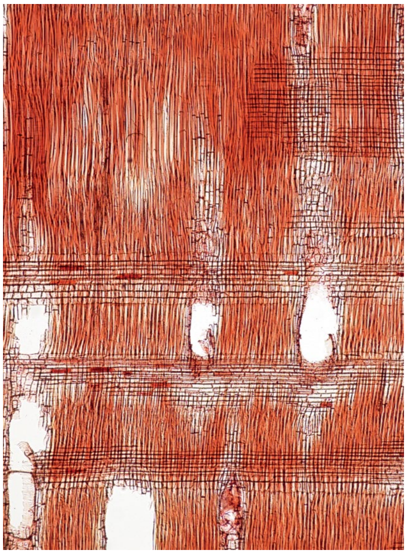
Moraceae | Common name: **masamorro** | Lacandon name: **ak' hu'un**

Use: interior construction, framework, packaging, cellulose products, particle board, paper pulp, core and crossband veneer, container veneer and plywood, possibly for peeled veneer and decorative sliced veneer

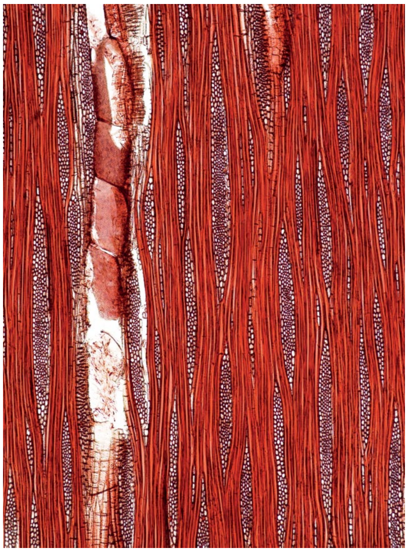
Radial section in actual size.
Upper half of the sample sanded and unfinished,
the lower half oil finish.



cross section



radial section



tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 35 m	
Diameter	up to 60 cm	
Bole	Regular, straight clear for 20 m	
Heartwood and sapwood (Munsell color chart)	without colored heartwood	
Condition	Sapwood	Heartwood
Green	10 YR HUE / 10 YR 8/6	
Air dried	10 YR HUE / 10 YR 8/2	
Grain	Slightly, broadly shallowly interlocked and irregular	
Texture	coarse	

Moisture content and density

No. of test trees / samples: Sapwood (S) 3/6 ; Heartwood (H) 0/0.

Density	ρ_0	S	406	...	**445**	...	476	kg/m³
		H						
Moisture content (MC) green		S	81	...	**92**	...	102	%
		H						
EMC(21 °C/65%)		S			**14**			%
		H						

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

Dimensional stability

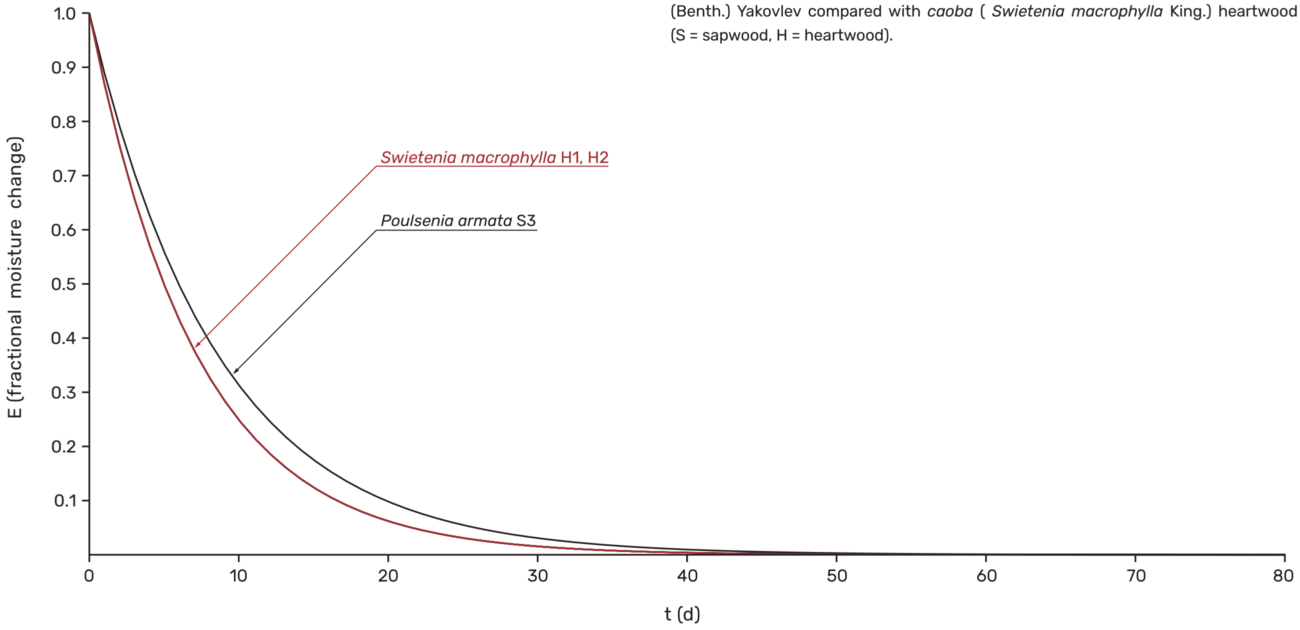
No. of test trees / samples: Sapwood (S) 3/6 ; Heartwood (H) 0/0.

Density	ρ_0	S	406	...	**445**	...	476	kg / m³	
		H		...		...		kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.25	...	**0.29**	...	0.32	% / %	favourable
	q_{tang}	H		...		...		% / %	
	q_{rad}	S	0.14	...	**0.16**	...	0.17	% / %	
	q_{rad}	H		...		...		% / %	
	q_{tang} / q_{rad}	S	1.67	...	**1.85**	...	2.07		normal
	q_{tang} / q_{rad}	H		...		...			
	$q_{tang} - q_{rad}$	S	0.10	...	**0.13**	...	0.16	% / %	normal
	$q_{tang} - q_{rad}$	H		...		...		% / %	
Swelling coefficient and anisotropy	h_{tang}	S	0.040	...	**0.045**	...	0.051	% / %	favourable
	h_{tang}	H		...		...		% / %	
	h_{rad}	S	0.023	...	**0.024**	...	0.025	% / %	
	h_{rad}	H		...		...		% / %	
	h_{tang} / h_{rad}	S	1.74	...	**1.89**	...	2.13		normal
	h_{tang} / h_{rad}	H		...		...			
	$h_{tang} - h_{rad}$	S	0.017	...	**0.021**	...	0.027	% / %	normal
	$h_{tang} - h_{rad}$	H		...		...		% / %	
Sorption coefficient	s	S	0.15	...	**0.16**	...	0.16	% / %	normal
	s	H		...		...		% / %	

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	445
	Seasoning time	days	140
	Initial moisture content	%	87
	Final moisture content	%	20
	Checking		2
	Warping		1
	Seasoning degrade		1
	$t_{eq0.5}$ days	S3:6	5
	t_{eq} days	S3:39	37
Recommended drying schedule	Drying gradient		3.1
	T_1	°C	70
	T_2	°C	80

25. *Poulsenia armata* (Miq.) Standl.



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
Sapwood	65/1S	451	6.4	6.65	4.7
	65/2S	470	6.3	1.85	1.00
	65/3S	398	5.9	1.99	0.78
Heartwood					

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			3 / 5	3 / 5
Weight loss	average	%	6	37
	minimum	%	3	33
	maximum	%	12	46
Resistance to decay			very resistant	moderately resistant
Proportion of samples in each class	1	%	80	0
	2	%	20	0
	3	%	0	80
	4	%	0	20

Mechanical properties in green condition

Number of test trees				3	
Basic density ρ_b			kg/m³	400	medium
	Stress at proportional limit		MPa	28.4	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	75.4	medium
	Stiffness	Modulus of elasticity	GPa	6.4	very low
Compression	Maximal compression strength parallel to grain		MPa	23.2	medium
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	18.4	low
		Rad.	kN	2.28	very low
Janka hardness	Resistance to identation	Tang.	kN	2.59	low
		End	kN	2.76	low

Machining and related properties

Number of test trees				1
Number of test samples				8
Moisture content	Min - max		%	13.5 - 14.0
Planing	Defect free samples		%	25

		Angle		
		30°	20°	15°
Speed	7.6 m/min	25	0	-
	13.1 m/min	13	0	-

Shaping	Good to excellent samples	%	13
Turning	Fair to excellent samples	%	20
Nailing	Samples free from complete splits	%	19
Screwing	Samples free from complete splits	%	100

Slicing, sliced veneer - Assessment of relevant properties

not tested
Heating temperature
Flich degrade due to thermal treatment
Ease of cutting
Drying degrade
Finishing quality

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

Heating temperature	20-50°C
Log degrade due to hydrothermal treatment	light
Ease of peeling	moderately easy to peel
Gluing	good
Mechanical properties of plywood	satisfactory

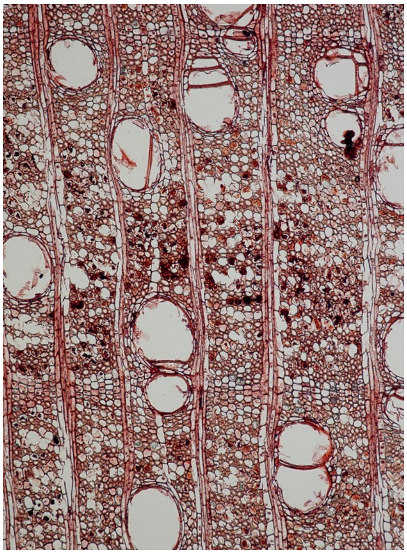
Pseudobombax ellipticum (Kunth) Dugand

sin.: /

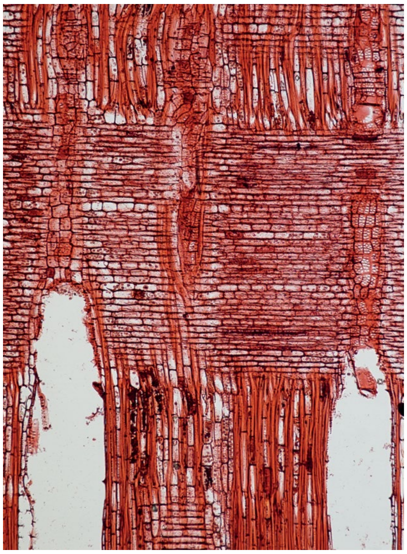
Malvaceae | Common name: **amapola** | Lacandon name: **ch'ulte'**

Use: interior construction, framework, peeled veneer, packaging, cellulose products, particle board, construction plywood, decorative sliced veneer, core and crossband veneer, container veneer and plywood, interior coverings, paper pulp

Radial section in actual size.
Upper half of the sample sanded and unfinished,
the lower half oil finish.



cross section



radial section

tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 30 m
Diameter	up to 150 cm
Bole	Up to 20m, occasionally with small buttresses
Heartwood and sapwood (Munsell color chart)	heartwood slightly differentiated from sapwood, biological status unknown

Condition	Sapwood	Heartwood
Green	5 R HUE / 3.75 R 6/12	10 R HUE / 10 R 7/8
Air dried	7.5 YR HUE / 7.5 YR 8/4	10 R HUE / 10 R 6/6

Grain	straight or slightly interlocked, sometimes shallowly interlocked
Texture	coarse

Moisture content and density

No. of test trees / samples: Sapwood (S) 1/2 ; Heartwood (H) 2/4.

Density	ρ_0	S	439	...	**444**	...	448	kg/m³
		H	470	...	**482**	...	492	kg/m³
Moisture content (MC) green		S	138	...	**142**	...	145	%
		H	103	...	**109**	...	116	%
EMC(21 °C/65%)		S			**16**			%
		H			**15**			%

Dimensional stability

No. of test trees / samples: Sapwood (S) 1/2 ; Heartwood (H) 2/4.

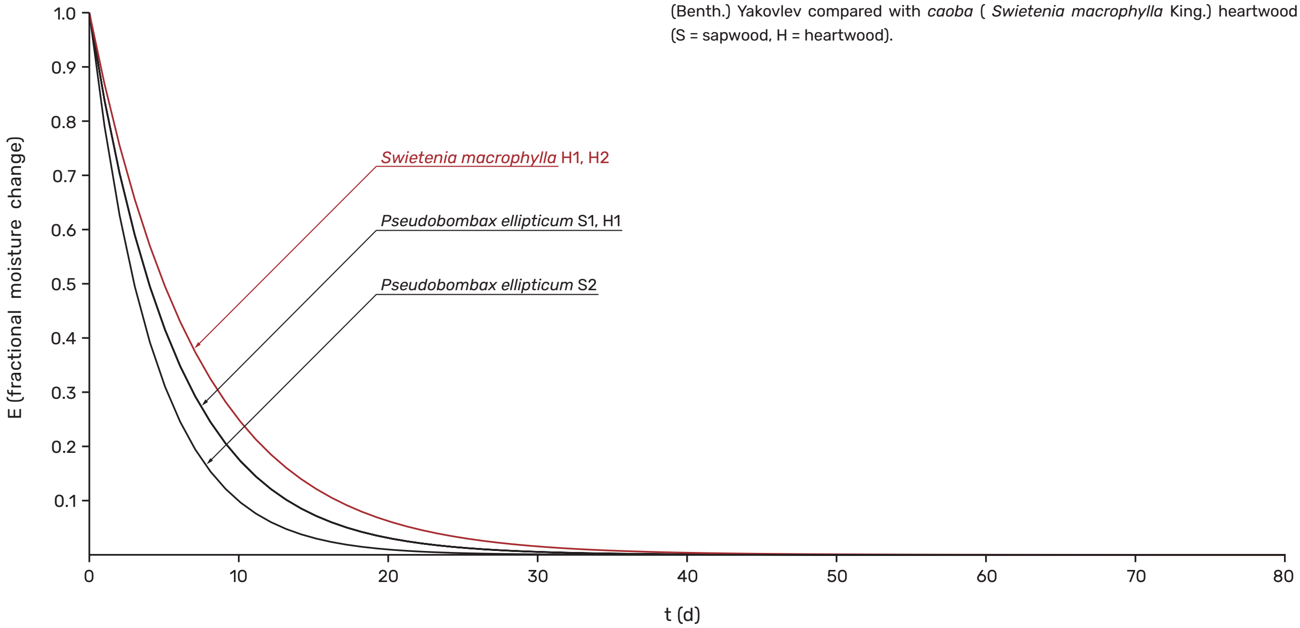
Density	ρ_0	S	439	...	**444**	...	448	kg / m³	
		H	470	...	**482**	...	492	kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.25	...	**0.25**	...	0.25	% / %	favourable
	q_{tang}	H	0.27	...	**0.28**	...	0.29	% / %	favourable
	q_{rad}	S	0.11	...	**0.12**	...	0.12	% / %	
	q_{rad}	H	0.13	...	**0.14**	...	0.14	% / %	
	q_{tang} / q_{rad}	S	2.08	...	**2.18**	...	2.27		unfavourable
	q_{tang} / q_{rad}	H	2.07	...	**2.08**	...	2.08		unfavourable
	$q_{tang} - q_{rad}$	S	0.13	...	**0.14**	...	0.14	% / %	normal
	$q_{tang} - q_{rad}$	H	0.14	...	**0.15**	...	0.15	% / %	normal
Swelling coefficient and anisotropy	h_{tang}	S	0.041	...	**0.042**	...	0.042	% / %	favourable
	h_{tang}	H	0.041	...	**0.043**	...	0.045	% / %	favourable
	h_{rad}	S	0.019	...	**0.020**	...	0.020	% / %	
	h_{rad}	H	0.020	...	**0.020**	...	0.022	% / %	
	h_{tang} / h_{rad}	S	2.10	...	**2.13**	...	2.16		unfavourable
	h_{tang} / h_{rad}	H	2.05	...	**2.09**	...	2.14		unfavourable
	$h_{tang} - h_{rad}$	S	0.022	...	**0.022**	...	0.022	% / %	normal
	$h_{tang} - h_{rad}$	H	0.021	...	**0.023**	...	0.024	% / %	normal
Sorption coefficient	s	S	0.16	...	**0.17**	...	0.17	% / %	unfavourable
	s	H	0.15	...	**0.16**	...	0.16	% / %	normal

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	482
	Seasoning time	days	112
	Initial moisture content	%	120
	Final moisture content	%	21
	Checking		0
	Warping		9
	Seasoning degrade		2
	$t_{eq0.5}$ days	S1:4, S2:3, H1:4	4
	t_{eq} days	S1:29, S2:26, H1:29	29
Recommended drying schedule	Drying gradient		2.6
	T_1	°C	50
	T_2	°C	80

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

26. *Pseudobombax ellipticum* (Kunth) Dugand



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
Sapwood	29/1S	443	5.5		
	29/2S	502	6.0	2.36	0.0007
Heartwood	29/1H	466		2.81	0.004

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			3 / 5	3 / 5
Weight loss	average	%	15	41
	minimum	%	11	37
	maximum	%	16	46
Resistance to decay			resistant	moderately resistant
Proportion of samples in each class	1	%	0	0
	2	%	100	0
	3	%	0	60
	4	%	0	40

Mechanical properties in green condition

Number of test trees				3	
Basic density ρ_b			kg/m³	440	medium
Static ben-ding-centre loading	Stress at propor-tional limit		MPa	17.8	
	Maximum bending strength	Modulus of rupture	MPa	49.1	low
	Stiffness	Modulus of elasticity	GPa	6.9	very low
Compression	Maximal compression strength parallel to grain		MPa	19.9	low
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	82.0	exceptionally high
Janka hardness	Resistance to identation	Rad.	kN	2.18	very low
		Tang.	kN	1.90	very low
		End	kN	2.26	very low

Machining and related properties

Number of test trees					1
Number of test samples					12
Moisture content	Min - max		%		14.0 - 14.0
Planing	Defect free samples		%		100
		Angle			
		30°	20°	15°	
Speed	7.6 m/min	100	83	-	
	13.1 m/min	42	67	-	
Shaping	Good to excellent samples		%		58
Turning	Fair to excellent samples		%		80
Nailing	Samples free from complete splits		%		25
Screwing	Samples free from complete splits		%		95

Slicing, sliced veneer - Assessment of relevant properties

not tested	
Heating temperature	
Flich degrade due to thermal treatment	
Ease of cutting	
Drying degrade	
Finishing quality	

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

Heating temperature	20-50°C
Log degrade due to hydrothermal treatment	moderate
Ease of peeling	easy to peel
Gluing	good
Mechanical properties of plywood	satisfactory

Pseudolmedia glabrata (Liebm.) C.C.Berg

sin.: ***Pseudolmedia oxyphyllaria* J. D. Smith**

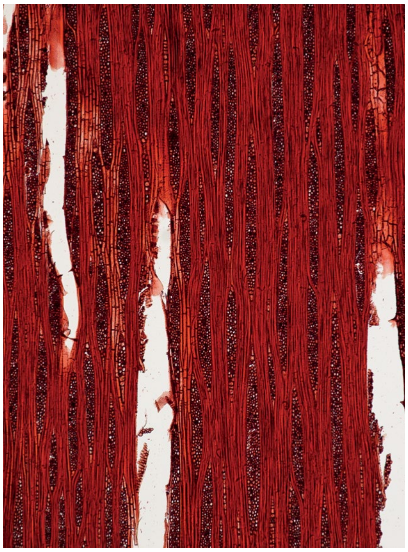
Moraceae | Common name: **mamba** | Lacandon name: **hach bamax, tso'ots bamax**

Use: problematic wood, possibly for cellulose products and particle board, decorative sliced veneer, container veneer and plywood, interior coverings

Radial section in actual size.
Upper half of the sample sanded and unfinished,
the lower half oil finish.

cross section

radial section



tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 35 m	
Diameter	up to 100 cm	
Bole	straight and regular, clear for 20 m	
Heartwood and sapwood (Munsell color chart)	without colored heartwood	
Condition	Sapwood	Heartwood
Green	2.5 YR HUE / 1.25 YR 5/12	
Air dried	5 YR HUE / 5 YR 8/4	
Grain	straight, wawy, ocasionally slighly interlocked	
Texture	fine to medium	

Moisture content and density

No. of test trees / samples: Sapwood (S) 0/0 ; Heartwood (H) 2/4.

Density	ρ_0	S							
		H	708	...	**723**	...	737	kg/m³
Moisture content (MC) green		S						
		H	60	...	**65**	...	68	%
EMC(21 °C/65%)		S						
		H			**14**			%

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ *days* – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} *days* – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

Dimensional stability

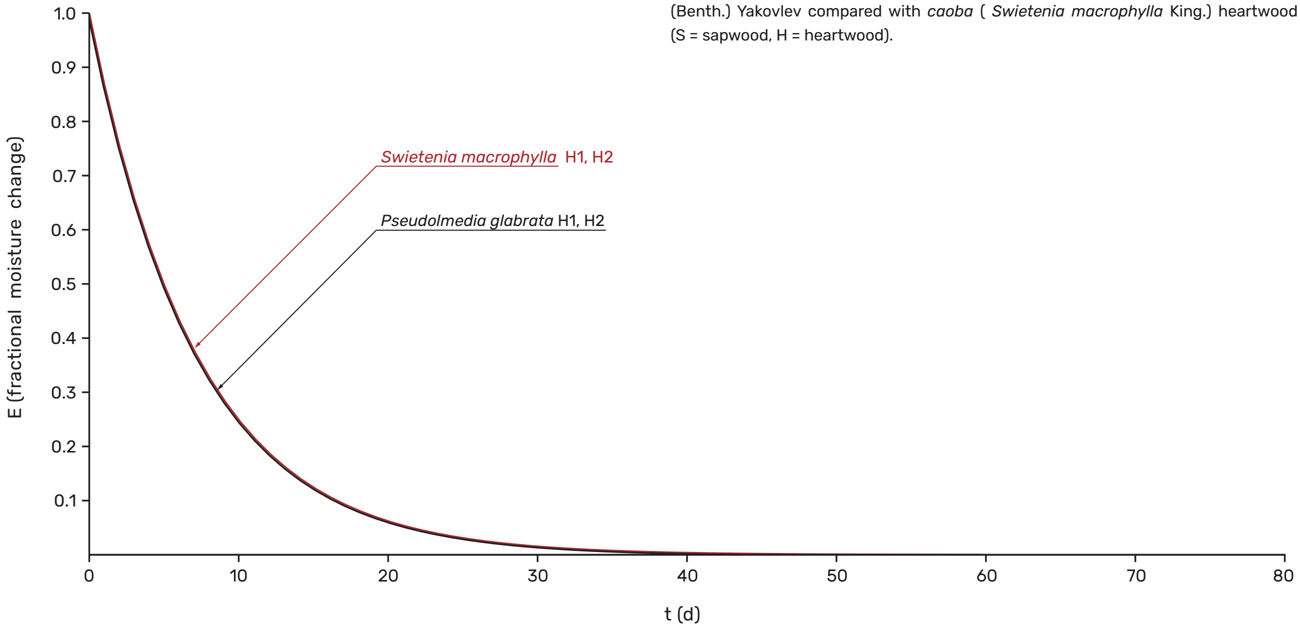
No. of test trees / samples: Sapwood (S) / ; Heartwood (H) 2/4.

Density	ρ_0	S		...		...		kg / m³	
		H	708	...	**723**	...	737	kg / m³	
Differential swelling and anisotropy	q_{tang}	S		...		...		% / %	
	q_{tang}	H	0.45	...	**0.45**	...	0.46	% / %	unfavourable
	q_{rad}	S		...		...		% / %	
	q_{rad}	H	0.17	...	**0.18**	...	0.18	% / %	
	q_{tang} / q_{rad}	S		...		...			
	q_{tang} / q_{rad}	H	2.50	...	**2.55**	...	2.65		unfavourable
	$q_{tang} - q_{rad}$	S		...		...		% / %	
	$q_{tang} - q_{rad}$	H	0.27	...	**0.28**	...	0.28	% / %	unfavourable
Swelling coefficient and anisotropy	h_{tang}	S		...		...		% / %	
	h_{tang}	H	0.070	...	**0.070**	...	0.071	% / %	unfavourable
	h_{rad}	S		...		...		% / %	
	h_{rad}	H	0.027	...	**0.028**	...	0.029	% / %	
	h_{tang} / h_{rad}	S		...		...			
	h_{tang} / h_{rad}	H	2.41	...	**2.51**	...	2.59		unfavourable
	$h_{tang} - h_{rad}$	S		...		...		% / %	
	$h_{tang} - h_{rad}$	H	0.041	...	**0.042**	...	0.043	% / %	unfavourable
Sorption coefficient	S	S		...		...		% / %	
	S	H	0.15	...	**0.16**	...	0.16	% / %	normal

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	723
	Seasoning time	days	91
	Initial moisture content	%	73
	Final moisture content	%	20
	Checking		90
	Warping		3
	Seasoning degrade		3
	$t_{eq0.5}$ days	H1, H2:5	5
	t_{eq} days	H1:36, H2:35	36
Recommended drying schedule	Drying gradient		2.1
	T_1	°C	40
	T_2	°C	60

27. *Pseudolmedia glabrata* (Liebm.) C.C.Berg



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
Sapwood					
Heartwood	30/1H	737	6.1	1.82	0.009
	30/2H	716	6.6	1.19	0.03

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			2 / 5	2 / 5
Weight loss	average	%	42	38
	minimum	%	38	26
	maximum	%	50	43
Resistance to decay			moderately resistant	moderately resistant
Proportion of samples in each class	1	%	0	0
	2	%	0	0
	3	%	80	100
	4	%	20	0

Mechanical properties in green condition

Number of test trees				2	
Basic density ρ_b			kg/m³	650	high
	Stress at proportional limit		MPa	39.7	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	80.9	high
	Stiffness	Modulus of elasticity	GPa	12.0	high
Compression	Maximal compression strength parallel to grain		MPa	36.2	high
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	29.0	medium
		Rad.	kN	5.29	high
Janka hardness	Resistance to identation	Tang.	kN	5.18	high
		End	kN	5.40	high

Machining and related properties

Number of test trees				1
Number of test samples				9
Moisture content	Min - max		%	12.5 - 14.5
Planing	Defect free samples		%	89

		Angle		
		30°	20°	15°
Speed	7.6 m/min	89	56	-
	13.1 m/min	78	0	-

Shaping	Good to excellent samples	%	67
Turning	Fair to excellent samples	%	60
Nailing	Samples free from complete splits	%	6
Screwing	Samples free from complete splits	%	56

Slicing, sliced veneer - Assessment of relevant properties

not tested
Heating temperature
Flich degrade due to thermal treatment
Ease of cutting
Drying degrade
Finishing quality

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

not tested
Heating temperature
Log degrade due to hydrothermal treatment
Ease of peeling
Gluing
Mechanical properties of plywood

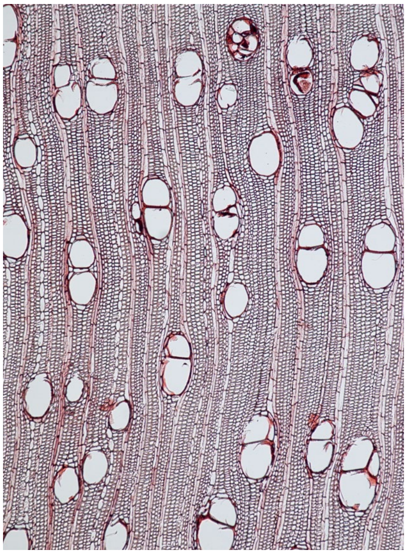
Pterocarpus rohrii Vahl

sin.: ***Pterocarpus hayesii* Hemsl.**

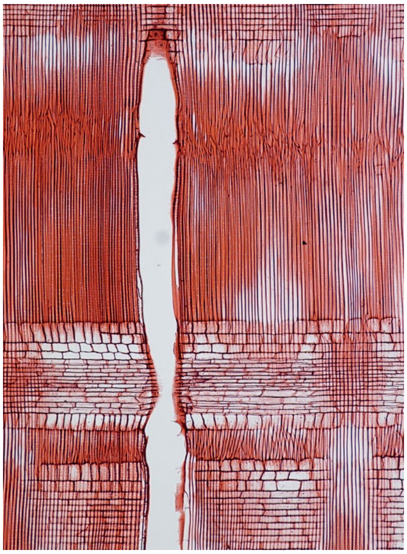
Fabaceae | Common name: **palo de sangre** | Lacandon name: **/**

Use: interior construction, peeled veneer, packaging, cellulose products, paper pulp, particle board, framework, interior coverings, container veneer and plywood, core and crossband veneer, construction plywood, possibly for decorative sliced veneer

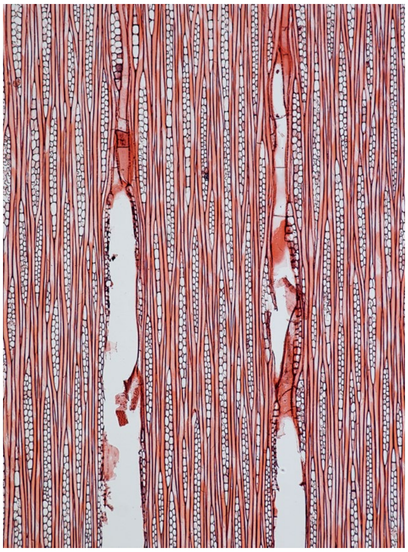
Radial section in actual size.
Upper half of the sample sanded and unfinished,
the lower half oil finish.



cross section



radial section



tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 45 m
Diameter	up to 100 cm
Bole	straight regular, clear for 25 m
Heartwood and sapwood (Munsell color chart)	Completely differentiated

Condition	Sapwood	Heartwood
Green	2.5 Y HUE / 2.5 Y 8.5/6	2.5 YR HUE / 2.5 YR 6/8
Air dried	2.5 Y HUE / 2.5 Y 8.5/2	7.5 YR HUE / 7.5 YR 6/4

Grain	straight
Texture	medium to coarse

Moisture content and density

No. of test trees / samples: Sapwood (S) 1/2 ; Heartwood (H) 2/4.

Density	ρ_0	S	507	...	**508**	...	509	kg/m³
		H	425	...	**429**	...	435	kg/m³
Moisture content (MC) green		S	74	...	**75**	...	76	%
		H	98	...	**107**	...	115	%
EMC(21 °C/65%)		S			**14**			%
		H			**14**			%

Dimensional stability

No. of test trees / samples: Sapwood (S) 1/2 ; Heartwood (H) 2/4.

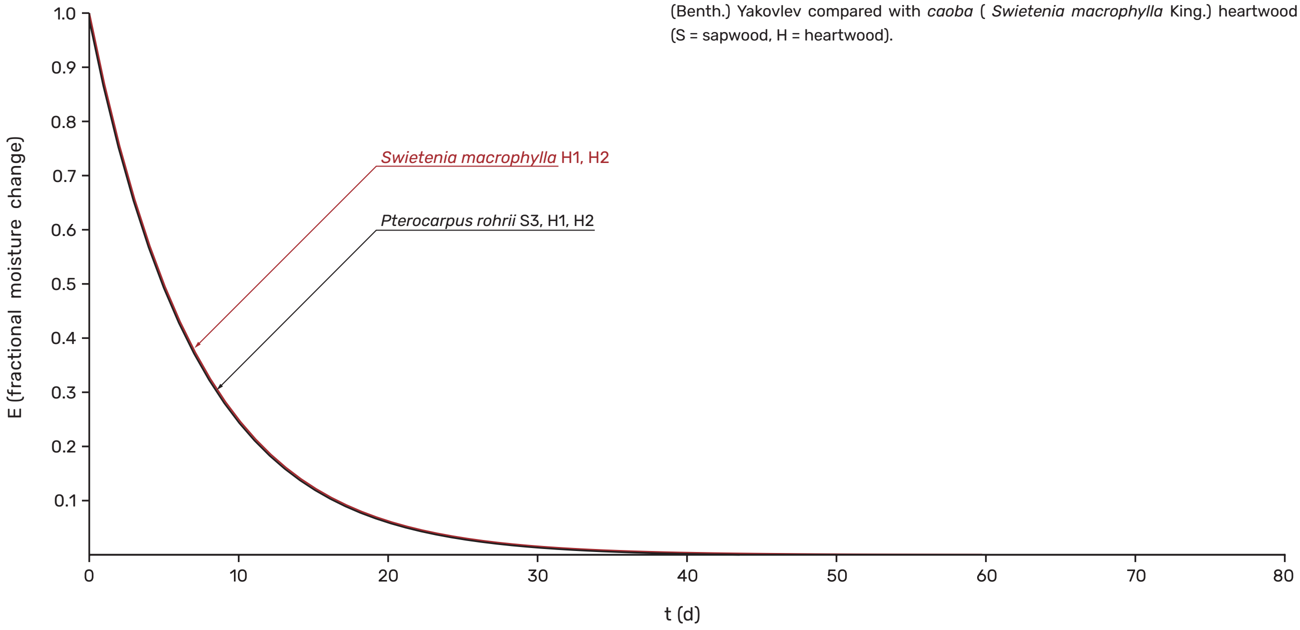
Density	ρ_0	S	507	...	**508**	...	509	kg / m³	
		H	425	...	**429**	...	435	kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.37	...	**0.37**	...	0.37	% / %	normal
	q_{tang}	H	0.36	...	**0.37**	...	0.37	% / %	normal
	q_{rad}	S	0.19	...	**0.19**	...	0.19	% / %	
	q_{rad}	H	0.14	...	**0.15**	...	0.15	% / %	
	q_{tang} / q_{rad}	S	1.95	...	**1.95**	...	1.95		normal
	q_{tang} / q_{rad}	H	2.47	...	**2.52**	...	2.57		unfavourable
	$q_{tang} - q_{rad}$	S	0.18	...	**0.18**	...	0.18	% / %	normal
	$q_{tang} - q_{rad}$	H	0.22	...	**0.22**	...	0.22	% / %	unfavourable
Swelling coefficient and anisotropy	h_{tang}	S	0.059	...	**0.059**	...	0.059	% / %	normal
	h_{tang}	H	0.057	...	**0.058**	...	0.059	% / %	normal
	h_{rad}	S	0.030	...	**0.030**	...	0.030	% / %	
	h_{rad}	H	0.022	...	**0.023**	...	0.024	% / %	
	h_{tang} / h_{rad}	S	1.97	...	**1.97**	...	1.97		normal
	h_{tang} / h_{rad}	H	2.46	...	**2.53**	...	2.59		unfavourable
	$h_{tang} - h_{rad}$	S	0.029	...	**0.029**	...	0.029	% / %	normal
	$h_{tang} - h_{rad}$	H	0.035	...	**0.035**	...	0.036	% / %	normal
Sorption coefficient	s	S	0.16	...	**0.16**	...	0.16	% / %	normal
	s	H	0.16	...	**0.16**	...	0.16	% / %	normal

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	508
	Seasoning time	days	77
	Initial moisture content	%	80
	Final moisture content	%	20
	Checking		12
	Warping		11
	Seasoning degrade		2-3
	$t_{eq0.5}$ days	S3, H1, H2:5	5
	t_{eq} days	S3, H1:36, H2:37	37
Recommended drying schedule	Drying gradient		2.6
	T_1	°C	50
	T_2	°C	70

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

28. *Pterocarpus rohrii* Vahl



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density ρ_0 kg/m3	pH - value	Ash content %	Silica content %
Sapwood	56/3S	491	5.6	0.53	0.0004
Heartwood	56/1H	432	5.1	0.65	0.0005
	56/2H	445	4.8	0.88	0.00009

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			3 / 6	3 / 6
Weight loss	average	%	47	41
	minimum	%	13	34
	maximum	%	64	52
Resistance to decay			non-resistant	moderately resistant
Proportion of samples in each class	1	%	17	0
	2	%	0	0
	3	%	17	83
	4	%	66	17

Mechanical properties in green condition

Number of test trees				3	
Basic density ρ_b			kg/m³	450	medium
	Stress at propor-tional limit		MPa	23.8	
Static ben-ding-centre loading	Maximum bending strength	Modulus of rupture	MPa	49.3	low
	Stiffness	Modulus of elasticity	GPa	9.0	low
Compression	Maximal compression strength parallel to grain		MPa	21.9	medium
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	11.8	very low
		Rad.	kN	1.84	very low
Janka hardness	Resistance to identation	Tang.	kN	2.00	very low
		End	kN	2.27	very low

Machining and related properties

Number of test trees				1
Number of test samples				10
Moisture content	Min - max		%	13.5 - 13.5
Planing	Defect free samples		%	70

		Angle		
		30°	20°	15°
Speed	7.6 m/min	70	40	-
	13.1 m/min	50	10	-

Shaping	Good to excellent samples	%	30
Turning	Fair to excellent samples	%	10
Nailing	Samples free from complete splits	%	90
Screwing	Samples free from complete splits	%	90

Slicing, sliced veneer - Assessment of relevant properties

	not tested
Heating temperature	
Flich degrade due to thermal treatment	
Ease of cutting	
Drying degrade	
Finishing quality	

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

Heating temperature	50-60°C
Log degrade due to hydrothermal treatment	light
Ease of peeling	easy to peel
Gluing	satisfactory to good
Mechanical properties of plywood	satisfactory

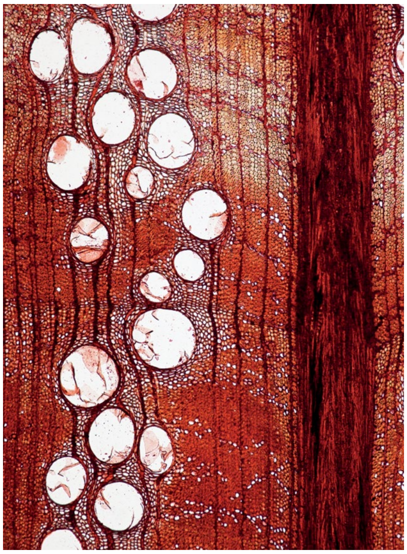
Quercus acutifolia Née

sin.: ***Quercus anglohondurensis*** **C. H. Mull.**

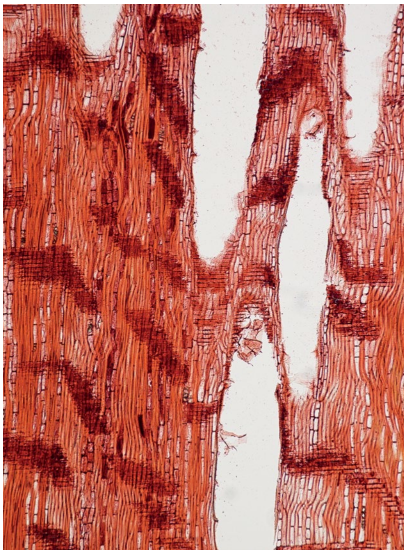
Fagaceae | Common name: **chiquinib de montaña** | Lacandon name: **/**

Use: interior construction, exterior construction, furniture, decorative sliced veneer, flooring, rail sleepers, hydraulic works

Radial section in actual size.
Upper half of the sample sanded and unfinished, the lower half oil finish.



cross section



radial section

tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 45 m	
Diameter	up to 100 cm	
Bole	straight regular, clear for 25 m	
Heartwood and sapwood (Munsell color chart)	Completely differentiated	
Condition	Sapwood	Heartwood
Green	2.5 Y HUE / 2.5 Y 8.5/6	2.5 YR HUE / 2.5 YR 6/8
Air dried	2.5 Y HUE / 2.5 Y 8.5/2	7.5 YR HUE / 7.5 YR 6/4
Grain	straight	
Texture	medium to coarse	

Moisture content and density

No. of test trees / samples: Sapwood (S) 0/0 ; Heartwood (H) 3/6

Density	ρ_0	S						
		H	831	...	**857**	...	882	kg/m³
Moisture content (MC) green		S						%
		H	63	...	**74**	...	88	%
EMC(21 °C/65%)		S						%
		H			**13**			%

Dimensional stability

No. of test trees / samples: Sapwood (S) / ; Heartwood (H) 3/6.

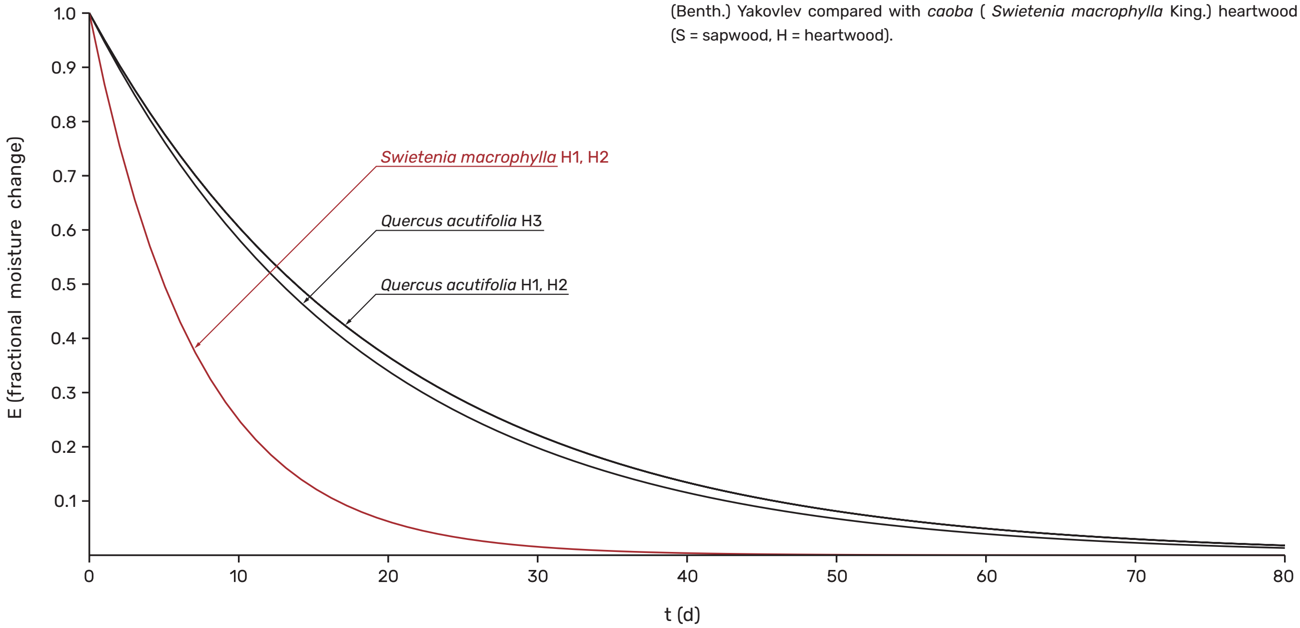
Density	ρ_0	S		...		...		kg / m³	
		H	831	...	**857**	...	882	kg / m³	
Differential swelling and anisotropy	q_{tang}	S		...		...		% / %	
	q_{tang}	H	0.51	...	**0.52**	...	0.54	% / %	unfavourable
	q_{rad}	S		...		...		% / %	
	q_{rad}	H	0.19	...	**0.21**	...	0.23	% / %	
	q_{tang} / q_{rad}	S		...		...			
	q_{tang} / q_{rad}	H	2.32	...	**2.46**	...	2.74		unfavourable
	$q_{tang} - q_{rad}$	S		...		...		% / %	
	$q_{tang} - q_{rad}$	H	0.29	...	**0.31**	...	0.33	% / %	unfavourable
Swelling coefficient and anisotropy	h_{tang}	S		...		...		% / %	
	h_{tang}	H	0.076	...	**0.078**	...	0.081	% / %	unfavourable
	h_{rad}	S		...		...		% / %	
	h_{rad}	H	0.028	...	**0.032**	...	0.035	% / %	
	h_{tang} / h_{rad}	S		...		...			
	h_{tang} / h_{rad}	H	2.31	...	**2.46**	...	2.71		unfavourable
	$h_{tang} - h_{rad}$	S		...		...		% / %	
	$h_{tang} - h_{rad}$	H	0.045	...	**0.046**	...	0.048	% / %	unfavourable
Sorption coefficient	S	S		...		...		% / %	
	S	H	0.15	...	**0.15**	...	0.15	% / %	favourable

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	857
	Seasoning time	days	–
	Initial moisture content	%	55
	Final moisture content	%	18
	Checking		106
	Warping		6
	Seasoning degrade		2-3
	$t_{eq0.5}$ days	H1, h2:14, H3:13	9
	t_{eq} days	H1, H2:77, H3:73	76
Recommended drying schedule	Drying gradient		1.5
	T_1	°C	30
	T_2	°C	50

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

29. *Quercus acutifolia* Née



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
Sapwood					
Heartwood	101/1H	879	4.1	0.46	0.004
	101/2H	845	3.7	0.18	0.001
	101/3H	874	4.0	0.28	0.003

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			3 / 5	3 / 5
Weight loss	average	%	7	20
	minimum	%	1	1
	maximum	%	16	37
Resistance to decay			very resistant	resistant
Proportion of samples in each class	1	%	80	20
	2	%	20	40
	3	%	0	40
	4	%	0	0

Mechanical properties in green condition

Number of test trees				3	
Basic density ρ_b			kg/m³	690	high
	Stress at proportional limit		MPa	42.2	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	81.8	high
	Stiffness	Modulus of elasticity	GPa	15.3	high
Compression	Maximal compression strength parallel to grain		MPa	37.5	high
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	30.2	medium
		Rad.	kN	6.80	very high
Janka hardness	Resistance to identation	Tang.	kN	6.67	very high
		End	kN	6.01	high

Machining and related properties

Number of test trees				1
Number of test samples				10
Moisture content	Min - max		%	13.5 - 15.5
Planing	Defect free samples		%	90

		Angle		
		30°	20°	15°
Speed	7.6 m/min	90	90	-
	13.1 m/min	50	80	-

Shaping	Good to excellent samples	%	100
Turning	Fair to excellent samples	%	100
Nailing	Samples free from complete splits	%	15
Screwing	Samples free from complete splits	%	75

Slicing, sliced veneer - Assessment of relevant properties

Heating temperature	80-90 °C
Flich degrade due to thermal treatment	light
Ease of cutting	difficult to cut
Drying degrade	some/little wrinkling and checking to pronounced tendency to checking and wrinkling
Finishing quality	good

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

	not tested
Heating temperature	
Log degrade due to hydrothermal treatment	
Ease of peeling	
Gluing	
Mechanical properties of plywood	

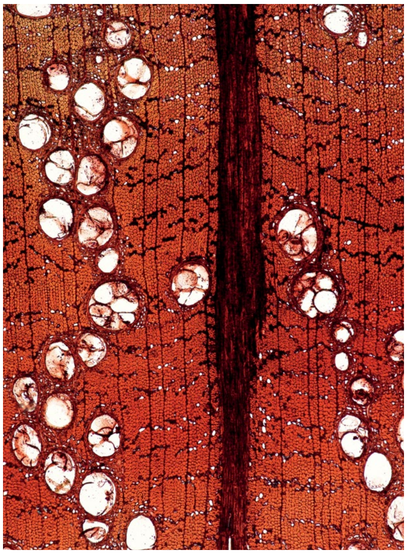
Quercus skinneri Benth.

sin.: **/**

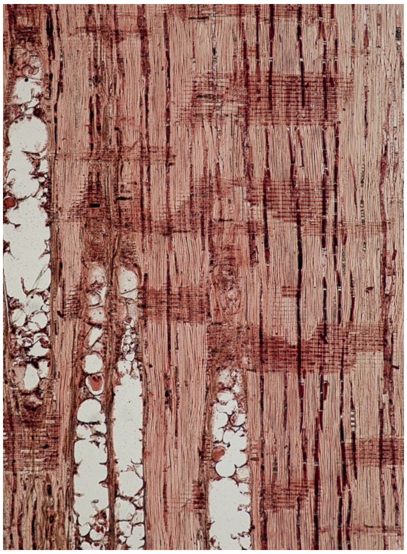
Fagaceae | Common name: **cololté** | Lacandon name: **pixan k'ambul (äh)**

Use: interior construction, exterior construction, furniture, decorative sliced veneer, flooring, rail sleepers, hydraulic works

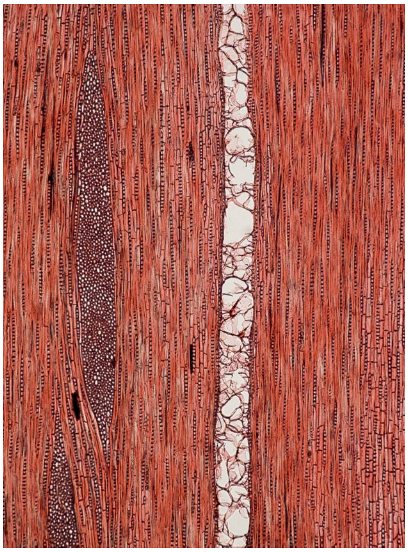
Radial section in actual size.
Upper half of the sample sanded and unfinished, the lower half oil finish.



cross section



radial section



tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 45 m		
Diameter	up to 100 cm		
Bole	Regular, up to 30m		
Heartwood and sapwood (Munsell color chart)	heartwood clealy demarcated from sapwood		
Condition	Sapwood	Heartwood	
Green	2.5 Y HUE / 2.5 Y 8.5/6	5 R HUE / 5 R 3/2	
Air dried	2.5 Y HUE / 2.5 Y 8.5/2	7.5 YR HUE / 7.5 YR 6/4	7.5 YR HUE / 7.5 YR 44
Grain	straight		
Texture	medium to coarse		

Moisture content and density

No. of test trees / samples: Sapwood (S) 0/0 ; Heartwood (H) 3/6.

Density	ρ_0	S						
		H	1016	...	**1060**	...	1143	kg/m³
Moisture content (MC) green		S						
		H	52	...	**56**	...	63	%
EMC(21 °C/65%)		S						
		H			**14**			%

Dimensional stability

No. of test trees / samples: Sapwood (S) / ; Heartwood (H) 3/6.

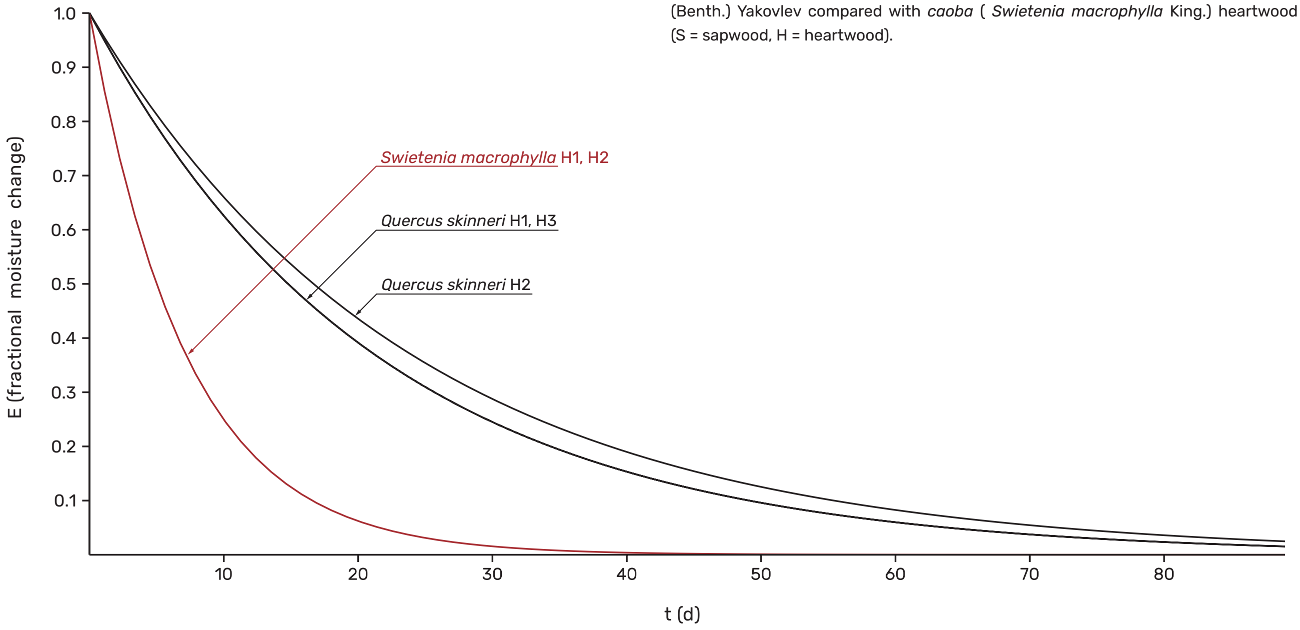
Density	ρ_0	S		...		...		kg / m³	
		H	1016	...	**1060**	...	1143	kg / m³	
Differential swelling and anisotropy	q_{tang}	S		...		...		% / %	
	q_{tang}	H	0.52	...	**0.55**	...	0.57	% / %	unfavourable
	q_{rad}	S		...		...		% / %	
	q_{rad}	H	0.31	...	**0.33**	...	0.35	% / %	
	q_{tang} / q_{rad}	S		...		...			
	q_{tang} / q_{rad}	H	1.58	...	**1.69**	...	1.78		normal
	$q_{tang} - q_{rad}$	S		...		...		% / %	
	$q_{tang} - q_{rad}$	H	0.20	...	**0.23**	...	0.25	% / %	unfavourable
Swelling coefficient and anisotropy	h_{tang}	S		...		...		% / %	
	h_{tang}	H	0.075	...	**0.080**	...	0.083	% / %	unfavourable
	h_{rad}	S		...		...		% / %	
	h_{rad}	H	0.045	...	**0.047**	...	0.049	% / %	
	h_{tang} / h_{rad}	S		...		...			
	h_{tang} / h_{rad}	H	1.58	...	**1.70**	...	1.80		normal
	$h_{tang} - h_{rad}$	S		...		...		% / %	
	$h_{tang} - h_{rad}$	H	0.028	...	**0.033**	...	0.036	% / %	normal
Sorption coefficient	S	S		...		...		% / %	
	S	H	0.14	...	**0.15**	...	0.15	% / %	favourable

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	1060
	Seasoning time	days	210
	Initial moisture content	%	71
	Final moisture content	%	19
	Checking		174
	Warping		1
	Seasoning degrade		2
	$t_{eq0.5}$ days	H1:15, H2:17, H3: 15	9
	t_{eq} days	H1:82, H2:89, H3:82	84
Recommended drying schedule	Drying gradient		1.5
	T_1	°C	30
	T_2	°C	50

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

30. *Quercus skinneri* Benth.



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density ρ_0 kg/m3	pH - value	Ash content %	Silica content %
Sapwood					
Heartwood	31/1H	1046	4.7	0.52	0.002
	31/2H	1173	3.9	0.47	0.003
	31/3H	1011	4.3	0.37	0.002

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			3 / 5	3 / 5
Weight loss	average	%	1	3
	minimum	%	0	1
	maximum	%	1	9
Resistance to decay			very resistant	very resistant
Proportion of samples in each class	1	%	100	100
	2	%	0	0
	3	%	0	0
	4	%	0	0

Mechanical properties in green condition

Number of test trees				3	
Basic density ρ_b			kg/m³	820	very high
	Stress at proportional limit		MPa	54.0	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	107.0	high
	Stiffness	Modulus of elasticity	GPa	17.0	very high
Compression	Maximal compression strength parallel to grain		MPa	49.0	high
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	47.1	very high
		Rad.	kN	8.48	very high
Janka hardness	Resistance to identation	Tang.	kN	7.53	very high
		End	kN	7.89	very high

Machining and related properties

Number of test trees					1
Number of test samples					10
Moisture content	Min - max			%	15.0 - 15.5
Planing	Defect free samples			%	100
		Angle			
		30°	20°		15°
Speed	7.6 m/min	100	100		-
	13.1 m/min	90	100		-
Shaping	Good to excellent samples			%	100
Turning	Fair to excellent samples			%	90
Nailing	Samples free from complete splits			%	30
Screwing	Samples free from complete splits			%	45

Slicing, sliced veneer - Assessment of relevant properties

Heating temperature	80-90 °C
Flich degrade due to thermal treatment	light
Ease of cutting	moderately easy to cut
Drying degrade	some/little wrinkling and checking
Finishing quality	good

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

	not tested
Heating temperature	
Log degrade due to hydrothermal treatment	
Ease of peeling	
Gluing	
Mechanical properties of plywood	

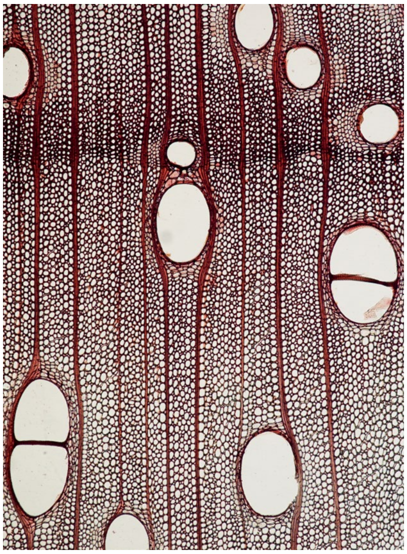
Schizolobium parahyba (Vell.) S.F.Blake

sin.: ***Schizolobium parahybum* (Vell.) Blake**

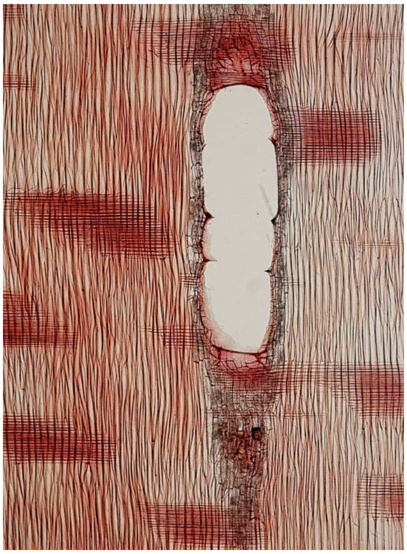
Fabaceae | Common name: **palo de picho** | Lacandon name: **pets'k'in**

Use: peeled veneer, packaging, cellulose products, paper pulp, particle board, core and crossband veneer, possibly for framework

Radial section in actual size.
Upper half of the sample sanded and unfinished,
the lower half oil finish.



cross section



radial section

tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 35 m
Diameter	up to 100 cm
Bole	straight with small buttresses, up to 25m
Heartwood and sapwood (Munsell color chart)	colored heartwood absent

Condition	Sapwood	Heartwood
Green	5 Y HUE / 5 Y 9/2	
Air dried	5 Y HUE / 5 Y 9/2	

Grain	Shallowly to steeply interlocked
Texture	coarse

Moisture content and density

No. of test trees / samples: Sapwood (S) 3/6 ; Heartwood (H) 0/0.

Density	ρ_0	S	276	...	**317**	...	347	kg/m³
		H						
Moisture content (MC) green		S	122	...	**161**	...	184	%
		H						
EMC(21 °C/65%)		S			**13**			%
		H						
Seasoning shrinkage Green –> EMC(21 °C/65%)	$\beta_{tang\ N}$	S	3.16	...	**3.43**	...	3.76	%
	$\beta_{tang\ N}$	H						
	$\beta_{rad\ N}$	S	0.70	...	**0.93**	...	1.14	%
	$\beta_{rad\ N}$	H						
	$\beta_{tang\ N}/\beta_{rad\ N}$	S			**3.69**			
	$\beta_{tang\ N}/\beta_{rad\ N}$	H						

Dimensional stability

No. of test trees / samples: Sapwood (S) 3/6 ; Heartwood (H) 0/0.

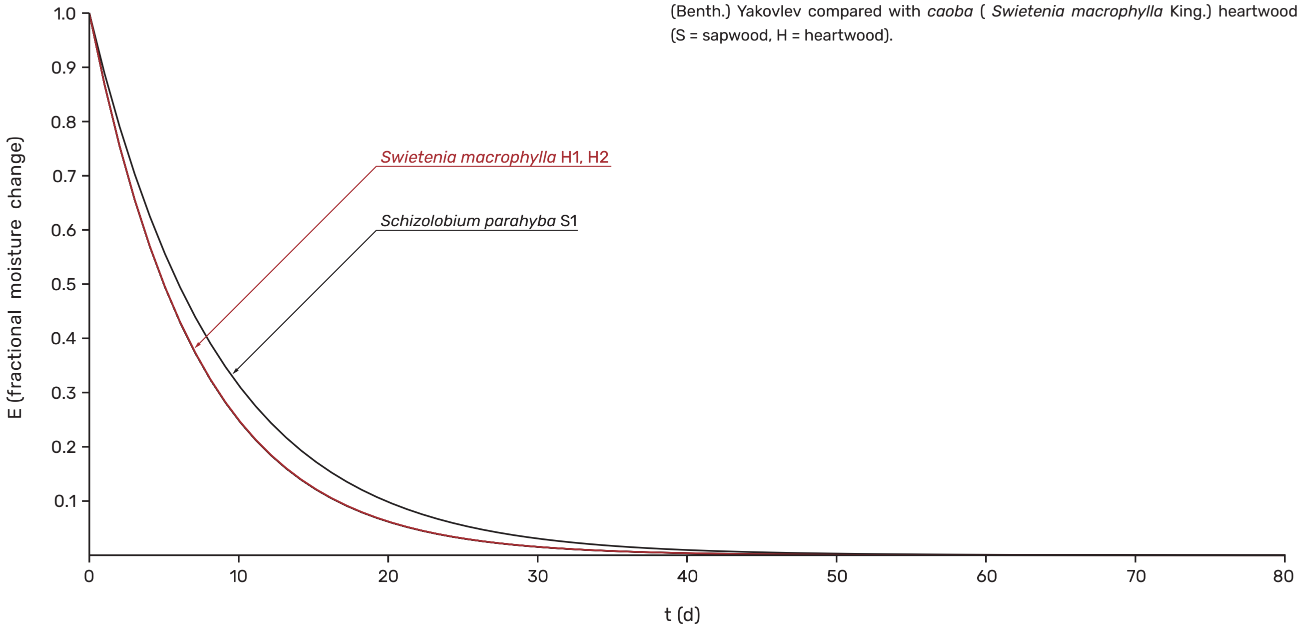
Density	ρ_0	S	276	...	**317**	...	347	kg / m³	
		H		...		...		kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.23	...	**0.24**	...	0.26	% / %	favourable
	q_{tang}	H		...		...		% / %	
	q_{rad}	S	0.08	...	**0.09**	...	0.10	% / %	
	q_{rad}	H		...		...		% / %	
	q_{tang}/q_{rad}	S	2.10	...	**2.70**	...	3.25		unfavourable
	q_{tang}/q_{rad}	H		...		...			
	$q_{tang}-q_{rad}$	S	0.13	...	**0.15**	...	0.18	% / %	normal
	$q_{tang}-q_{rad}$	H		...		...		% / %	
Swelling coefficient and anisotropy	h_{tang}	S	0.037	...	**0.039**	...	0.042	% / %	favourable
	h_{tang}	H		...		...		% / %	
	h_{rad}	S	0.012	...	**0.014**	...	0.016	% / %	
	h_{rad}	H		...		...		% / %	
	h_{tang}/h_{rad}	S	2.38	...	**2.83**	...	3.50		unfavourable
	h_{tang}/h_{rad}	H		...		...			
	$h_{tang}-h_{rad}$	S	0.022	...	**0.025**	...	0.030	% / %	normal
	$h_{tang}-h_{rad}$	H		...		...		% / %	
Sorption coefficient	S	S	0.15	...	**0.16**	...	0.16	% / %	normal
	S	H		...		...		% / %	

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	317
	Seasoning time	days	84
	Initial moisture content	%	80
	Final moisture content	%	19
	Checking		89
	Warping		1
	Seasoning degrade		1
	$t_{eq0.5}$ days	S1:6	5
	t_{eq} days	S1:39	35
Recommended drying schedule	Drying gradient		2.6
	T_1	°C	70
	T_2	°C	90

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

31. *Schizolobium parahyba* (Vell.) S.F.Blake



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
Sapwood	32/1S	267	5.2	0.52	0.001
	32/2S	333	5.0	0.43	0.002
	32/3S	317	5.1	0.75	0.002
Heartwood					

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			3 / 5	3 / 5
Weight loss	average	%	61	50
	minimum	%	53	26
	maximum	%	69	36
Resistance to decay			non-resistant	non-resistant
Proportion of samples in each class	1	%	0	0
	2	%	0	0
	3	%	0	20
	4	%	100	80

Mechanical properties in green condition

Number of test trees				3	
Basic density ρ_b			kg/m³	300	low
	Stress at propor-tional limit		MPa	18.3	
Static ben-ding-centre loading	Maximum bending strength	Modulus of rupture	MPa	36.1	low
	Stiffness	Modulus of elasticity	GPa	6.1	very low
Compression	Maximal compression strength parallel to grain		MPa	15.2	low
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	14.9	very low
		Rad.	kN	1.45	very low
Janka hardness	Resistance to identation	Tang.	kN	1.52	very low
		End	kN	1.82	very low

Machining and related properties

Number of test trees				1
Number of test samples				10
Moisture content	Min - max		%	12.5 - 13.5
Planing	Defect free samples		%	80

		Angle		
		30°	20°	15°
Speed	7.6 m/min	80	0	-
	13.1 m/min	70	10	-

Shaping	Good to excellent samples	%	0
Turning	Fair to excellent samples	%	20
Nailing	Samples free from complete splits	%	95
Screwing	Samples free from complete splits	%	100

Slicing, sliced veneer - Assessment of relevant properties

not tested
Heating temperature
Flich degrade due to thermal treatment
Ease of cutting
Drying degrade
Finishing quality

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

Heating temperature	as low as possible
Log degrade due to hydrothermal treatment	light
Ease of peeling	easy to moderately easy to peel
Gluing	good
Mechanical properties of plywood	satisfactory

Sebastiania tuerckheimiana (Pax & K.Hoffm.) Lundell

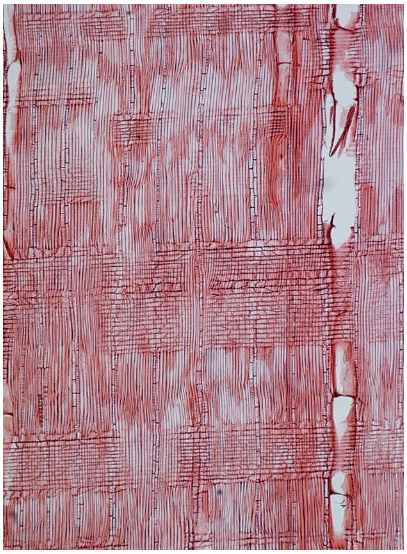
sin.: ***Sebastiania longicuspis* Standl.**

Euphorbiaceae | Common name: **chechen blanco** | Lacandon name: **/**

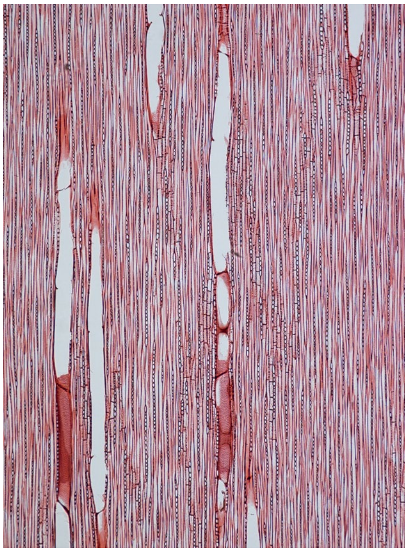
Use: interior construction, framework, particle board, interior coverings, possibly for furniture

Radial section in actual size.
Upper half of the sample sanded and unfinished,
the lower half oil finish.

cross section



radial section



tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 25 m	
Diameter	up to 50 cm	
Bole	Up to 17m, regular	
Heartwood and sapwood (Munsell color chart)	no colored heartwood	
Condition	Sapwood	Heartwood
Green	5 YR HUE / 5 YR 8/4	
Air dried	7.5 YR HUE / 7.5 YR 9/2	
Grain	straight	
Texture	Medium to fine	

Moisture content and density

No. of test trees / samples: Sapwood (S) 3/6 ; Heartwood (H) 0/0.

Density	ρ_0	S	588	...	**607**	...	626	kg/m³
		H						
Moisture content (MC) green		S	50	...	**59**	...	64	%
		H						
EMC(21 °C/65%)		S			**14**			%
		H						

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

Dimensional stability

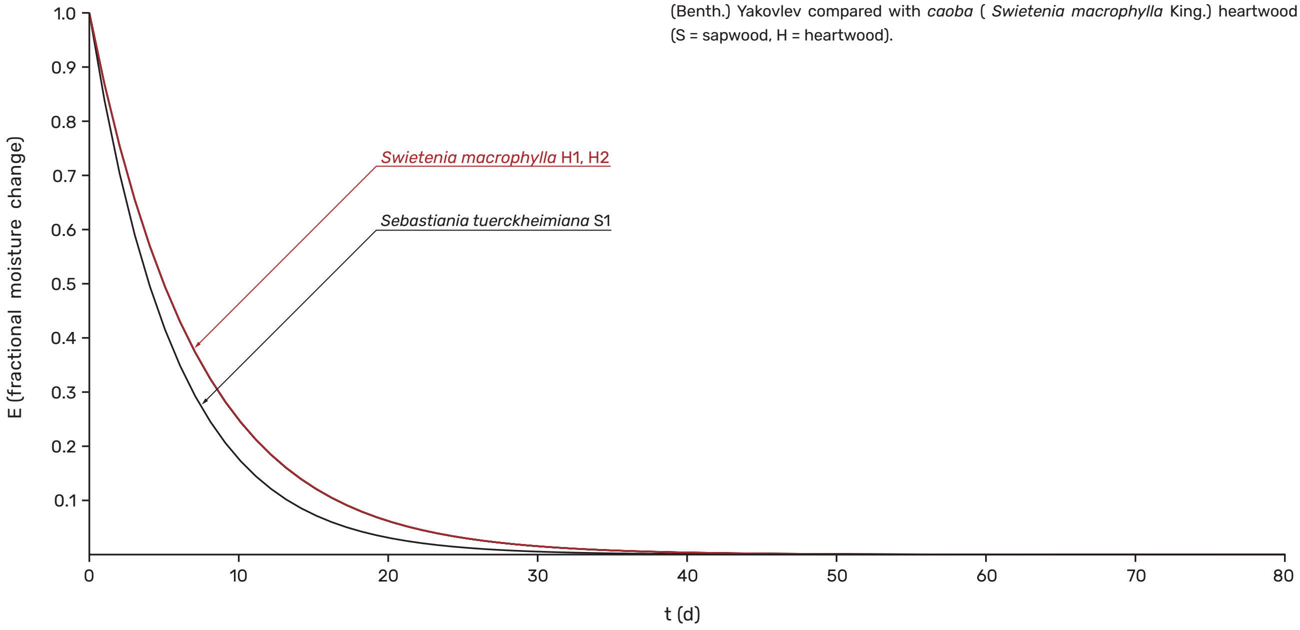
No. of test trees / samples: Sapwood (S) 3/6 ; Heartwood (H) 0/0.

Density	ρ_0	S	588	...	**607**	...	626	kg / m³	
		H		...		...		kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.29	...	**0.31**	...	0.33	% / %	normal
	q_{tang}	H		...		...		% / %	
	q_{rad}	S	0.14	...	**0.15**	...	0.17	% / %	
	q_{rad}	H		...		...		% / %	
	q_{tang} / q_{rad}	S	1.94	...	**2.05**	...	2.21		unfavourable
	q_{tang} / q_{rad}	H		...		...			
	$q_{tang} - q_{rad}$	S	0.15	...	**0.16**	...	0.17	% / %	normal
	$q_{tang} - q_{rad}$	H		...		...		% / %	
Swelling coefficient and anisotropy	h_{tang}	S	0.047	...	**0.050**	...	0.520	% / %	normal
	h_{tang}	H		...		...		% / %	
	h_{rad}	S	0.022	...	**0.024**	...	0.027	% / %	
	h_{rad}	H		...		...		% / %	
	h_{tang} / h_{rad}	S	1.93	...	**2.05**	...	2.27		unfavourable
	h_{tang} / h_{rad}	H		...		...			
	$h_{tang} - h_{rad}$	S	0.024	...	**0.025**	...	0.028	% / %	normal
	$h_{tang} - h_{rad}$	H		...		...		% / %	
Sorption coefficient	s	S	0.16	...	**0.16**	...	0.16	% / %	normal
	s	H		...		...		% / %	

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	607
	Seasoning time	days	91
	Initial moisture content	%	59
	Final moisture content	%	19
	Checking		4
	Warping		1
	Seasoning degrade		1
	$t_{eq0.5}$ days	S1:4	5
	t_{eq} days	S1:30	32
Recommended drying schedule	Drying gradient		3.1
	T_1	°C	70
	T_2	°C	90

32. *Sebastiania tuerckheimiana* (Pax & K.Hoffm.) Lundell



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density ρ_0 kg/m3	pH - value	Ash content %	Silica content %
Sapwood	48/1S	583	5.4	0.60	0.0008
	48/2S	607	5.2	0.51	0.0004
	48/3S	620	5.3	0.52	0.0003
Heartwood					

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			3 / 5	3 / 5
Weight loss	average	%	46	46
	minimum	%	7	40
	maximum	%	70	49
Resistance to decay			non-resistant	non-resistant
Proportion of samples in each class	1	%	20	0
	2	%	0	0
	3	%	20	20
	4	%	60	80

Mechanical properties in green condition

Number of test trees				1	
Basic density ρ_b			kg/m³	570	high
	Stress at proportional limit		MPa	36.4	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	81.2	high
	Stiffness	Modulus of elasticity	GPa	12.2	high
Compression	Maximal compression strength parallel to grain		MPa	33.3	medium
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	27.5	medium
		Rad.	kN	3.61	medium
Janka hardness	Resistance to identation	Tang.	kN	3.73	medium
		End	kN	4.25	medium

Machining and related properties

Number of test trees				1
Number of test samples				10
Moisture content	Min - max		%	14.5 - 18.5
Planing	Defect free samples		%	90

		Angle		
		30°	20°	15°
Speed	7.6 m/min	90	70	-
	13.1 m/min	70	60	-

Shaping	Good to excellent samples	%	100
Turning	Fair to excellent samples	%	100
Nailing	Samples free from complete splits	%	10
Screwing	Samples free from complete splits	%	65

Slicing, sliced veneer - Assessment of relevant properties

not tested
Heating temperature
Flich degrade due to thermal treatment
Ease of cutting
Drying degrade
Finishing quality

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

not tested
Heating temperature
Log degrade due to hydrothermal treatment
Ease of peeling
Gluing
Mechanical properties of plywood

Sideroxylon stevensonii (Standl.) Standl. & Steyerm.

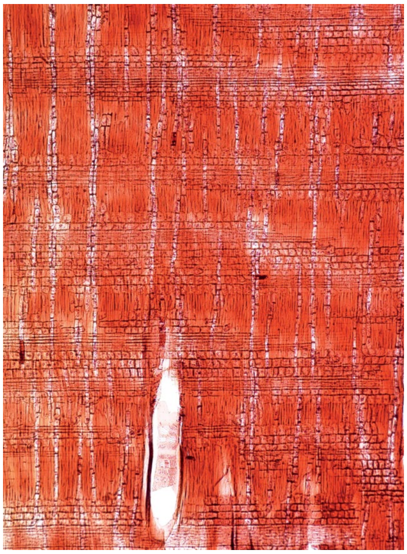
sin.: ***Dipholis stevensonii* Standl.**

Sapotaceae | Common name: **guaité** | Lacandon name: **subul**

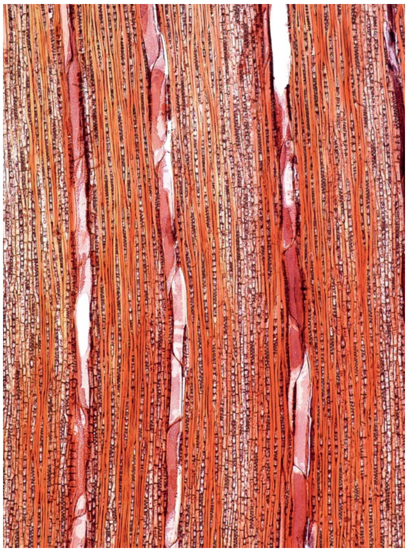
Use: interior construction, exterior construction, furniture, decorative sliced veneer, rail sleepers, hydraulic works, framework

Radial section in actual size.
Upper half of the sample sanded and unfinished,
the lower half oil finish.

cross section



radial section



tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 50 m	
Diameter	up to 70 cm	
Bole	Up to 30m, regular	
Heartwood and sapwood (Munsell color chart)	colored heartwood	
Condition	Sapwood	Heartwood
Green	5 YR HUE / 5 YR 8/4	7.5 R HUE / 7.5 R 7/6
Air dried	7.5 YR HUE / 7.5 YR 9/2	2.5 YR HUE / 2.5 YR 6/6
Grain	straight	
Texture	fine	

Moisture content and density

No. of test trees / samples: Sapwood (S) 1/2 ; Heartwood (H) 2/4.

Density	ρ_0	S	968	...	**969**	...	970	kg/m³
		H	904	...	**938**	...	972	kg/m³
Moisture content (MC) green		S	45	...	**46**	...	46	%
		H	49	...	**54**	...	58	%
EMC(21 °C/65%)		S			**13**			%
		H			**13**			%

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

Dimensional stability

No. of test trees / samples: Sapwood (S) 1/2 ; Heartwood (H) 2/4.

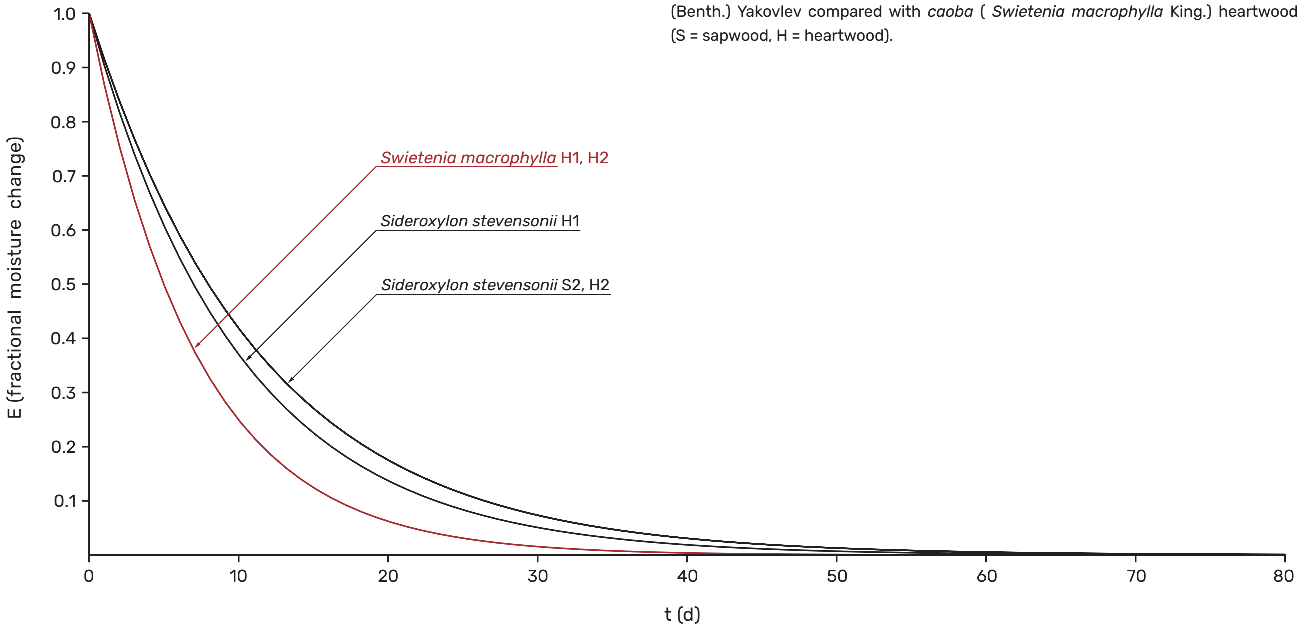
Density	ρ_0	S	968	...	**969**	...	970	kg / m³	
		H	904	...	**938**	...	972	kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.47	...	**0.47**	...	0.47	% / %	unfavourable
	q_{tang}	H	0.45	...	**0.47**	...	0.49	% / %	unfavourable
	q_{rad}	S	0.25	...	**0.25**	...	0.25	% / %	
	q_{rad}	H	0.29	...	**0.29**	...	0.30	% / %	
	q_{tang} / q_{rad}	S	1.88	...	**1.88**	...	1.88		normal
	q_{tang} / q_{rad}	H	1.50	...	**1.61**	...	1.69		normal
	$q_{tang} - q_{rad}$	S	0.22	...	**0.22**	...	0.22	% / %	unfavourable
	$q_{tang} - q_{rad}$	H	0.15	...	**0.18**	...	0.20	% / %	normal
Swelling coefficient and anisotropy	h_{tang}	S	0.068	...	**0.069**	...	0.069	% / %	unfavourable
	h_{tang}	H	0.068	...	**0.070**	...	0.073	% / %	unfavourable
	h_{rad}	S	0.036	...	**0.037**	...	0.037	% / %	
	h_{rad}	H	0.042	...	**0.043**	...	0.044	% / %	
	h_{tang} / h_{rad}	S	1.86	...	**1.88**	...	1.89		normal
	h_{tang} / h_{rad}	H	1.55	...	**1.64**	...	1.71		normal
	$h_{tang} - h_{rad}$	S	0.032	...	**0.032**	...	0.032	% / %	normal
	$h_{tang} - h_{rad}$	H	0.024	...	**0.028**	...	0.031	% / %	normal
Sorption coefficient	s	S	0.15	...	**0.15**	...	0.15	% / %	favourable
	s	H	0.15	...	**0.15**	...	0.15	% / %	favourable

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	938
	Seasoning time	days	154
	Initial moisture content	%	55
	Final moisture content	%	19
	Checking		27
	Warping		8
	Seasoning degrade		2
	$t_{eq0.5}$ days	S2:8, H1:7, H2:8	8
	t_{eq} days	S2:51, H1:48, H2:52	51
Recommended drying schedule	Drying gradient		1.8
	T_1	°C	50
	T_2	°C	70

33. *Sideroxylon stevensonii* (Standl.) Standl. & Steyerm.

Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).



pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
Sapwood	100/2S	987			
Heartwood	100/1H	905	5.1	1.00	0.49
	100/2H	980	5.1	0.82	0.68

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			2 / 5	2 / 5
Weight loss	average	%	1	16
	minimum	%	0	7
	maximum	%	2	24
Resistance to decay			very resistant	resistant
Proportion of samples in each class	1	%	100	20
	2	%	0	80
	3	%	0	0
	4	%	0	0

Mechanical properties in green condition

Number of test trees				2	
Basic density ρ_b			kg/m³	800	very high
	Stress at proportional limit		MPa	57.7	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	114.4	very high
	Stiffness	Modulus of elasticity	GPa	17.8	very high
Compression	Maximal compression strength parallel to grain		MPa	48.4	high
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	47.9	very high
		Rad.	kN	7.69	very high
Janka hardness	Resistance to identation	Tang.	kN	7.35	very high
		End	kN	8.04	very high

Machining and related properties

Number of test trees				1
Number of test samples				10
Moisture content	Min - max		%	14.0 - 14.5
Planing	Defect free samples		%	100

		Angle		
		30°	20°	15°
Speed	7.6 m/min	75	100	-
	13.1 m/min	33	58	-

Shaping	Good to excellent samples	%	100
Turning	Fair to excellent samples	%	100
Nailing	Samples free from complete splits	%	0
Screwing	Samples free from complete splits	%	22

Slicing, sliced veneer - Assessment of relevant properties

Heating temperature	80-90 °C
Flich degrade due to thermal treatment	light
Ease of cutting	difficult to cut
Drying degrade	some/little wrinkling and checking
Finishing quality	good

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

	not tested
Heating temperature	
Log degrade due to hydrothermal treatment	
Ease of peeling	
Gluing	
Mechanical properties of plywood	

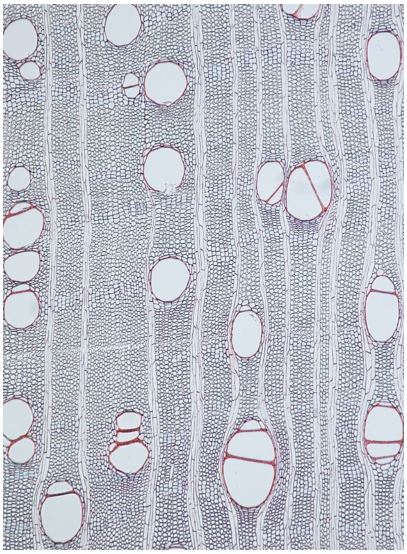
Simarouba glauca DC.

sin.: /

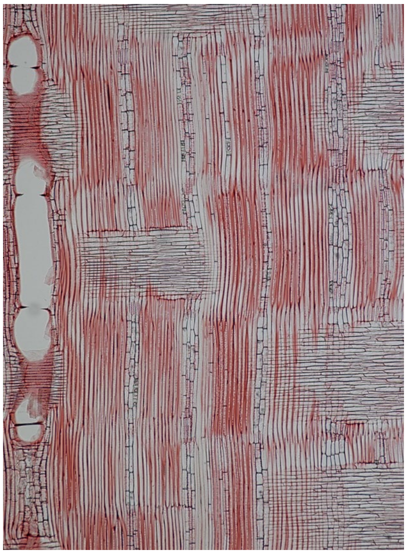
Simaroubaceae | Common name: **pasa'ak** | Lacandon name: /

Use: interior construction, framework, peeled veneer, decorative sliced veneer, packaging, cellulose products, paper pulp, construction plywood, core and crossband veneer, container veneer and plywood, interior coverings, particle board

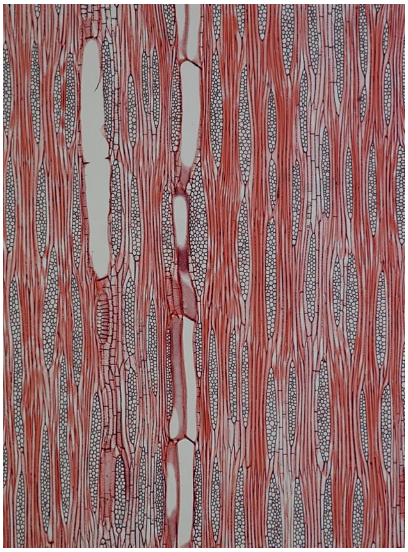
Radial section in actual size.
Upper half of the sample sanded and unfinished,
the lower half oil finish.



cross section



radial section



tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 30 m	
Diameter	up to 50 cm	
Bole	regular clear for 20 m	
Heartwood and sapwood (Munsell color chart)	no colored heartwood	
Condition	Sapwood	Heartwood
Green	2.5 y HUE / 2.5 y 8.5/6	
Air dried	2.5 Y HUE / 2.5 Y 9/2	
Grain	generally straight	
Texture	medium	

Moisture content and density

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 0/0.

Density	ρ_0	S	402	...	**439**	...	474	kg/m³
		H						
Moisture content (MC) green		S	91	...	**98**	...	104	%
		H						
EMC(21 °C/65%)		S			**14**			%
		H						

Dimensional stability

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 0/0.

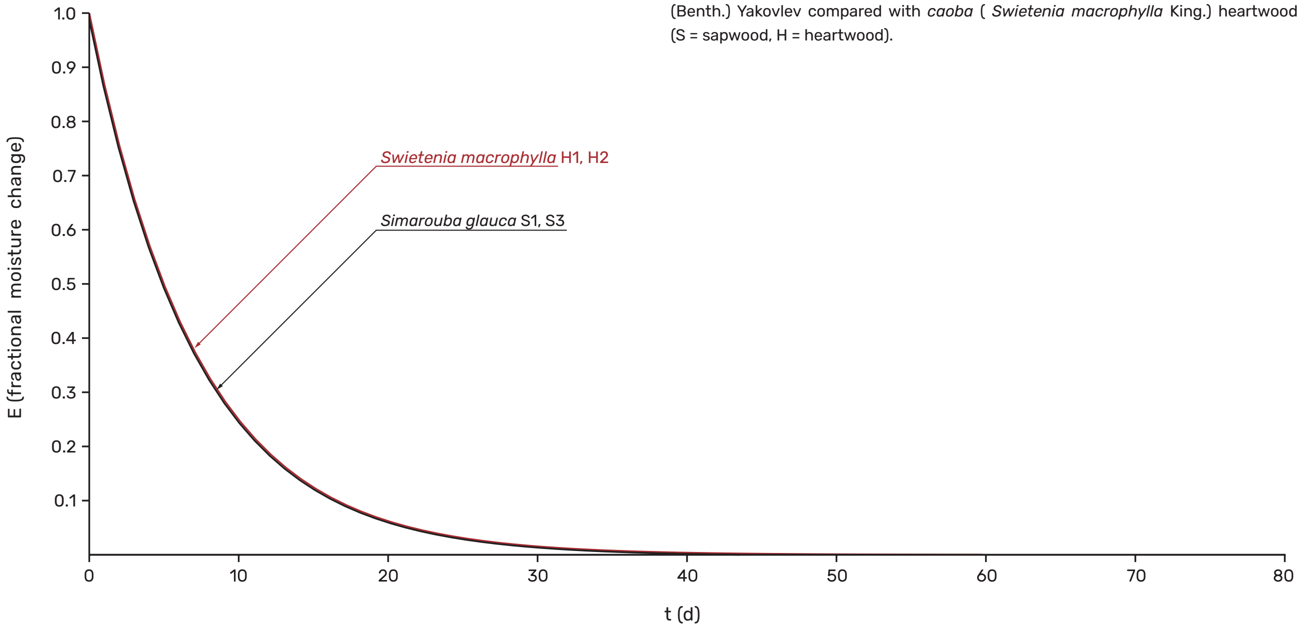
Density	ρ_0	S	402	...	**439**	...	474	kg / m³	
		H		...		...		kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.25	...	**0.27**	...	0.29	% / %	favourable
	q_{tang}	H		...		...		% / %	
	q_{rad}	S	0.12	...	**0.14**	...	0.15	% / %	
	q_{rad}	H		...		...		% / %	
	q_{tang} / q_{rad}	S	1.67	...	**2.02**	...	2.42		unfavourable
	q_{tang} / q_{rad}	H		...		...			
	$q_{tang} - q_{rad}$	S	0.10	...	**0.13**	...	0.17	% / %	normal
	$q_{tang} - q_{rad}$	H		...		...		% / %	
Swelling coefficient and anisotropy	h_{tang}	S	0.042	...	**0.044**	...	0.046	% / %	favourable
	h_{tang}	H		...		...		% / %	
	h_{rad}	S	0.019	...	**0.022**	...	0.025	% / %	
	h_{rad}	H		...		...		% / %	
	h_{tang} / h_{rad}	S	1.72	...	**2.01**	...	2.30		unfavourable
	h_{tang} / h_{rad}	H		...		...			
	$h_{tang} - h_{rad}$	S	0.018	...	**0.022**	...	0.026	% / %	normal
	$h_{tang} - h_{rad}$	H		...		...		% / %	
Sorption coefficient	S	S	0.16	...	**0.17**	...	0.17	% / %	unfavourable
	S	H		...		...		% / %	

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	–
	Seasoning time	days	–
	Initial moisture content	%	–
	Final moisture content	%	–
	Checking		–
	Warping		–
	Seasoning degrade		–
	$t_{eq0.5}$ days	S1, S3:5	–
	t_{eq} days	S1:35, S3:37	–
Recommended drying schedule	Drying gradient		–
	T_1	°C	–
	T_2	°C	–

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

34. *Simarouba glauca* DC.



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density ρ_0 kg/m3	pH - value	Ash content %	Silica content %
Sapwood	35/1S	408	5.5	0.46	0.001
	35/3S	480	5.3	0.42	0.0004
Heartwood					

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			2 / 5	2 / 5
Weight loss	average	%	60	43
	minimum	%	52	37
	maximum	%	68	53
Resistance to decay			non-resistant	moderately resistant
Proportion of samples in each class	1	%	0	0
	2	%	0	0
	3	%	0	60
	4	%	100	40

Mechanical properties in green condition

Number of test trees				2	
Basic density ρ_b			kg/m³	460	medium
	Stress at proportional limit		MPa	24.1	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	49.6	low
	Stiffness	Modulus of elasticity	GPa	7.8	very low
Compression	Maximal compression strength parallel to grain		MPa	20.5	low
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	19.2	low
		Rad.	kN	2.10	very low
Janka hardness	Resistance to identation	Tang.	kN	2.46	low
		End	kN	2.46	low

Machining and related properties

Number of test trees				not tested	
Number of test samples					
Moisture content	Min - max	%	-		
Planing	Defect free samples	%			
		Angle			
		30°	20°	15°	
Speed	7.6 m/min				
	13.1 m/min				
Shaping	Good to excellent samples	%			
Turning	Fair to excellent samples	%			
Nailing	Samples free from complete splits	%			
Screwing	Samples free from complete splits	%			

Slicing, sliced veneer - Assessment of relevant properties

	not tested
Heating temperature	
Flich degrade due to thermal treatment	
Ease of cutting	
Drying degrade	
Finishing quality	

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

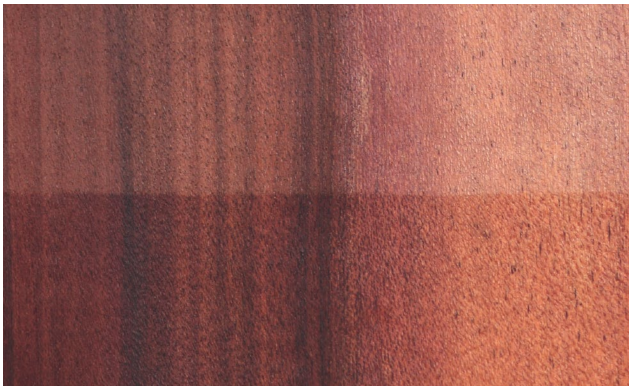
	not tested
Heating temperature	
Log degrade due to hydrothermal treatment	
Ease of peeling	
Gluing	
Mechanical properties of plywood	

Simira salvadorensis (Standl.) Steyerm.

sin.: ***Sickingia salvadorensis* (Standl.) Standl.**

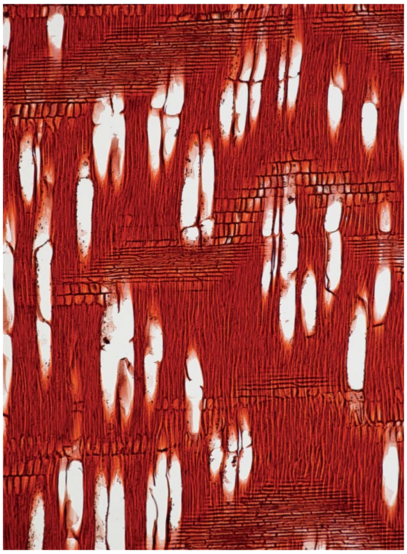
Rubiaceae | Common name: **chacahuanté** | Lacandon name: **/**

Use: interior construction, exterior construction, furniture, decorative sliced veneer, flooring, rail sleepers

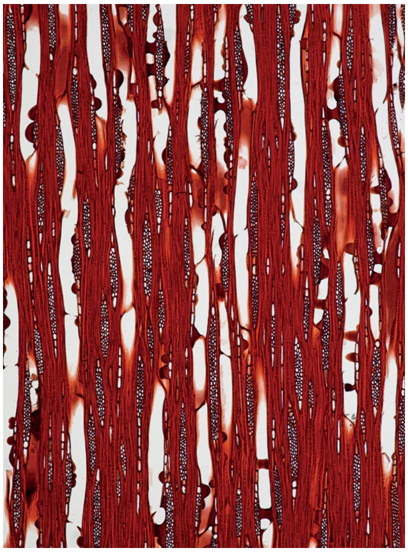


Radial section in actual size.
Upper half of the sample sanded and unfinished, the lower half oil finish.

cross section



radial section



tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 40 m	
Diameter	up to 70 cm	
Bole	Regular, clear for 20 m	
Heartwood and sapwood (Munsell color chart)	heartwood clearly demarcated from sapwood	
Condition	Sapwood	Heartwood
Green	3 R HUE / 3.75 R 6/12	5 R HUE / 5 R 4/10
Air dried	2.5 YR HUE / 2.5 YR 6/4	5 R HUE / 5 R 4/8
Grain	generally straight but bound to be interlocked	
Texture	fine and uniform	

Moisture content and density

No. of test trees / samples: Sapwood (S) 1/2 ; Heartwood (H) 1/2.

Density	ρ_0	S	764	...	**769**	...	773	kg/m³
		H	779	...	**780**	...	780	kg/m³
Moisture content (MC) green		S	56	...	**56**	...	56	%
		H	61	...	**62**	...	62	%
EMC(21 °C/65%)		S			**14**			%
		H			**14**			%

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

Dimensional stability

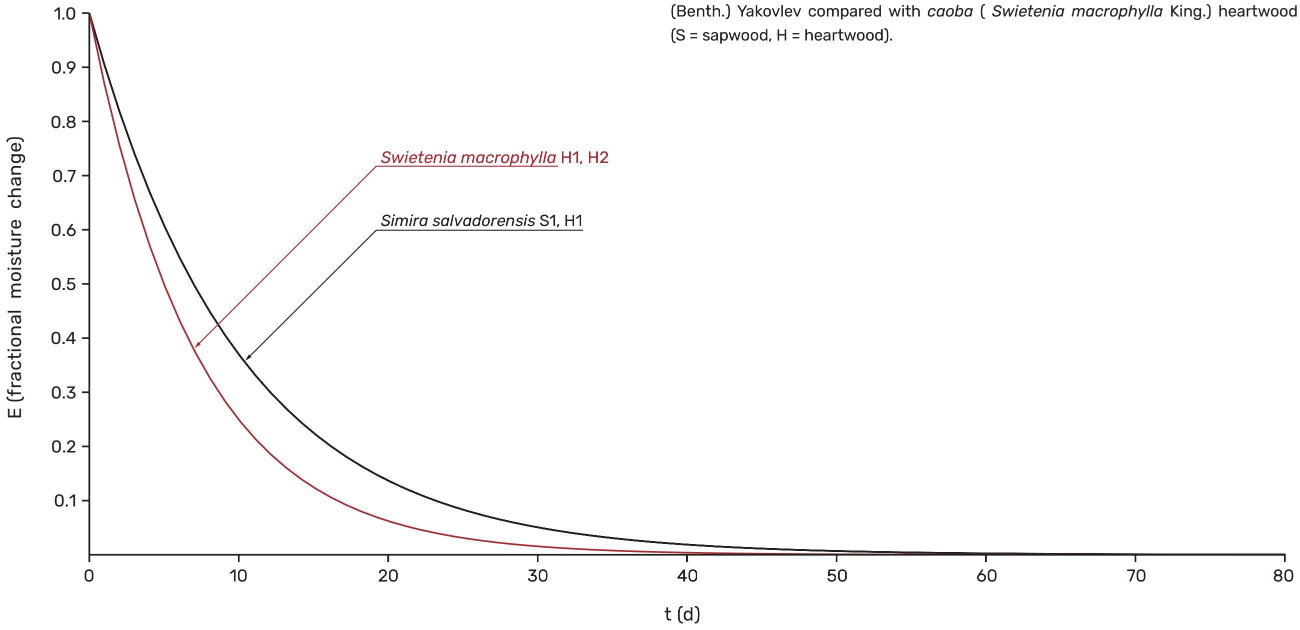
No. of test trees / samples: Sapwood (S) 1/2 ; Heartwood (H) 1/2.

Density	ρ_0	S	764	...	**769**	...	773	kg / m³	
		H	779	...	**780**	...	780	kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.42	...	**0.45**	...	0.47	% / %	unfavourable
	q_{tang}	H	0.42	...	**0.43**	...	0.43	% / %	unfavourable
	q_{rad}	S	0.21	...	**0.22**	...	0.23	% / %	
	q_{rad}	H	0.21	...	**0.22**	...	0.22	% / %	
	q_{tang} / q_{rad}	S	2.00	...	**2.02**	...	2.04		unfavourable
	q_{tang} / q_{rad}	H	1.91	...	**1.98**	...	2.05		normal
	$q_{tang} - q_{rad}$	S	0.21	...	**0.23**	...	0.24	% / %	unfavourable
	$q_{tang} - q_{rad}$	H	0.20	...	**0.21**	...	0.22	% / %	unfavourable
Swelling coefficient and anisotropy	h_{tang}	S	0.065	...	**0.068**	...	0.070	% / %	unfavourable
	h_{tang}	H	0.057	...	**0.058**	...	0.058	% / %	unfavourable
	h_{rad}	S	0.032	...	**0.033**	...	0.034	% / %	
	h_{rad}	H	0.029	...	**0.029**	...	0.029	% / %	
	h_{tang} / h_{rad}	S	2.03	...	**2.05**	...	2.06		unfavourable
	h_{tang} / h_{rad}	H	1.97	...	**2.00**	...	2.03		normal
	$h_{tang} - h_{rad}$	S	0.033	...	**0.035**	...	0.036	% / %	normal
	$h_{tang} - h_{rad}$	H	0.028	...	**0.029**	...	0.030	% / %	normal
Sorption coefficient	S	S	0.15	...	**0.15**	...	0.15	% / %	favourable
	S	H	0.13	...	**0.14**	...	0.14	% / %	favourable

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	780
	Seasoning time	days	154
	Initial moisture content	%	58
	Final moisture content	%	19
	Checking		55
	Warping		3
	Seasoning degrade		1-2
	$t_{eq0.5}$ days	S1, H1:7	7
	t_{eq} days	S1, H1:46	46
Recommended drying schedule	Drying gradient		2.1
	T_1	°C	50
	T_2	°C	70

35. *Simira salvadorensis* (Standl.) Steyerm.



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
Sapwood	33/1S	773	6.3		
Heartwood	33/1H	802	5.9	0.42	0.0003

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			1 / 2	1 / 2
Weight loss	average	%	0	0
	minimum	%	0	0
	maximum	%	0	0
Resistance to decay			very resistant	very resistant
Proportion of samples in each class	1	%	100	100
	2	%	0	0
	3	%	0	0
	4	%	0	0

Mechanical properties in green condition

Number of test trees				1	
Basic density ρ_b			kg/m³	660	high
	Stress at proportional limit		MPa	39.7	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	82.4	high
	Stiffness	Modulus of elasticity	GPa	11.9	medium
Compression	Maximal compression strength parallel to grain		MPa	43.3	high
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	35.7	high
		Rad.	kN	5.96	high
Janka hardness	Resistance to identation	Tang.	kN	4.93	high
		End	kN	6.37	high

Machining and related properties

Number of test trees					1
Number of test samples					10
Moisture content	Min - max			%	15.0 - 16.5
Planing	Defect free samples			%	100
		Angle			
		30°	20°		15°
Speed	7.6 m/min	100	100		100
	13.1 m/min	80	90		-
Shaping	Good to excellent samples			%	100
Turning	Fair to excellent samples			%	100
Nailing	Samples free from complete splits			%	5
Screwing	Samples free from complete splits			%	25

Slicing, sliced veneer - Assessment of relevant properties

Heating temperature	80-90 °C
Flich degrade due to thermal treatment	light
Ease of cutting	easy to cut
Drying degrade	without checking and wrinkling to some/ little wrinkling and checking
Finishing quality	good

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

	not tested
Heating temperature	
Log degrade due to hydrothermal treatment	
Ease of peeling	
Gluing	
Mechanical properties of plywood	

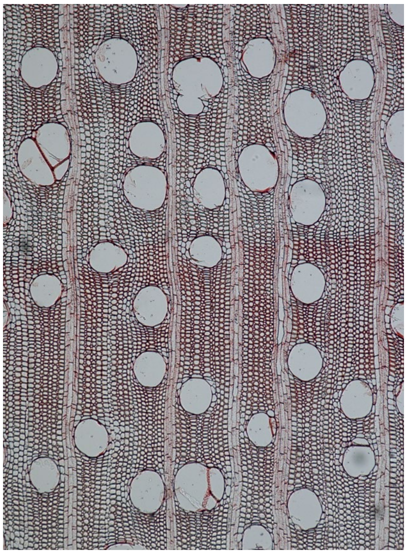
Spondias mombin Jacq.

sin.: ***Spondias mombin* L.**

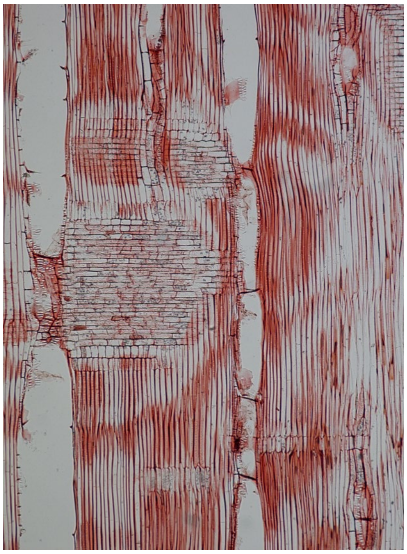
Anacardiaceae | Common name: **jobo** | Lacandon name: **k'inim**

Use: peeled veneer, decorative sliced veneer, packaging, cellulose products, particle board, paper pulp, core and crossband veneer, container veneer and plywood, possibly for interior construction

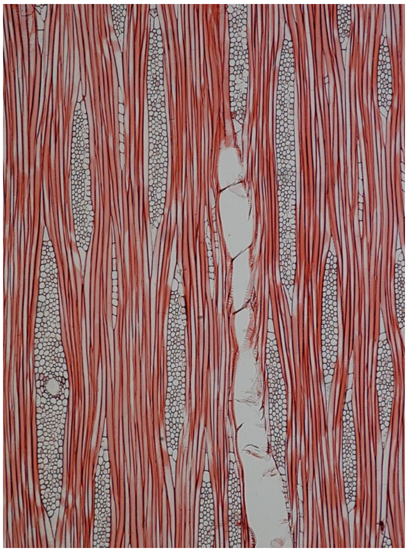
Radial section in actual size.
Upper half of the sample sanded and unfinished, the lower half oil finish.



cross section



radial section



tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 30 m
Diameter	up to 120 cm
Bole	regular clear for 20 m
Heartwood and sapwood (Munsell color chart)	no colored heartwood

Condition	Sapwood	Heartwood
Green	7.5 Y HUE / 7.5 Y 9/4	
Air dried	2.5 Y HUE / 2.5 Y 8.5/2	

Grain	straight
Texture	medium to coarse

Moisture content and density

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 0/0.

Density	ρ_0	S	461	...	**491**	...	519	kg/m³
		H						
Moisture content (MC) green		S	84	...	**89**	...	91	%
		H						
EMC(21 °C/65%)		S			**13**			%
		H						%

Dimensional stability

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 0/0.

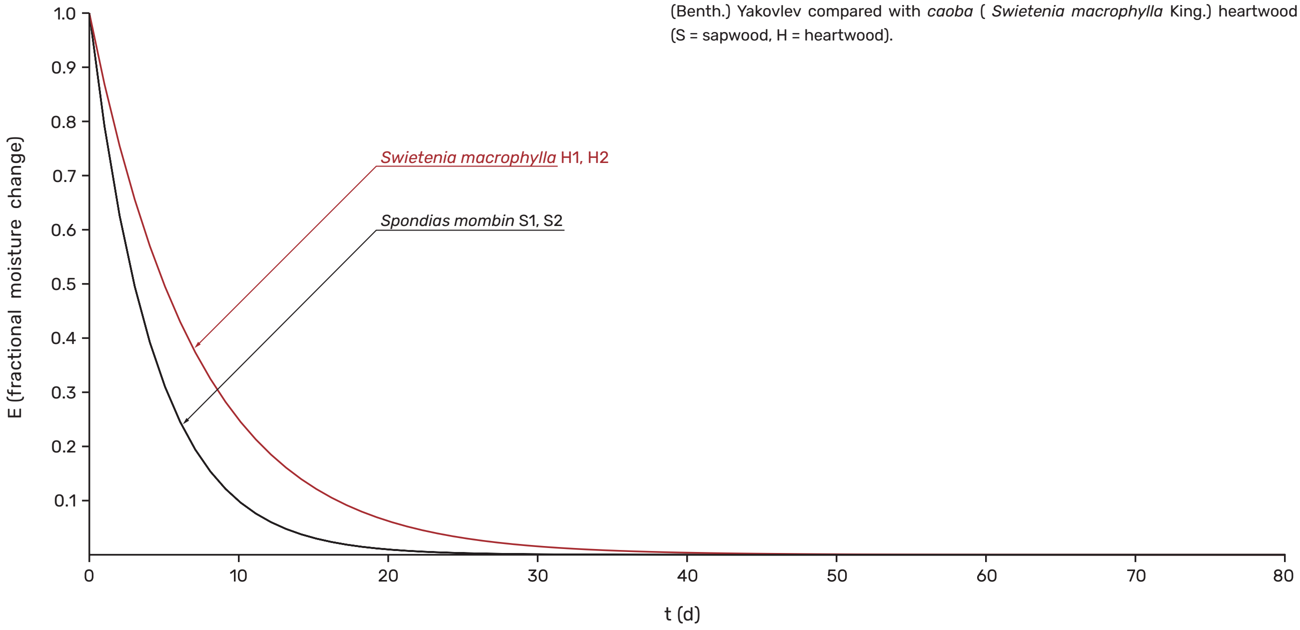
Density	ρ_0	S	461	...	**491**	...	519	kg / m³	
		H		...		...		kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.28	...	**0.28**	...	0.29	% / %	favourable
	q_{tang}	H		...		...		% / %	
	q_{rad}	S	0.14	...	**0.16**	...	0.17	% / %	
	q_{rad}	H		...		...		% / %	
	q_{tang} / q_{rad}	S	1.65	...	**1.84**	...	2.07		normal
	q_{tang} / q_{rad}	H		...		...			
	$q_{tang} - q_{rad}$	S	0.11	...	**0.13**	...	0.15	% / %	normal
	$q_{tang} - q_{rad}$	H		...		...		% / %	
Swelling coefficient and anisotropy	h_{tang}	S	0.045	...	**0.046**	...	0.046	% / %	favourable
	h_{tang}	H		...		...		% / %	
	h_{rad}	S	0.023	...	**0.026**	...	0.028	% / %	
	h_{rad}	H		...		...		% / %	
	h_{tang} / h_{rad}	S	1.61	...	**1.80**	...	2.00		normal
	h_{tang} / h_{rad}	H		...		...			
	$h_{tang} - h_{rad}$	S	0.017	...	**0.020**	...	0.023	% / %	normal
	$h_{tang} - h_{rad}$	H		...		...		% / %	
Sorption coefficient	s	S	0.16	...	**0.16**	...	0.16	% / %	normal
	s	H		...		...		% / %	

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	491
	Seasoning time	days	91
	Initial moisture content	%	90
	Final moisture content	%	19
	Checking		219
	Warping		16
	Seasoning degrade		3-4
	$t_{eq0.5}$ days	S1, S2:3	3
	t_{eq} days	S1:25, S2:24	25
Recommended drying schedule	Drying gradient		2.6
	T_1	°C	50
	T_2	°C	70

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

36. *Spondias mombin* Jacq.



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
	36/1S	511	5.2	0.53	0.0007
Sapwood	36/2S	479	5.6	2.45	0.002
Heartwood					

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			2 / 5	2 / 5
Weight loss	average	%	66	52
	minimum	%	52	44
	maximum	%	77	57
Resistance to decay			non-resistant	non-resistant
Proportion of samples in each class	1	%	0	0
	2	%	0	0
	3	%	0	20
	4	%	100	80

Mechanical properties in green condition

Number of test trees				2	
Basic density ρ_b			kg/m³	450	medium
	Stress at proportional limit		MPa	14.1	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	34.4	low
	Stiffness	Modulus of elasticity	GPa	6.2	very low
Compression	Maximal compression strength parallel to grain		MPa	17.9	low
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	18.4	low
		Rad.	kN	1.39	very low
Janka hardness	Resistance to identation	Tang.	kN	2.03	very low
		End	kN	2.18	very low

Machining and related properties

Number of test trees				1
Number of test samples				9
Moisture content	Min - max		%	11.0 - 12.5
Planing	Defect free samples		%	89

		Angle		
		30°	20°	15°
Speed	7.6 m/min	89	45	-
	13.1 m/min	56	45	-

Shaping	Good to excellent samples	%	0
Turning	Fair to excellent samples	%	0
Nailing	Samples free from complete splits	%	95
Screwing	Samples free from complete splits	%	95

Slicing, sliced veneer - Assessment of relevant properties

	not tested
Heating temperature	
Flich degrade due to thermal treatment	
Ease of cutting	
Drying degrade	
Finishing quality	

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

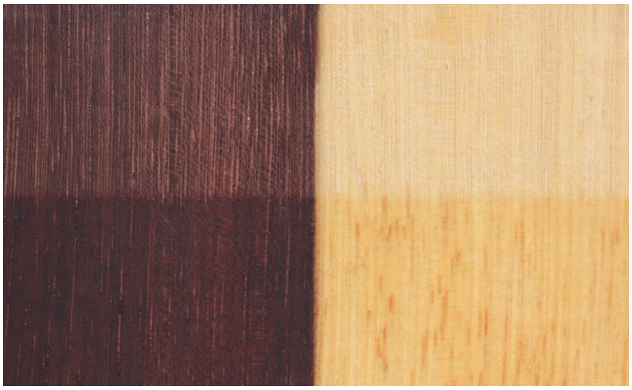
Heating temperature	50-60°C
Log degrade due to hydrothermal treatment	severe
Ease of peeling	
Gluing	
Mechanical properties of plywood	

Swartzia cubensis (Britton & Wilson) Standl.

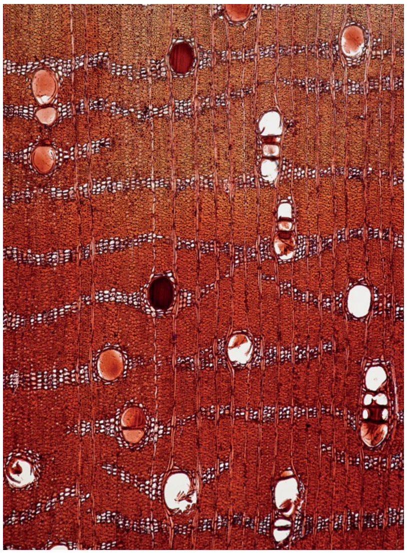
sin.: /

Fabaceae | Common name: **corazón azul** | Lacandon name: /

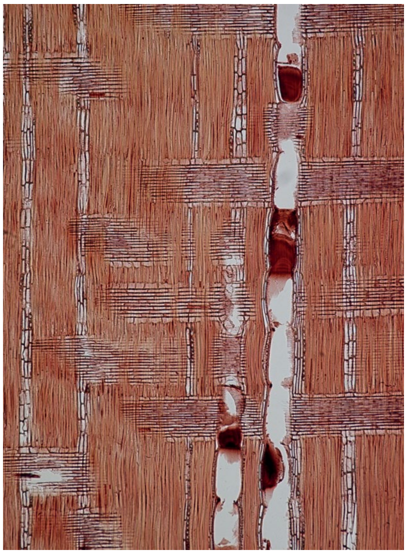
Use: interior construction, exterior construction, furniture, decorative sliced veneer, flooring, rail sleepers, sapwood requires preservative treatment, hydraulic works



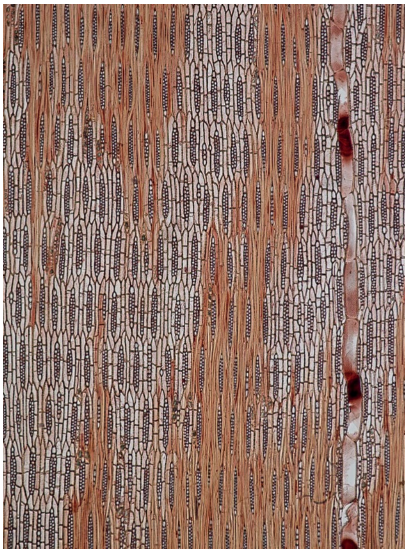
Radial section in actual size.
Upper half of the sample sanded and unfinished,
the lower half oil finish.



cross section



radial section



tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 40 m	
Diameter	up to 150 cm	
Bole	Regular, straight clear for 25 m	
Heartwood and sapwood (Munsell color chart)	heartwood demarcated from sapwood	
Condition	Sapwood	Heartwood
Green	2.5 Y HUE / 2.5 Y 8.5/6	5 R HUE / 5 R 4/6
Air dried	10 YR HUE / 10 YR 8/4	10 R HUE / 10 R 3/4
Grain	Slightly or shallowly and narrowly interlocked	
Texture	medium	

Moisture content and density

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 2/4.

Density	ρ_0	S	926	...	**933**	...	940	kg/m³
		H	1000	...	**1045**	...	1089	kg/m³
Moisture content (MC) green		S	46	...	**46**	...	46	%
		H	46	...	**49**	...	52	%
EMC(21 °C/65%)		S			**14**			%
		H			**13**			%

Dimensional stability

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 2/4.

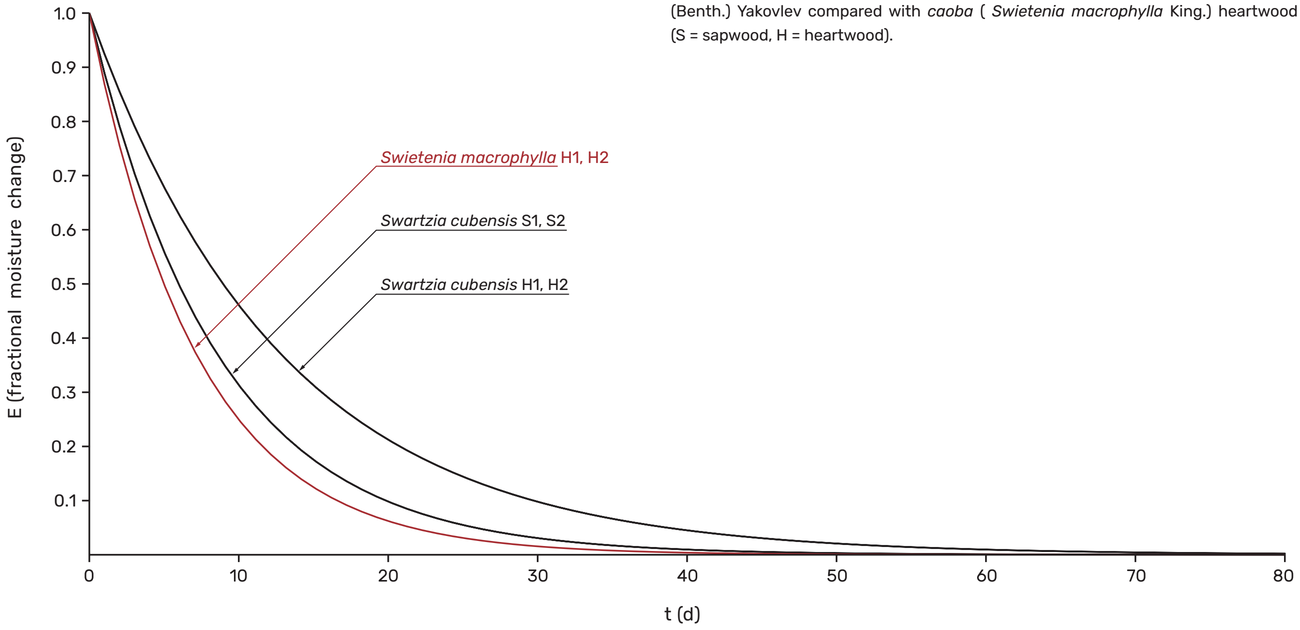
Density	ρ_0	S	926	...	**933**	...	940	kg / m³	
		H	1000	...	**1045**	...	1089	kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.43	...	**0.44**	...	0.45	% / %	unfavourable
	q_{tang}	H	0.45	...	**0.47**	...	0.49	% / %	unfavourable
	q_{rad}	S	0.28	...	**0.29**	...	0.30	% / %	
	q_{rad}	H	0.33	...	**0.36**	...	0.38	% / %	
	q_{tang} / q_{rad}	S	1.47	...	**1.52**	...	1.57		favourable
	q_{tang} / q_{rad}	H	1.26	...	**1.31**	...	1.36		favourable
	$q_{tang} - q_{rad}$	S	0.14	...	**0.15**	...	0.16	% / %	normal
	$q_{tang} - q_{rad}$	H	0.10	...	**0.11**	...	0.12	% / %	favourable
Swelling coefficient and anisotropy	h_{tang}	S	0.068	...	**0.070**	...	0.071	% / %	unfavourable
	h_{tang}	H	0.061	...	**0.063**	...	0.064	% / %	unfavourable
	h_{rad}	S	0.044	...	**0.046**	...	0.048	% / %	
	h_{rad}	H	0.046	...	**0.048**	...	0.050	% / %	
	h_{tang} / h_{rad}	S	1.46	...	**1.51**	...	1.59		favourable
	h_{tang} / h_{rad}	H	1.26	...	**1.31**	...	1.37		favourable
	$h_{tang} - h_{rad}$	S	0.022	...	**0.024**	...	0.026	% / %	normal
	$h_{tang} - h_{rad}$	H	0.013	...	**0.015**	...	0.017	% / %	favourable
Sorption coefficient	s	S	0.16	...	**0.16**	...	0.16	% / %	normal
	s	H	0.13	...	**0.13**	...	0.14	% / %	very favourable

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	1045
	Seasoning time	days	147
	Initial moisture content	%	48
	Final moisture content	%	18
	Checking		62
	Warping		8
	Seasoning degrade		2
	$t_{eq0.5}$ days	S1, S2:6, H1, H2:9	9
	t_{eq} days	S1, S2:39, H1:57, H3:56	57
Recommended drying schedule	Drying gradient		1.8
	T_1	°C	50
	T_2	°C	70

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

37. *Swartzia cubensis* (Britton & Wilson) Standl.



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
Sapwood	37/1S	927	5.2		
	37/2S	954	4.9		
Heartwood	37/1H	1034	5.1	0.54	0.0004
	37/2H	1093	4.9	0.50	0.0002

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			2 / 5	2 / 5
Weight loss	average	%	0	1
	minimum	%	0	1
	maximum	%	0	3
Resistance to decay			very resistant	very resistant
Proportion of samples in each class	1	%	100	100
	2	%	0	0
	3	%	0	0
	4	%	0	0

Mechanical properties in green condition

Number of test trees				2	
Basic density ρ_b			kg/m³	830	very high
	Stress at proportional limit		MPa	68.6	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	132.3	very high
	Stiffness	Modulus of elasticity	GPa	18.0	very high
Compression	Maximal compression strength parallel to grain		MPa	59.0	very high
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	41.6	high
		Rad.	kN	8.00	very high
Janka hardness	Resistance to identation	Tang.	kN	8.56	very high
		End	kN	9.29	very high

Machining and related properties

Number of test trees				1
Number of test samples				10
Moisture content	Min - max		%	12.5 - 13.5
Planing	Defect free samples		%	90

		Angle		
		30°	20°	15°
Speed	7.6 m/min	80	90	-
	13.1 m/min	50	40	-

Shaping	Good to excellent samples	%	100
Turning	Fair to excellent samples	%	100
Nailing	Samples free from complete splits	%	0
Screwing	Samples free from complete splits	%	0

Slicing, sliced veneer - Assessment of relevant properties

Heating temperature	80-90 °C
Flich degrade due to thermal treatment	light
Ease of cutting	difficult to cut
Drying degrade	without checking and wrinkling to some/ little wrinkling and checking
Finishing quality	good

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

	not tested
Heating temperature	
Log degrade due to hydrothermal treatment	
Ease of peeling	
Gluing	
Mechanical properties of plywood	

Swietenia macrophylla G. King

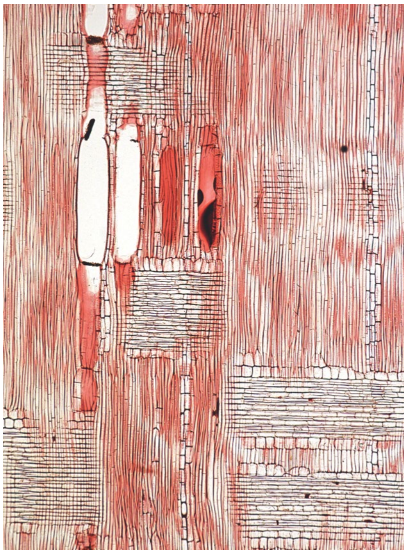
sin.: /

Meliaceae | Common name: **caoba** | Lacandon name: **puuna' (äh)**

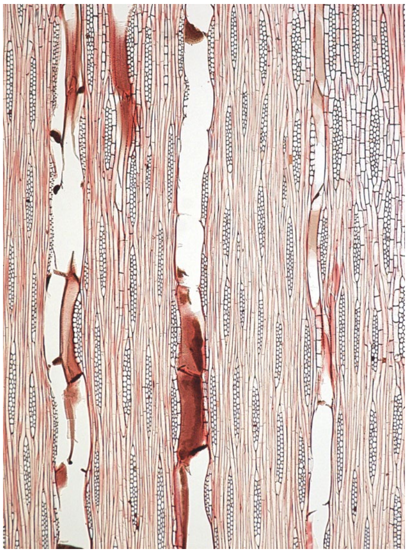
Use: interior construction, framework, furniture, peeled veneer, decorative sliced veneer, packaging, particle board, construction plywood, core and crossband veneer, container veneer and plywood, exterior construction, interior coverings, exterior coverings, paper pulp, boat building

Radial section in actual size.
Upper half of the sample sanded and unfinished, the lower half oil finish.

cross section



radial section



tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 50 m	
Diameter	up to 350 cm	
Bole	Regular, straight clear for 30 m	
Heartwood and sapwood (Munsell color chart)	heartwood clearly demarcated from sapwood	
Condition	Sapwood	Heartwood
Green	5 YR HUE / 5 YR 8/4	10 R HUE / 10 R 7/8
Air dried	2.5 YR HUE / 2.5 YR 8/4	7.5 YR HUE / 7.5 YR 7/6
Grain	mainly straight, but also interlocked, typically shallowly interlocked	
Texture	medium to coarse	

Moisture content and density

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 2/4.

Density	ρ_0	S	398	...	**458**	...	518	kg/m³
		H	358	...	**403**	...	446	kg/m³
Moisture content (MC) green		S	78	...	**80**	...	83	%
		H	71	...	**76**	...	81	%
EMC(21 °C/65%)		S			**14**			%
		H			**15**			%

Dimensional stability

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 2/4.

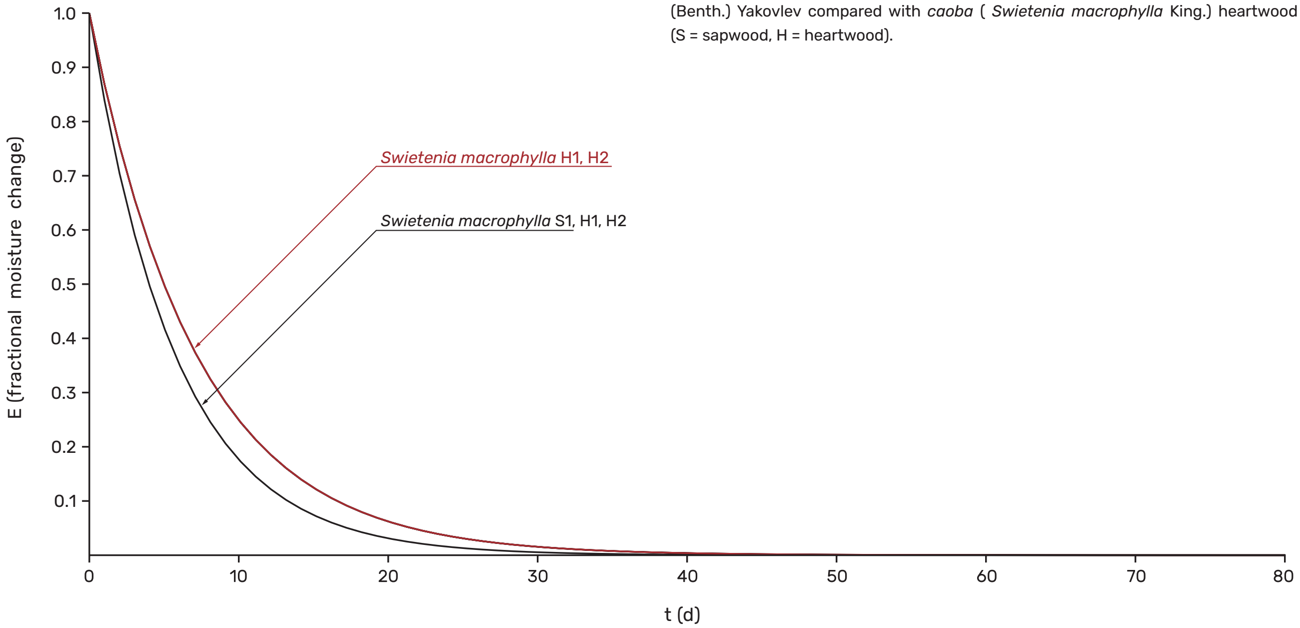
Density	ρ_0	S	398	...	**458**	...	518	kg / m³	
		H	358	...	**403**	...	446	kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.24	...	**0.26**	...	0.28	% / %	favourable
	q_{tang}	H	0.26	...	**0.27**	...	0.27	% / %	favourable
	q_{rad}	S	0.14	...	**0.16**	...	0.18	% / %	
	q_{rad}	H	0.15	...	**0.17**	...	0.18	% / %	
	q_{tang} / q_{rad}	S	1.44	...	**1.65**	...	1.80		normal
	q_{tang} / q_{rad}	H	1.50	...	**1.62**	...	1.73		favourable
	$q_{tang} - q_{rad}$	S	0.08	...	**0.10**	...	0.12	% / %	favourable
	$q_{tang} - q_{rad}$	H	0.09	...	**0.10**	...	0.11	% / %	favourable
Swelling coefficient and anisotropy	h_{tang}	S	0.041	...	**0.042**	...	0.043	% / %	favourable
	h_{tang}	H	0.040	...	**0.041**	...	0.042	% / %	favourable
	h_{rad}	S	0.024	...	**0.026**	...	0.028	% / %	
	h_{rad}	H	0.024	...	**0.026**	...	0.028	% / %	
	h_{tang} / h_{rad}	S	1.64	...	**1.64**	...	1.79		normal
	h_{tang} / h_{rad}	H	1.43	...	**1.58**	...	1.75		favourable
	$h_{tang} - h_{rad}$	S	0.013	...	**0.016**	...	0.019	% / %	favourable
	$h_{tang} - h_{rad}$	H	0.012	...	**0.015**	...	0.018	% / %	favourable
Sorption coefficient	S	S	0.15	...	**0.16**	...	0.17	% / %	normal
	S	H	0.15	...	**0.16**	...	0.16	% / %	normal

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	403
	Seasoning time	days	154
	Initial moisture content	%	92
	Final moisture content	%	20
	Checking		5
	Warping		2
	Seasoning degrade		1
	$t_{eq0.5}$ days	S1:4, H1, H2:5	5
	t_{eq} days	S1:32, H1:35, H2:38	37
Recommended drying schedule	Drying gradient		3.0
	T_1	°C	60
	T_2	°C	80

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

38. *Swietenia macrophylla* G. King



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
Sapwood	45/1S	402	5.0		
	45/2S		5.1		
Heartwood	45/1H	347	5.3	0.32	0.0008
	45/2H	443	5.2	0.34	0.0004

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			2 / 5	2 / 5
Weight loss	average	%	16	36
	minimum	%	1	16
	maximum	%	45	50
Resistance to decay			resistant	moderately resistant
Proportion of samples in each class	1	%	60	0
	2	%	0	20
	3	%	20	40
	4	%	20	40

Mechanical properties in green condition

Number of test trees				2	
Basic density ρ_b			kg/m³	420	medium
Static bending-centre loading	Stress at proportional limit		MPa	21.4	
	Maximum bending strength	Modulus of rupture	MPa	52.6	medium
	Stiffness	Modulus of elasticity	GPa	9.4	low
Compression	Maximal compression strength parallel to grain		MPa	22.4	medium
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	14.5	very low
Janka hardness	Resistance to identation	Rad.	kN	1.78	very low
		Tang.	kN	2.05	very low
		End	kN	2.10	very low

Machining and related properties

Number of test trees				1
Number of test samples				12
Moisture content	Min - max		%	15.0 - 16.0
Planing	Defect free samples		%	100

		Angle		
		30°	20°	15°
Speed	7.6 m/min	100	100	-
	13.1 m/min	75	92	-

Shaping	Good to excellent samples	%	67
Turning	Fair to excellent samples	%	80
Nailing	Samples free from complete splits	%	100
Screwing	Samples free from complete splits	%	95

Slicing, sliced veneer - Assessment of relevant properties

not tested
Heating temperature
Flich degrade due to thermal treatment
Ease of cutting
Drying degrade
Finishing quality

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

not tested
Heating temperature
Log degrade due to hydrothermal treatment
Ease of peeling
Gluing
Mechanical properties of plywood

Terminalia amazonica (J.F.Gmel.) Exell

sin.: /

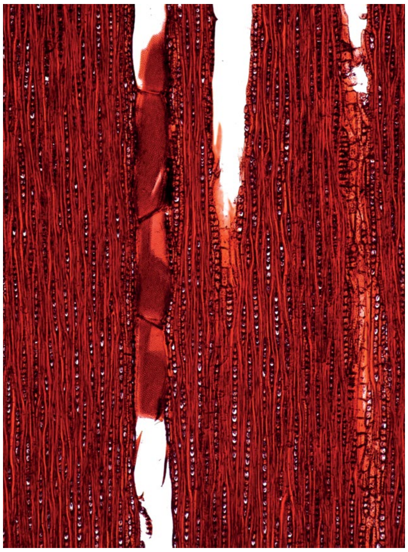
Combretaceae | Common name: **canshán** | Lacandon name: **k'änxa'an, pukte'**

Use: interior construction, exterior construction, framework, furniture, flooring, rail sleepers, exterior coverings, hydraulic works, possibly for decorative sliced veneer, container veneer and plywood

Radial section in actual size.
Upper half of the sample sanded and unfinished,
the lower half oil finish.

cross section

radial section



tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 60 m	
Diameter	up to 300 cm	
Bole	regular clear for 30 m, occasionally with buttresses	
Heartwood and sapwood (Munsell color chart)	status of heartwood unclear, probably wound initiated discolored wood	
Condition	Sapwood	Heartwood
Green	2.5 Y HUE / 2.5 Y 7/10	2.5 Y HUE / 2.5 Y 5/8
Air dried	2.5 Y HUE / 2.5 Y 8/4	
Grain	straight or slightly interlocked	
Texture	medium	

Moisture content and density

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 0/0.

Density	ρ_0	S	639	...	**663**	...	686	kg/m³
		H						
Moisture content (MC) green		S	53	...	**56**	...	58	%
		H						
EMC(21 °C/65%)		S			**14**			%
		H						

Dimensional stability

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 0/0.

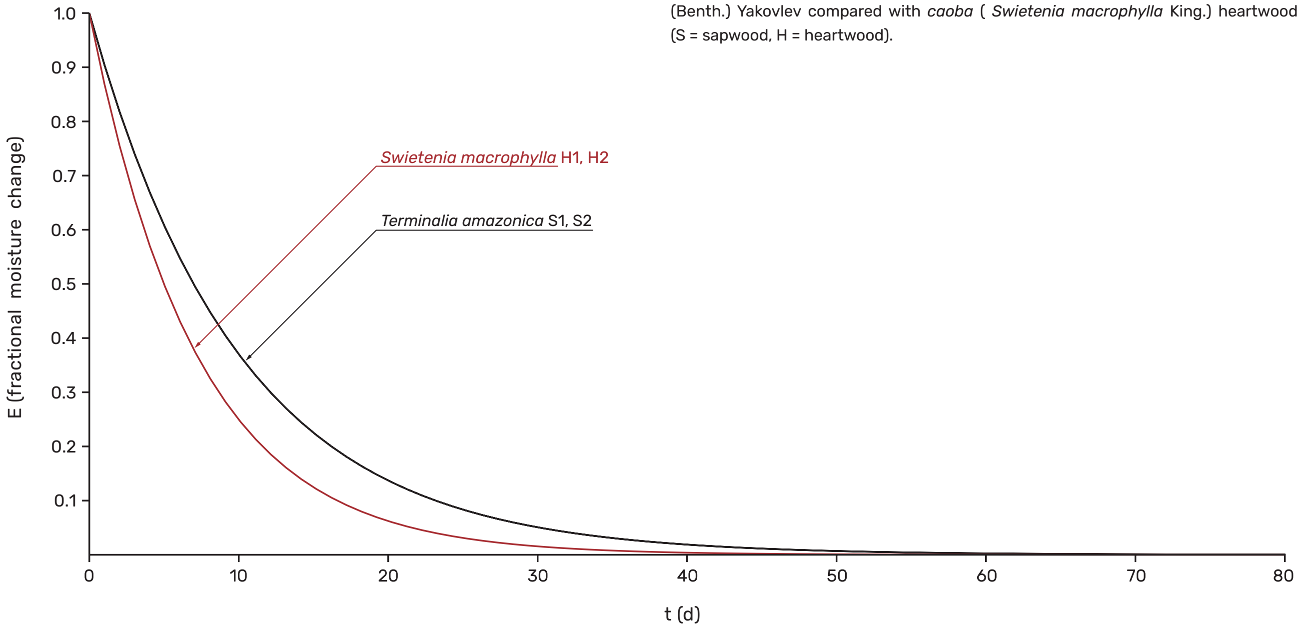
Density	ρ_0	S	639	...	**663**	...	686	kg / m³	
		H		...		...		kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.32	...	**0.33**	...	0.34	% / %	normal
	q_{tang}	H		...		...		% / %	
	q_{rad}	S	0.19	...	**0.20**	...	0.20	% / %	
	q_{rad}	H		...		...		% / %	
	q_{tang} / q_{rad}	S	1.60	...	**1.67**	...	1.70		normal
	q_{tang} / q_{rad}	H		...		...			
	$q_{tang} - q_{rad}$	S	0.12	...	**0.13**	...	0.14	% / %	normal
	$q_{tang} - q_{rad}$	H		...		...		% / %	
Swelling coefficient and anisotropy	h_{tang}	S	0.049	...	**0.051**	...	0.052	% / %	normal
	h_{tang}	H		...		...		% / %	
	h_{rad}	S	0.030	...	**0.030**	...	0.030	% / %	
	h_{rad}	H		...		...		% / %	
	h_{tang} / h_{rad}	S	1.63	...	**1.68**	...	1.73		normal
	h_{tang} / h_{rad}	H		...		...			
	$h_{tang} - h_{rad}$	S	0.019	...	**0.021**	...	0.022	% / %	normal
	$h_{tang} - h_{rad}$	H		...		...		% / %	
Sorption coefficient	S	S	0.15	...	**0.15**	...	0.15	% / %	favourable
	S	H		...		...		% / %	

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	663
	Seasoning time	days	154
	Initial moisture content	%	78
	Final moisture content	%	20
	Checking		111
	Warping		3
	Seasoning degrade		1-2
	$t_{eq0.5}$ days	S1, S2:7	7
	t_{eq} days	S1, S2:47	47
Recommended drying schedule	Drying gradient		2.6
	T_1	°C	50
	T_2	°C	70

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

39. *Terminalia amazonica* (J.F.Gmel.) Exell



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
Sapwood	41/1S	702	4.3	0.51	0.0003
	41/2S	636	4.4	0.61	0.0003
Heartwood					

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			2 / 5	2 / 5
Weight loss	average	%	2	20
	minimum	%	1	8
	maximum	%	3	39
Resistance to decay			very resistant	resistant
Proportion of samples in each class	1	%	100	20
	2	%	0	40
	3	%	0	40
	4	%	0	0

Mechanical properties in green condition

Number of test trees				2	
Basic density ρ_b			kg/m³	660	high
	Stress at proportional limit		MPa	43.3	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	89.6	high
	Stiffness	Modulus of elasticity	GPa	12.8	high
Compression	Maximal compression strength parallel to grain		MPa	40.1	high
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	36.5	high
		Rad.	kN	4.06	medium
Janka hardness	Resistance to identation	Tang.	kN	3.89	medium
		End	kN	4.88	high

Machining and related properties

Number of test trees					1
Number of test samples					10
Moisture content	Min - max			%	14.0 - 14.5
Planing	Defect free samples			%	100
		Angle			
		30°	20°	15°	
Speed	7.6 m/min	100	100	-	
	13.1 m/min	30	80	-	
Shaping	Good to excellent samples			%	100
Turning	Fair to excellent samples			%	100
Nailing	Samples free from complete splits			%	95
Screwing	Samples free from complete splits			%	55

Slicing, sliced veneer - Assessment of relevant properties

not tested	
Heating temperature	
Flich degrade due to thermal treatment	
Ease of cutting	
Drying degrade	
Finishing quality	

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

Heating temperature	70-80°C
Log degrade due to hydrothermal treatment	none
Ease of peeling	moderately easy to peel to difficult to peel
Gluing	satisfactory
Mechanical properties of plywood	satisfactory

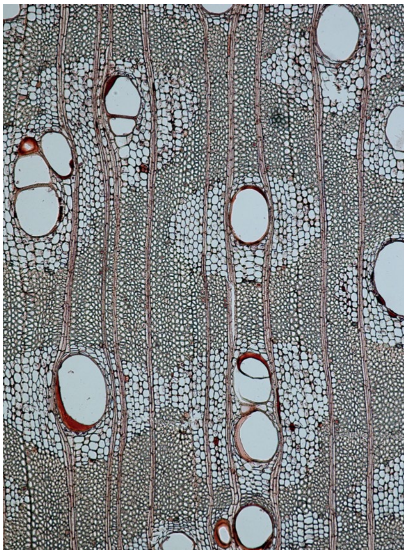
Vatairea lundellii (Standl.) Record

sin.: /

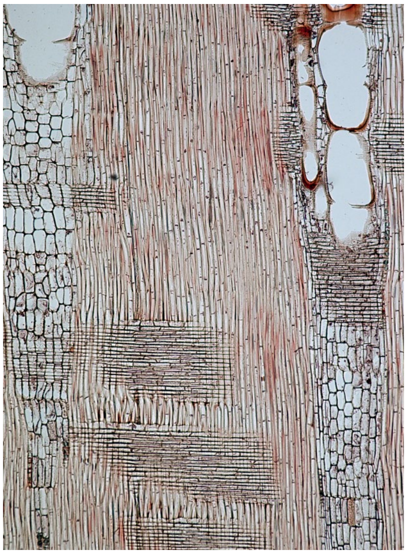
Fabaceae | Common name: **tinco** | Lacandon name: /

Use: interior construction, exterior construction, framework, flooring, rail sleepers, hydraulic works, possible for decorative sliced veneer

Radial section in actual size.
Upper half of the sample sanded and unfinished,
the lower half oil finish.



cross section



radial section

tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 40 m	
Diameter	up to 100 cm	
Bole	with thin and well developed butresses, clear for 30 m	
Heartwood and sapwood (Munsell color chart)	heartwood clearly differentiated from sapwood	
Condition	Sapwood	Heartwood
Green	10 YR HUE / 10 YR 8/6	10 YR HUE / 10 YR 6/10
Air dried	7.5 YR HUE / 7.5 YR 8/7	5 YR HUE / 5 YR 5/6
Grain	Typically narrowly interlocked	
Texture	coarse	

Moisture content and density

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 2/4.

Density	ρ_0	S	762	...	**780**	...	799	kg/m³
		H	588	...	**628**	...	667	kg/m³
Moisture content (MC) green		S	61	...	**62**	...	62	%
		H	97	...	**105**	...	112	%
EMC(21 °C/65%)		S			**14**			%
		H			**13**			%

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

Dimensional stability

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 2/4.

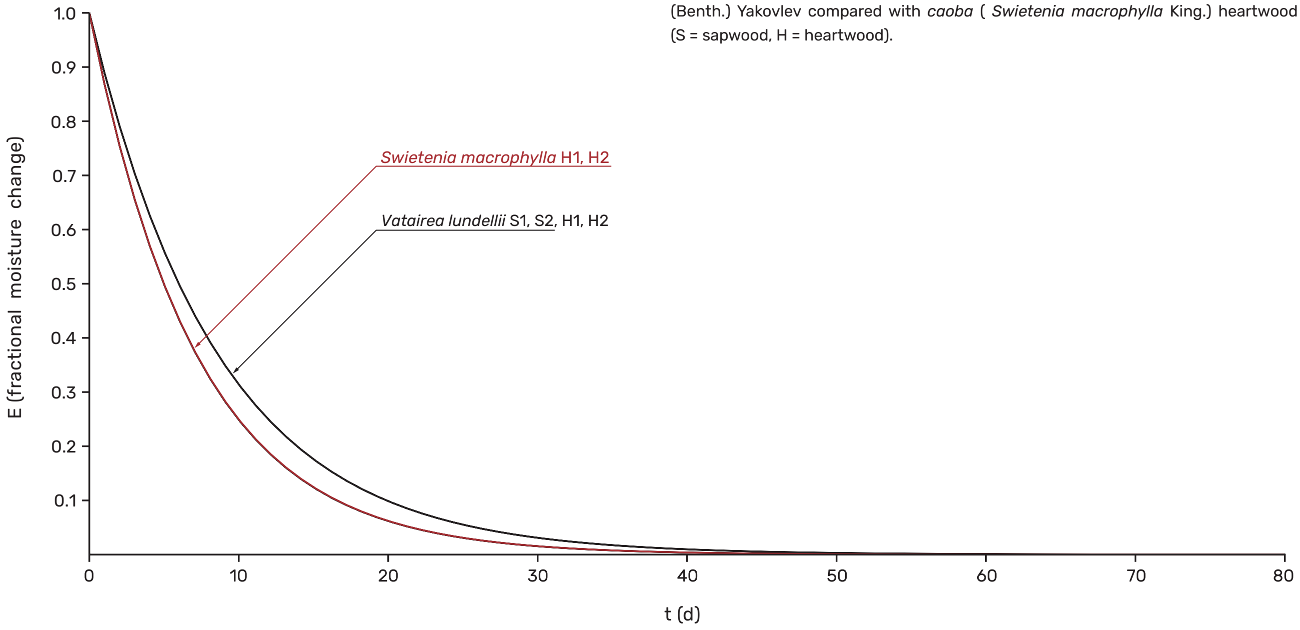
Density	ρ_0	S	762	...	**780**	...	799	kg / m³	
		H	588	...	**628**	...	667	kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.41	...	**0.42**	...	0.43	% / %	unfavourable
	q_{tang}	H	0.34	...	**0.36**	...	0.38	% / %	normal
	q_{rad}	S	0.21	...	**0.22**	...	0.22	% / %	
	q_{rad}	H	0.20	...	**0.21**	...	0.21	% / %	
	q_{tang} / q_{rad}	S	1.86	...	**1.94**	...	2.00		normal
	q_{tang} / q_{rad}	H	1.70	...	**1.77**	...	1.81		normal
	$q_{tang} - q_{rad}$	S	0.19	...	**0.20**	...	0.21	% / %	normal
	$q_{tang} - q_{rad}$	H	0.14	...	**0.16**	...	0.17	% / %	normal
Swelling coefficient and anisotropy	h_{tang}	S	0.064	...	**0.066**	...	0.068	% / %	unfavourable
	h_{tang}	H	0.044	...	**0.050**	...	0.054	% / %	normal
	h_{rad}	S	0.033	...	**0.034**	...	0.034	% / %	
	h_{rad}	H	0.026	...	**0.028**	...	0.029	% / %	
	h_{tang} / h_{rad}	S	1.88	...	**1.96**	...	2.00		normal
	h_{tang} / h_{rad}	H	1.69	...	**1.78**	...	1.86		normal
	$h_{tang} - h_{rad}$	S	0.030	...	**0.032**	...	0.034	% / %	normal
	$h_{tang} - h_{rad}$	H	0.018	...	**0.022**	...	0.025	% / %	normal
Sorption coefficient	s	S	0.16	...	**0.16**	...	0.16	% / %	normal
	s	H	0.13	...	**0.14**	...	0.14	% / %	favourable

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	780
	Seasoning time	days	154
	Initial moisture content	%	82
	Final moisture content	%	18
	Checking		0
	Warping		4
	Seasoning degrade		2
	$t_{eq0.5}$ days	S1, S2:6 H1, H2:5	5
	t_{eq} days	S1:43, S2:41, H1:34, H2:33	34
Recommended drying schedule	Drying gradient		2.1
	T_1	°C	50
	T_2	°C	70

40. *Vatairea lundellii* (Standl.) Record

Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).



pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
Sapwood	43/1S	837	5.2		
	43/2S	802	5.9		
Heartwood	43/1H	664	4.7	0.54	0.0003
	43/2H	587	4.7	0.51	0.0003

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			3 / 5	3 / 5
Weight loss	average	%	1	5
	minimum	%	0	2
	maximum	%	1	7
Resistance to decay			very resistant	very resistant
Proportion of samples in each class	1	%	100	100
	2	%	0	0
	3	%	0	0
	4	%	0	0

Mechanical properties in green condition

Number of test trees				3	
Basic density ρ_b			kg/m³	660	high
	Stress at proportional limit		MPa	42.9	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	77.2	high
	Stiffness	Modulus of elasticity	GPa	12.3	high
Compression	Maximal compression strength parallel to grain		MPa	37.7	high
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	25.1	medium
		Rad.	kN	4.40	high
Janka hardness	Resistance to identation	Tang.	kN	4.85	high
		End	kN	4.77	high

Machining and related properties

Number of test trees				1
Number of test samples				10
Moisture content	Min - max		%	14.0 - 14.0
Planing	Defect free samples		%	60

		Angle		
		30°	20°	15°
Speed	7.6 m/min	60	30	10
	13.1 m/min	20	10	10

Shaping	Good to excellent samples	%	20
Turning	Fair to excellent samples	%	40
Nailing	Samples free from complete splits	%	55
Screwing	Samples free from complete splits	%	80

Slicing, sliced veneer - Assessment of relevant properties

Heating temperature	80-90 °C
Flich degrade due to thermal treatment	none
Ease of cutting	moderately easy to cut
Drying degrade	without checking and wrinkling to some/ little wrinkling and checking
Finishing quality	good

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

	not tested
Heating temperature	
Log degrade due to hydrothermal treatment	
Ease of peeling	
Gluing	
Mechanical properties of plywood	

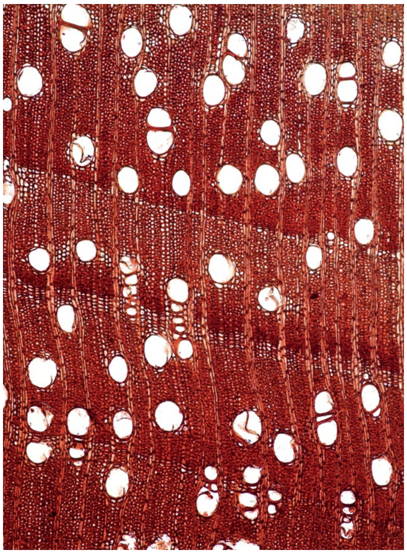
Vitex gaumeri Greenm.

sin.: /

Lamiaceae | Common name: **ya'axnik** | Lacandon name: /

Use: interior construction, framework, decorative sliced veneer, flooring, container veneer and plywood, possibly for furniture

Radial section in actual size.
Upper half of the sample sanded and unfinished,
the lower half oil finish.



cross section

radial section

tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 30 m
Diameter	up to 80 cm
Bole	irregular clear for 15 m
Heartwood and sapwood (Munsell color chart)	no colored heartwood

Condition	Sapwood	Heartwood
Green	2.5 Y HUE / 2.5 Y 8.5/8	
Air dried	10 YR HUE / 10 YR 7/4	

Grain	Slightly, narrowly interlocked
Texture	Medium to fine

Moisture content and density

No. of test trees / samples: Sapwood (S) 3/6 ; Heartwood (H) 0/0.

Density	ρ_0	S	615	...	**660**	...	691	kg/m³
		H						
Moisture content (MC) green		S	59	...	**71**	...	86	%
		H						
EMC(21 °C/65%)		S			**14**			%
		H						

Dimensional stability

No. of test trees / samples: Sapwood (S) 3/6 ; Heartwood (H) 0/0.

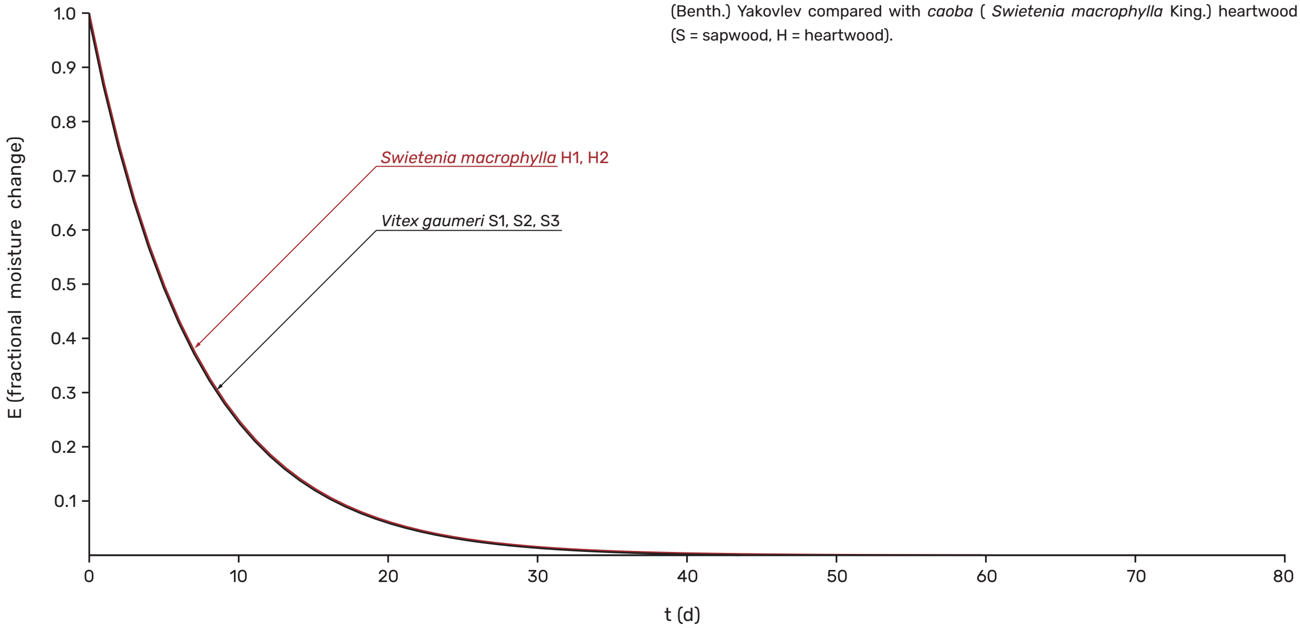
Density	ρ_0	S	615	...	**660**	...	691	kg / m³	
		H		...		...		kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.36	...	**0.37**	...	0.40	% / %	normal
	q_{tang}	H		...		...		% / %	
	q_{rad}	S	0.18	...	**0.19**	...	0.20	% / %	
	q_{rad}	H		...		...		% / %	
	q_{tang} / q_{rad}	S	1.85	...	**1.97**	...	2.11		normal
	q_{tang} / q_{rad}	H		...		...			
	$q_{tang} - q_{rad}$	S	0.17	...	**0.18**	...	0.21	% / %	normal
	$q_{tang} - q_{rad}$	H		...		...		% / %	
Swelling coefficient and anisotropy	h_{tang}	S	0.056	...	**0.058**	...	0.063	% / %	normal
	h_{tang}	H		...		...		% / %	
	h_{rad}	S	0.028	...	**0.029**	...	0.032	% / %	
	h_{rad}	H		...		...		% / %	
	h_{tang} / h_{rad}	S	1.31	...	**1.98**	...	2.17		normal
	h_{tang} / h_{rad}	H		...		...			
	$h_{tang} - h_{rad}$	S	0.025	...	**0.029**	...	0.034	% / %	normal
	$h_{tang} - h_{rad}$	H		...		...		% / %	
Sorption coefficient	s	S	0.15	...	**0.16**	...	0.16	% / %	normal
	s	H		...		...		% / %	

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	660
	Seasoning time	days	–
	Initial moisture content	%	–
	Final moisture content	%	–
	Checking		57
	Warping		3
	Seasoning degrade		1-2
	$t_{eq0.5}$ days	S1, S2, S3:5	5
	t_{eq} days	S1:33, S2, S3:35	34
Recommended drying schedule	Drying gradient		2.6
	T_1	°C	70
	T_2	°C	80

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

41. *Vitex gaumeri* Greenm.



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
Sapwood	60/1S	631	5.9	0.69	0.046
	60/2S	713	5.8	1.49	0.0007
	60/3S	648	5.8	0.57	0.15
Heartwood					

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			3 / 5	3 / 5
Weight loss	average	%	23	26
	minimum	%	5	24
	maximum	%	33	29
Resistance to decay			resistant	moderately resistant
Proportion of samples in each class	1	%	20	0
	2	%	20	20
	3	%	60	80
	4	%	0	0

Mechanical properties in green condition

Number of test trees				3	
Basic density ρ_b			kg/m³	670	high
Static bending-centre loading	Stress at proportional limit		MPa	43.8	
	Maximum bending strength	Modulus of rupture	MPa	96.6	high
	Stiffness	Modulus of elasticity	GPa	12.4	high
Compression	Maximal compression strength parallel to grain		MPa	41.2	high
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	34.5	medium
Janka hardness	Resistance to identation	Rad.	kN	5.86	high
		Tang.	kN	5.19	high
		End	kN	5.68	high

Machining and related properties

Number of test trees				1
Number of test samples				10
Moisture content	Min - max		%	14.0 - 15.0
Planing	Defect free samples		%	70

		Angle		
		30°	20°	15°
Speed	7.6 m/min	50	70	20
	13.1 m/min	0	0	0

Shaping	Good to excellent samples	%	90
Turning	Fair to excellent samples	%	90
Nailing	Samples free from complete splits	%	25
Screwing	Samples free from complete splits	%	60

Slicing, sliced veneer - Assessment of relevant properties

not tested
Heating temperature
Flich degrade due to thermal treatment
Ease of cutting
Drying degrade
Finishing quality

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

not tested
Heating temperature
Log degrade due to hydrothermal treatment
Ease of peeling
Gluing
Mechanical properties of plywood

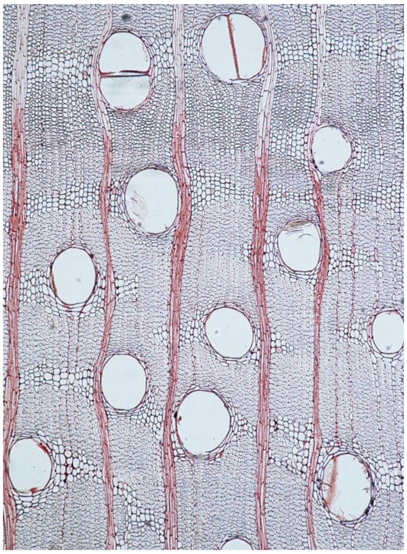
Vochysia guatemalensis J. D. Smith

sin.: ***Vochysia hondurensis*** **Sprague**

Vochysiaceae | Common name: **maca blanca** | Lacandon name: **/**

Use: interior construction, packaging, cellulose products, particle board, decorative sliced veneer, peeled veneer, construction plywood, container veneer and plywood, paper pulp

Radial section in actual size.
Upper half of the sample sanded and unfinished,
the lower half oil finish.



cross section

radial section

tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 40 m	
Diameter	up to 100 cm	
Bole	regular clear for 30 m	
Heartwood and sapwood (Munsell color chart)	without colored heartwood	
Condition	Sapwood	Heartwood
Green	7.5 YR HUE / 7.5 YR 8/2	
Air dried	7.5 YR HUE / 7.5 YR 8/2	
Grain	slightly or broadly shallowly interlocked	
Texture	coarse	

Moisture content and density

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 0/0.

Density	ρ_0	S	511	...	**547**	...	582	kg/m³
		H						
Moisture content (MC) green		S	57	...	**114**	...	157	%
		H						
EMC(21 °C/65%)		S			**13**			%
		H						

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

Dimensional stability

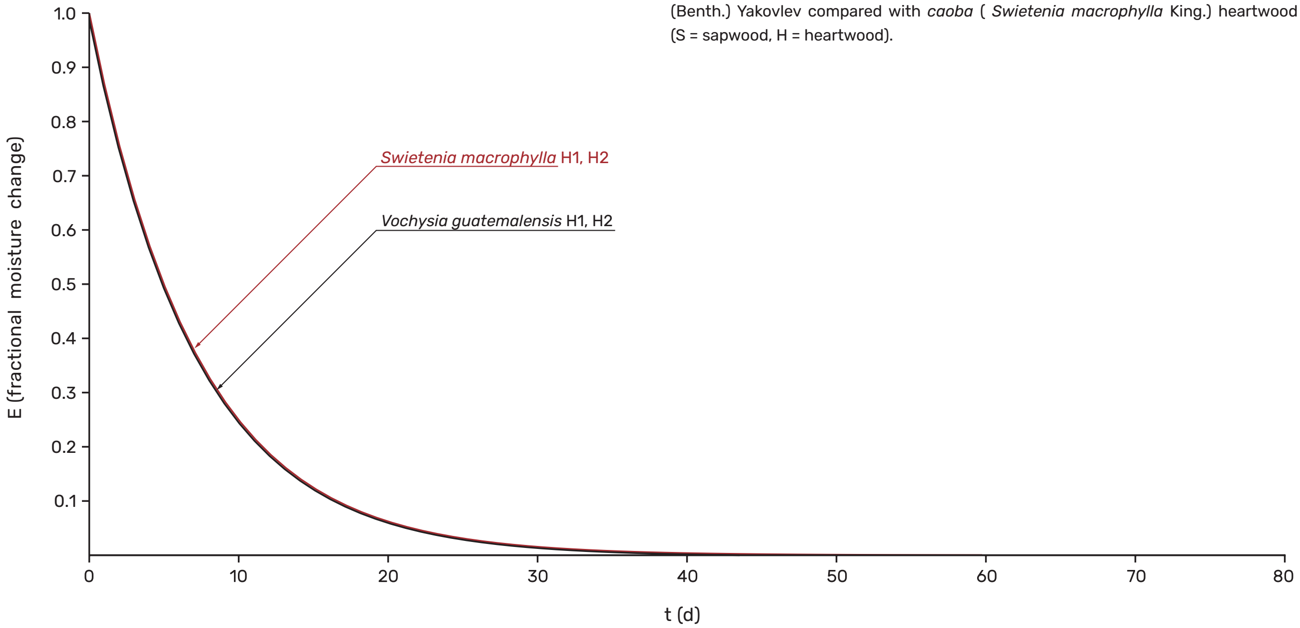
No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 0/0.

Density	ρ_0	S	511	... **547** ...	582	kg / m³	
		H		... ...		kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.40	... **0.43** ...	0.46	%/%	unfavourable
	q_{tang}	H		... ...		%/%	
	q_{rad}	S	0.16	... **0.17** ...	0.17	%/%	
	q_{rad}	H		... ...		%/%	
	q_{tang} / q_{rad}	S	2.50	... **2.62** ...	2.71		unfavourable
	q_{tang} / q_{rad}	H		... ...			
	$q_{tang} - q_{rad}$	S	0.24	... **0.27** ...	0.29	%/%	normal
	$q_{tang} - q_{rad}$	H		... ...		%/%	
Swelling coefficient and anisotropy	h_{tang}	S	0.061	... **0.065** ...	0.069	%/%	normal
	h_{tang}	H		... ...		%/%	
	h_{rad}	S	0.024	... **0.025** ...	0.025	%/%	
	h_{rad}	H		... ...		%/%	
	h_{tang} / h_{rad}	S	2.54	... **2.65** ...	2.76		unfavourable
	h_{tang} / h_{rad}	H		... ...			
	$h_{tang} - h_{rad}$	S	0.037	... **0.041** ...	0.044	%/%	unfavourable
	$h_{tang} - h_{rad}$	H		... ...		%/%	
Sorption coefficient	S	S	0.15	... **0.15** ...	0.15	%/%	favourable
	S	H		... ...		%/%	

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	547
	Seasoning time	days	154
	Initial moisture content	%	143
	Final moisture content	%	18
	Checking		66
	Warping		9
	Seasoning degrade		2
	$t_{eq0.5}$ days	H1, H2:5	5
	t_{eq} days	H2:35, H2:33	34
Recommended drying schedule	Drying gradient		3.1
	T_1	°C	60
	T_2	°C	80

42. *Vochysia guatemalensis* J. D. Smith



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
Sapwood					
	61/1H	581	5.2	0.72	0.0001
Heartwood	61/2H	532	4.9	1.34	0.0003

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			2 / 5	2 / 5
Weight loss	average	%	56	27
	minimum	%	34	8
	maximum	%	65	42
Resistance to decay			non-resistant	moderately resistant
Proportion of samples in each class	1	%	0	40
	2	%	0	0
	3	%	20	60
	4	%	80	0

Mechanical properties in green condition

Number of test trees				2	
Basic density ρ_b			kg/m³	460	medium
	Stress at proportional limit		MPa	23.9	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	52.9	medium
	Stiffness	Modulus of elasticity	GPa	8.7	low
Compression	Maximal compression strength parallel to grain		MPa	22.4	medium
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	14.5	very low
		Rad.	kN	2.30	low
Janka hardness	Resistance to identation	Tang.	kN	2.27	very low
		End	kN	2.72	low

Machining and related properties

Number of test trees				1
Number of test samples				10
Moisture content	Min - max		%	14.5 - 16.5
Planing	Defect free samples		%	30

		Angle		
		30°	20°	15°
Speed	7.6 m/min	0	30	-
	13.1 m/min	0	0	-

Shaping	Good to excellent samples	%	30
Turning	Fair to excellent samples	%	40
Nailing	Samples free from complete splits	%	95
Screwing	Samples free from complete splits	%	100

Slicing, sliced veneer - Assessment of relevant properties

Heating temperature	55-60°C
Flich degrade due to thermal treatment	light
Ease of cutting	easy to cut
Drying degrade	without checking and wrinkling to some/ little wrinkling and checking
Finishing quality	satisfactory

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

Heating temperature	50-60°C
Log degrade due to hydrothermal treatment	moderate
Ease of peeling	moderately easy to peel
Gluing	satisfactory to good
Mechanical properties of plywood	satisfactory

Zuelania guidonia (Benth.) Yakovlev

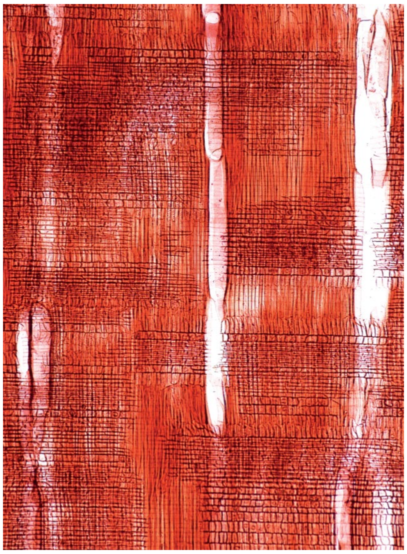
sin.: /

Salicaceae | Common name: **trementino** | Lacandon name: /

Use: interior construction, furniture, rail sleepers, cellulose products, particle board, container veneer and plywood, decorative sliced veneer

Radial section in actual size.
Upper half of the sample sanded and unfinished,
the lower half oil finish.

cross section



radial section

tangential section

500 µm

Tree, wood - Key Characteristics

Height	up to 35 m	
Diameter	up to 50 cm	
Bole	regular clear for 20 m	
Heartwood and sapwood (Munsell color chart)	no colored heartwood	
Condition	Sapwood	Heartwood
Green	2.5 Y HUE / 2.5 Y 8.5/4	
Air dried	2.5 Y HUE / 2.5 Y 8.5/4	
Grain	straight	
Texture	fine	

Moisture content and density

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 0/0.

Density	ρ_0	S	691	...	**698**	...	706	kg/m³
		H						
Moisture content (MC) green		S	76	...	**80**	...	85	%
		H						
EMC(21 °C/65%)		S			**14**			%
		H						

Dimensional stability

No. of test trees / samples: Sapwood (S) 2/4 ; Heartwood (H) 0/0.

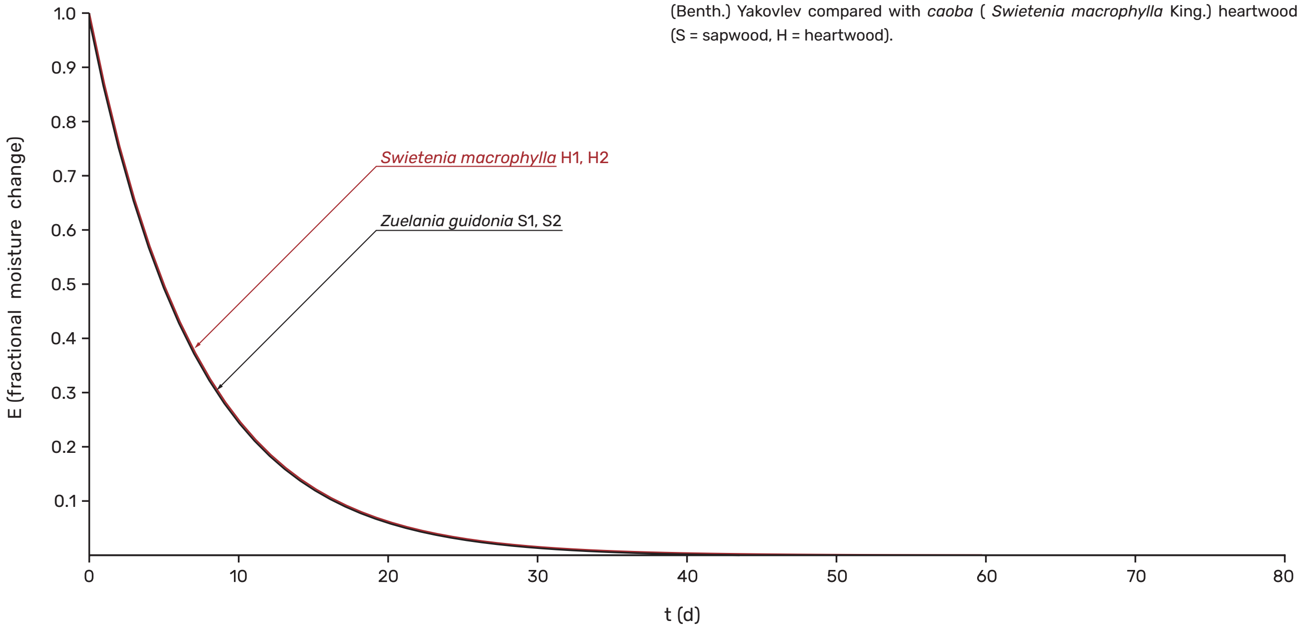
Density	ρ_0	S	691	...	**698**	...	706	kg / m³	
		H		...		...		kg / m³	
Differential swelling and anisotropy	q_{tang}	S	0.40	...	**0.42**	...	0.44	% / %	unfavourable
	q_{tang}	H		...		...		% / %	
	q_{rad}	S	0.15	...	**0.17**	...	0.18	% / %	
	q_{rad}	H		...		...		% / %	
	q_{tang} / q_{rad}	S	2.44	...	**2.56**	...	2.67		unfavourable
	q_{tang} / q_{rad}	H		...		...			
	$q_{tang} - q_{rad}$	S	0.25	...	**0.26**	...	0.26	% / %	unfavourable
	$q_{tang} - q_{rad}$	H		...		...		% / %	
Swelling coefficient and anisotropy	h_{tang}	S	0.064	...	**0.068**	...	0.072	% / %	unfavourable
	h_{tang}	H		...		...		% / %	
	h_{rad}	S	0.024	...	**0.027**	...	0.029	% / %	
	h_{rad}	H		...		...		% / %	
	h_{tang} / h_{rad}	S	2.48	...	**2.56**	...	2.67		unfavourable
	h_{tang} / h_{rad}	H		...		...			
	$h_{tang} - h_{rad}$	S	0.040	...	**0.042**	...	0.043	% / %	unfavourable
	$h_{tang} - h_{rad}$	H		...		...		% / %	
Sorption coefficient	S	S	0.16	...	**0.16**	...	0.16	% / %	normal
	S	H		...		...		% / %	

Seasoning characteristics and recommended drying schedule

	Density ρ_0	kg/m³	698
	Seasoning time	days	154
	Initial moisture content	%	75
	Final moisture content	%	20
	Checking		28
	Warping		6
	Seasoning degrade		2
	$t_{eq0.5}$ days	S1, S2:5	5
	t_{eq} days	S1:34, S2:35	35
Recommended drying schedule	Drying gradient		2.1
	T_1	°C	50
	T_2	°C	70

Seasoning time – tangential boards
Checking – relative increase in number and area of checks
Warping – relative increase in frequency and intensity of cup, bow, twist and crook
Seasoning degrade – 1 = slight, 2 = moderate, 3 = considerable, 4 = severe, based on the overall assessment of checking and warp increase
$t_{eq0.5}$ days – »half time« for wood to equilibrate between EMC 80% RH and 65% RH
t_{eq} days – total time for wood to equilibrate between EMC 80% RH and 65% RH
T1 – max. drying temperature above FSP
T2 – max. drying temperature below FSP

43. *Zuelania guidonia* (Sw.) Britton & Millspaugh



Fractional change in moisture content (E) between EMC at RH = 80 %, T = 21 °C and EMC at RH = 65 %, T = 21 °C as a function of time for *Acosmium panamense* (Benth.) Yakovlev compared with *caoba* (*Swietenia macrophylla* King.) heartwood (S = sapwood, H = heartwood).

pH-value, ash and silica content

	Sample	Density	pH - value	Ash content	Silica content
		ρ_0			
		kg/m3		%	%
Sapwood	62/1S	671	6.6	2.05	0.002
	62/2S	720	6.1	1.57	0.001
Heartwood					

Decay resistance / Natural durability

			Gloeophyllum trabeum (Pers.) Murrill	*Trametes versicolor* (L.) Lloyd
Number of test trees / Number of samples			2 / 4	2 / 5
Weight loss	average	%	8	41
	minimum	%	5	39
	maximum	%	11	43
Resistance to decay			very resistant	moderately resistant
Proportion of samples in each class	1	%	75	0
	2	%	25	0
	3	%	0	100
	4	%	0	0

Mechanical properties in green condition

Number of test trees				2	
Basic density ρ_b			kg/m³	610	high
	Stress at proportional limit		MPa	38.6	
Static bending-centre loading	Maximum bending strength	Modulus of rupture	MPa	81.6	high
	Stiffness	Modulus of elasticity	GPa	14.0	high
Compression	Maximal compression strength parallel to grain		MPa	32.6	medium
Single blow impact test	Resistance to suddenly applied loads	Toughness work per spec.	J	27.1	medium
		Rad.	kN	4.53	high
Janka hardness	Resistance to identation	Tang.	kN	4.33	high
		End	kN	4.92	high

Machining and related properties

Number of test trees				1
Number of test samples				9
Moisture content	Min - max		%	15.0 - 15.5
Planing	Defect free samples		%	100

		Angle		
		30°	20°	15°
Speed	7.6 m/min	78	100	-
	13.1 m/min	33	56	-

Shaping	Good to excellent samples	%	80
Turning	Fair to excellent samples	%	80
Nailing	Samples free from complete splits	%	6
Screwing	Samples free from complete splits	%	28

Slicing, sliced veneer - Assessment of relevant properties

not tested
Heating temperature
Flich degrade due to thermal treatment
Ease of cutting
Drying degrade
Finishing quality

Rotary cutting (peeling), rotary cut veneer and plywood - Assessment of relevant properties

not tested
Heating temperature
Log degrade due to hydrothermal treatment
Ease of peeling
Gluing
Mechanical properties of plywood

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Glossary

acahuales *pak che kol* **»planted milpa«; fallow cornfields (Cook 2016:122).** Traditionally, the Lacandons practice a sustainable form of swidden or slash-and-burn horticulture by which they transform a small areas of natural forest into harvestable forest. Their three zones of food production are the pristine forest, milpa (cultivated fields) and the management of fallowed *acahuales* or *pak che kol* ("planted tree milpa"). The Lacandon system rotates milpa and fallowed areas while intercropping to maintain nutrient balance in the rapid developmet of secondary forest after maize cultivation soil. This is in sharp contrast to the total exhaustion of the land from monocropping and livestock production practiced by their immigrant neighbors.

ADE Amazonian dark earths, *terra preta do indio*.

adelantado sp**.** governor of a Spanish province, acting as the chief civil and judicial authority, and as military commander-in-chief in time of war; (also) a military leader with the authority to explore, colonize, and govern new territories for the Spanish crown.

agroecology science of applying ecological concepts and principles to the design and management of sustainable agroecoystems; an ecological approach to agriculture that views agricultural areas as ecosystems and is concerned with the ecological impact of agricultural practices. (Merriam Webster)

agroforestry collective name for land-use systems and technologies where woody or arborescent perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between the different components. Agroforestry can also be defined as a dynamic, ecologically based, natural resource management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels. In particular, agroforestry is crucial to smallholder farmers and other rural people because it can enhance their food supply, income and health.Agroforestry systems are multifunctional systems that can provide a wide range of economic, sociocultural, and environmental benefits. (FAO Agroforestry 2015)

alpha diversity defined by Whittaker (1972) as »the species richness of a place« Alpha diversity is just the diversity of each site (local species pool). A community will have an high alpha diversity, when there is an high number of species and their abndances are much similar.

anisotropy (wood) property of being directionally dependent, which implies different properties in different directions, as opposed to isotropy. Due of its anisotropic structure consisting of predominantly axially oriented tissues, fibres and tracheary elements , wood is a typical anisotropic material resulting in oriented physical , mechanical and technologicl properties. Example: wood is easier to split along its grain than across it. Shrinkage is highest in the tangential direction, reduced by one half in radial direction and practically negligible in the axial direction, i.e. in the direction of fibres and cellulose microfibrills in the S2 cell wall layer. This is why mechanical properties are highest in the axial/longitudinal direction.

annuals plans that flower, produce seeds, and die in one growing season. Examples: maize, beans, tomatoes, chiles, macal, amaranth. All roots, stems and leaves of the plant die annually. Only the dormant seed bridges the gap between one generation and the next.

anthrosol soil that has been greatly modified by long-term human activity

archaeological tourism (archaeotourism) form of cultural tourism, which aims to promote public interest in archaeology and the conservation of historical sites. Archaeological tourism walks a fine line between promoting archaeological sites and an area's cultural heritage and causing more damage to them, thus becoming invasive tourism. (Archaeological turism 2017)

avocado →*Persea americana*

balsa → *Ochroma pyramidale*

banana →*Musa spp*

bark a on technical term used to cover all the tissues outside the xylem cylinder. In older trees usually divisible into inner (living) bark and outer (dead) bark or *rhytidome.*

basic density of wood ρ_b *Basic density of wood* $= \frac{\text{Oven-dry mass of wood}}{\text{Volume of wood when green}}$

The term »basic« emhasises that both parameters measured, the oven-dry mass and the swollen volumen, have constant and reproducible values. Basic density is the most useful descriptor of wood density (Walker 1993:73).

beta diversity defined by Whittaker (1972) as "the extent of species replacement or biotic change along environmental gradients." The beta diversity measures the turnover of species between two sites in terms of gain or loss of species. Beta diversity means the dissimilarity between communities of two sites (or two samples). The higher beta diversity means the two communities are more dissimilar.

binomial unque two-part Latin name taxonomists bestow on a species, such as e.g. *Swietenia macrophylla* (caoba, big-leaf mahogany). At the simplest level of scientific classification, each plant or animal has a name made up of two parts, a generic (or genus) name and a specific name or epithet. Together, these two names are referred to as a binomial.

biochar charcoal used as a soil amendment. *Biochar* is a stable solid, rich in carbon, and can endure in soil for thousands of years. Biochar is found in soils around the world as a result of vegetation fires and historic soil management practices. Intensive study of biochar-rich dark earths in the Amazon (terra preta), has led to a wider appreciation of biochar's unique properties as a soil enhancer. Biochar is found in soils around the world as a result of vegetation fires and historic soil management practices. Intensive study of biochar-rich dark earths in the Amazon (terra preta), has led to a wider appreciation of biochar's unique properties as a soil enhancer.

biodiversity variation of life forms within a given ecosystem, biome, or the entire Earth. Biodiversity must be considered on three levels: (1) species diversity, (2) genetic diversity and (3) ecosystem biodiversity.

biological corridor also wildlife corridor, habitat corridor, or green corridor, is geographically *defined* area which provides connectivity between landscapes, ecosystems and habitats, natural or modified, and ensures the maintenance of biodiversity and ecological and evolutionary processes. BC is an area of habitat connecting wildlife populations separated by human activities or structures (such as roads, development, or logging). This allows an exchange of individuals between populations, which may help prevent the negative effects of inbreeding and reduced genetic diversity (via genetic drift) that often occur within isolated populations. Corridors may also help facilitate the re-establishment of populations that have been reduced or eliminated due to random events (such as fires or disease) This may potentially moderate some of the worst effects of habitat fragmentation, wherein urbanization can split up habitat areas, causing animals to lose both their natural habitat and the ability to move between regions to use all of the resources they need to survive. Habitat fragmentation due to human development is an ever-increasing threat to biodiversity, and habitat corridors are a possible mitigation. (Wildlife corridor 2018)

biosphere reserve one of the protected areas established as part of a United Nations program to demonstrate the compatibility of biodiversity conservation and sustainable development to benefit local people. The biosphere reserves are nominated by national governments and remain under the sovereign jurisdiction of the states where they are located. Their status is internationally recognized. Biosphere reserves have three interrelated zones that aim to fulfil three complementary and mutually reinforcing functions:

The core area(s) comprises a strictly protected ecosystem that contributes to the conservation of landscapes, ecosystems, species and genetic variation. In core areas biological communities and ecosystemsare strictly protected. This is surrounded by the buffer zone surrounds or adjoins the core areas, and is used for activities compatible with sound ecological practices that can reinforce scientific research, monitoring, training and education. Here traditionalhuman activities-such s collection of thatch, medicinal plants, and smallfuelwood-are moitored and nondestructive research is conducted. Surrounding the buffer zone is the transition area in which some forms of sustainable development (such as small-scale farming) are allowed, along withsome extraction of natural resources (such as SFM logging) and experimental research (UNESCO Ecological Sciences for Sustainable Development Biosphere Reserves 2017, Barborak 1998; Primack 2008)

bound water in wood, water bound in the cell wall.

bracken → *Pteridium aquilinum*

breast heigt, diameter at breast height, DBH. Standard method of expressing the diameter of the trunk or bole of a standing tree. DBH is one of the most common dendrometric measurements. It is measured at approx. 1.3 m above ground.

broadleaved all trees classified botanically as Angiospermae. They are sometimes referred to as »hardwoods«.

Brosimum alicastrum *Sw. , Moraceae,* commonly known as the breadnut or Maya nut. It was planted by the Maya civilization two thousand years ago and it has been claimed in several publications by Dennis E. Puleston to have been a staple food in the Maya diet. Puleston demonstrated a strong correlation between ancient Maya settlement patterns and the distribution of relic stands of ramon trees.

burr or burl a growth on the tree trunk, branch or root that has tight swirling grain, resembling a mass or knot. Used for veneer or by turners. Very expensive.

buttress root (contrefor) large, wide roots on all sides of a shallowly rooted tree. They can grow up to 10 m tall. Typically, they are found in nutrient-poor rainforest soils and do not penetrate to deeper layers. They prevent the tree from falling over (hence the name buttress) while gathering more nutrients. contrefor

cacao →*Theobroma cacao*

carbon sequestration long-term removal, capture, or sequestration of carbon dioxide from the atmosphere to slow or reverse atmospheric CO_2 pollution and to mitigate or reverse climate change. Carbon dioxide (CO_2) is naturally captured from the atmosphere through biological, chemical, and physical processes. (from Wikipedia)

carrying capacity of an *ecosystem* is the largest population that it can sustain indefinitely with the available resources, also called the "maximum load" by population biologists.

capataz sp. boss; leader; supervisor; superintendant; headman; foreman of a pile-driving gang

Castilla elastica, Moraceae sp. *hule*; Lacandón Maya *k'ik'* .The ancient Maya made rubber balls for the Maya ballgame from *Castilla elastica*. The latex gathered was converted into usable rubber by mixing the latex with the juice of the morning glory species (*Ipomoea alba*) which, conveniently, is typically found in the wild as a vine climbing Castilla elastica. The rubber produced by this method found several uses, including most notably, the manufacture of balls for the Mesoamerican ballgame *ōllamaliztli.* Hundreds and perhaps even thousands of years before Charles Goodyear discovered the vulcanization process that made commercial rubber viable, Mesoamerican peoples were carrying out a similar process to produce rubber artifacts for a broad variety of uses, two MIT researchers have found.The researchers "have compiled a compelling case that ancient Mesoamerican peoples were the first polymer scientists, exerting substantial control over the mechanical properties of rubber for various applications," said materials scientist John McCloy of the Pacific Northwest National Laboratory, who was not involved in the research.(Nations 2006:108 and Maugh II 2010)

CBD *The Convention on Biological Diversity* defines the ecosystem approach as "a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way *ecosystem approach* is a way of making decisions in order to manage forestry activities sustainably. CBD obligates countries to protect the biodiversity within their borders, and international trade gives them the right to receive economic benefits from the use of that biodiversity.

Cedrela odorata, L. Meliaceae, syn. C. *mexicana* M. J. Roem., cedro, Cigar Box Cedar, Spanish »cedar«. It resembles the aroma of the unrelated true cedars (*Cedrus* spp.). Known also as Spanish cedar in English commerce, the aromatic wood is in high demand in the American tropics because it is naturally termite- and rot-resistant. An attractive, moderately lightweight wood (specific gravity 0.4), its primary use is in household articles used to store clothing. Cedro heartwood contains an aromatic and insect-repelling resin that is the source of its popular name. Cedro works easily and makes excellent plywood and veneer. This plant is often used for honey production (beekeeping) and humidor construction. It is occasionally used for tops or veneers on some kinds of electric guitars. The wood is the traditional choice for making the neck of flamenco and classical guitars. As the common name (Cigar Box Cedar) suggests, the timber is used in the manufacture of cigar boxes. Vulnerable (IUCN 2.3)

cedro → *Cedrela odorata*

chicozapote → *Manilkara zapota*

chinampas, »floating gardens« are constructed by first creating an enclosure on the lake with wooden stakes. This enclosure is then filled with alternating layers of mud and decaying vegetation until solid land above the water level is formed. In this way an artificial island is formed, and trees are planted on the edges because the roots of the trees help prevent erosion. The mixture of mud and vegetation makes the soil very fertile and is one reason why the chinampas are extremely productive. The water in the canals also contains fish, which not only provide more food but also add nitrogen-rich manure to the water, which in turn fertilizes the plants. No irrigation is generally needed as the plants absorb water directly from the canals, while overuse of water is prevented as the plants only absorb the water they need. The system is also resistant to droughts and floods. (Alatalo, E. 2016)

CITES *Convention on International Trade in Endengered Species,* treaty that obligates countries to protect biodiversity withoin their borders, and gives them the right to recieve economic benefits from the use of that biodiversity.The international treaty that established lists (known as *Appendices*) of species for which international trade is to be prohibited, regulated, or monitored.

clearcutting also known as clearfelling, is the felling and removal of all the trees in a stand or cut block regardless of age, species, or size of operation. Clearcutting is also recognized as a method of silviculture in Canada and countries with temperate and boreal growth forests. In logging operations the practice of clearcutting is often referred to as commercial clearcutting. Slash burning is also recognized as a form of clearcutting used more in tropical or sub tropical forests.

climax the end point of autogenic succession: the final seral stage in a sere. A self-replacing community that is relatively stable over several generations of the dominant plant species, or very persistent in comparison with other seral stages. The character of the climax community depends on the frequency and intensity of ecosystem disturbance relative to the ratebof autogenic succession fofr the site. (Kimmins 1997:523)

climatic climax a climax community and ecosystem condition (i.e. climax seral stage), the character of which is determined by the reginal climate. Climatic climax ecosystem conditions are found only where gthe rates of autogenic succession are high relative to the frequency and intensity of disturbanes that cause successional retrogression or retard or prevent ecosystem development under the influence of autogenic succession.

coa dibble stick

cotton Lacandon tämän (*Gossypium hirsutum* L.) Cotton was widely cultivated when the Lacndons wow their own fabric. But when commercial fabric became available, cotton became a secondary crop. Cotton is native to Mexico and Central America (cf. Cook 201:249)

cultigen a species of plant that is known only as a cultivated form and did not originate from wild type. It has been deliberately altered or selected by humans. (Collins English dictionary 2014)

density (symbol ρ) is defined as mass per unit volume. It has the SI unit kg m^{-3} or kg/m^3 and is an absolute quantity. The secific gravity (symbol SG) or more correctly *relative density* (symbol *d*) is the density of a substance divided by the density of water: former *specific gravity.*

drying shrinkage β_N (ger. Trocknungs-Schwindma β) according to DIN 52 184 (1979) shrinkage from green condition to EMC in normal climate 20/65.

Earth Overshoot Day (EOD) is the calculated illustrative calendar date on which humanity's resource consumption for the year exceeds Earth's capacity to regenerate those resources that year.

ecology relationship of a species to its biological and physical environment.

ecological forestry the central axiom of e.f. is that any manipulation of a forest ecosystem should emulate the natural disturbance patterns of the region prior to extensive human alteration of the landscape of the landscape. (Hunter, 1999:29, 56)

ecological engineering is an emerging study of integrating ecology and engineering, concerned with the design, monitoring, and construction of ecosystems. According to Mitsch (1996) "the design of sustainable ecosystems intends to integrate human society with its natural environment for the benefit of both". The *Center for Wetlands, University of Florida* defines e.e. as "...the design, construction and management of ecosystems that have value to both humans and the environment. Ecological engineering combines basic and applied science from engineering, ecology, economics, and natural sciences for the restoration and construction of aquatic and terrestrial ecosystems. The field is increasing in breadth and depth as more opportunities to design and use ecosystems as interfaces between technology and environment are explored." Mitsch and Jørgensen were the first to define ecological engineering and provide ecological engineering principles. Later they refined the definition and increased the number of principles. They defined and characterized ecological engineering in a 1989 book and clarified it further in their 2004 book. They suggest the goal of ecological engineering is: (a) the restoration of ecosystems that have been substantially disturbed by human activities such as environmental pollution or land disturbance, and (b) the development of new sustainable ecosystems that have both human and ecological values.

ecological footprint The area of productive land and water ecosystems required to produce the resources that the population consumes and assimilate the wastes that the population produces, wherever on Earth the land and water is located.

ecological imperialism is the theory advanced first by Alfred Crosby that European settlers were successful in colonization of other regions because of their accidental or deliberate introduction of animals, plants, and disease leading to major shifts in the ecology of the colonized areas and to population collapses in the endemic peoples. The many pathogens they carried with them adversely affected the native populations of North America, Australia, and Africa, and were far more destructive than weaponry: it is estimated that disease wiped out up to 90 percent of indigenous people in some locations. Alfred Crosby focused on European colonisation. (Crosby 2004, Ecological imperialism Available at https://www.revolvy.com/page/Ecological-imperialism (Accessed 27.12.2018), Ecological imperialism Available at:https://www.quora.com/What-is-ecological-imperialism (Accessed 27.12.2018).

ecological integrity the ability of an ecosystem to support and maintain ecological processes and a diverse community of organisms. The ecological integrity is measured as the degree to which a diverse community of native organisms is maintained, and is used as a proxy for ecological resilience, intended as the capacity of an ecosystem to adapt in the face of stressors, while maintaining the functions of interest.

ecological restoration includes activities to assist the recovery of ecosystem structure and function, and the associated provision of goods and services. Rooted in ecological theory, ecological restoration requires an integrated approach of different disciplines; including soil science, hydrology and conservation biology, together with the relevant socioeconomical and political frameworks.

ecosystem functional system of complementary relations between living organisms and their environment within a certain physical area. A biological community together with its associated physical and chemicsal environment. "Ecosystem" means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit. (Article 2 of the Convention on Biological diversity).

ecosystem approach The Convention on Biological Diversity (CBD:566) describes the ecosystem approach as a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use of biological diversity in an equitable way. It requires the application of appropriate scientific methodologies focused on levels of biological organization, which encompass the essential structure, processes, functions and interactions among biological organisms and their physical environment. It recognises that humans, with their cultural diversity, are an integral component of many ecosystems. The ecosystem approach thus requires adaptive management to deal with the complex and dynamic nature of ecosystems and in the absence of complete knowledge or understanding of their functioning.

ecoturism a form of tourism involving visiting fragile, pristine, and relatively undisturbed natural areas, intended as a low-impact and often small scale alternative to standard commercial mass tourism. It means responsible travel to natural areas conserving the environment and improving the well-being of the local people. Its purpose may be to educate the traveler, to provide funds for ecological conservation, to directly benefit the economic development and political empowerment of local communities. Tourism, especially in developing countries, focused on viewing unusual and/or especially charismsatic biological communities and species that are unique to country or region. (ecoturism 2018, Primack 2008)

El Pilar an ancient Maya city center and archeological site on the present-day border of Cayo District, Belize and Peten, Guatemala.

encomienda sp. 1. the system, instituted in 1503, under which a Spanish soldier or colonist was granted a tract of land or a village together with its Indian inhabitants. 2. the land or village together with its inhabitants.

encore is an additional performance given by performers after the planned show has ended, usually in response to extended applause from the audience.

entrada sp. exploring or conquering expedition in America.

equilibrium moisture content (**EMC**) wood is hygroscopic, which means that it responds to changes in atmospheric humidity. As the relative humidity (RH) drops, it loses bound water; as the RH increases, the wood regains bound water. For given RH level, a balance is evertrually reached at which wood is no longer gaining or losing moisture: equilibrium moisture content. This however, is a dynamic equilibrium and changes with relative humidity and temperature. Losing bound water results in shrinkage and its gainig in swelling.

ethnobotany study of how people of a particular culture and region make use of indigenous plants. Study of a region's plants and their practical uses through the traditional knowledge of a local culture and people. An ethnobotanist thus strives to document the local customs involving the practical uses of local flora for many aspects of life, such as medicines, foods, and clothing. (USDA Forest Service. Wikipedia)

fallow originally a term that means fields that are not being use for crops.

feral (forest) from lat. ferus »wild, uncultivated«, i.e. existing in a wild or uncultivated state. As depopulation, relocation, and forced labor recruitment left the dispersed forest gardens unattended in the Colonial period, they changed into what can be called the *feral forest* (Campbell *et al*. 2006, Nations 2006).

fibre, fiber a general term of convenience in wood anatomy for any long, narrow cell of wood (or b other than vessels and arenchyma. Often further qualfied as wood fibred or bast fibres; the former including both the tracheids of gymnosperms (softwoods) and the libriform wood fibres and fibretracheids of woody angiosperms (hardwoods). Also loosely for wood eleyments in general. (IAWA)

fibre saturation point (FSP) moisture content (MC) at which all the absorbed water has been removed but at which the cell walls are still fully saturated. For most species it is adequate to presume the fibre saturation point to be 30%. The FSP corresponds in theory to the moisture content of the timber when placed in a relative humidity of 100 %.

fiddle-back figure a form of curly figure exposed by quatersawing giving very straight grain with almost perpendicular curls from edge to edge. The name derives from the use of this figure for the backs of violins, which are traditionally made of European Sycamore.

figure or texture, in a broad sense, any design or distinctive markings on the longitudinal surfaces of wood; in restricted sense, such decorative designs in wood as are prized in the furniture and cabinetmaking industries, e.g. stripe or ribbon figure, due to interlocked grain esp. in tropical woods.

firebreak a strip of cleared or unplanted land intended to check a forest or grass fire.

flageolet tones the naturel a harmonics or oveetones of string instruments.

forest ecosystem an ecosystem dominated by trees, in which the microclimate, soils, hydrology, nutrient cycling, biomass creation, storage and turnover, and food chain processess reflect the dominance by large, long-livedwood plants.

forest ecosystem services number of goods and services provided by forest is large; a non-exhaustive list (cf.Forest ecosystem services 2015):

Wood and non-wood products: e.g. biomass based energy
Climate regulation: e.g. C-sequestration
Pollution control
Soil protection and formation: e.g. erosion control
Nutrients cycling
Biodiversity protection
Water regulation and supply
Recreation
Disturbance regulation

forest functions see forest ecosystem services

forest management sustainable management of forest resources and forest lands to meet the social, economic, cultural and spiritual human needs of present and future generations. These needs are for forest products and services, such as wood and wood products, water, food, fodder, medicine, fuel, shelter, employment, recreation, habitats for wildlife, landscape diversity, carbon sinks and reservoirs, and for other forest products. Appropriate measures should be taken to protect forests against harmful effects of pollution, including air-borne pollution, fires, pests and diseases in order to maintain their full multiple values. (Source: UNCED. 1992. Earth Summit - Rio Declaration & Forest Principles.)

Forest management deals with the overall administrative, economic, legal, social, technical and scientific aspects related to natural and planted forests. It implies various degrees of deliberate human intervention, ranging from actions aimed, at. safeguarding and maintaining the forest ecosystem and its functions, to favouring specific socially or economically valuable species or groups of species for the improved production of goods and services. Sustainable forest management will ensure that the values derived from the forest meet present-day needs while at the same time ensuring their continued availability and contribution to long-term development needs. (Source: FAO. 1993. The Challenge of Sustainable Forest Management - what future for the world's forests?)

Forest Principles (also *Rio Forest Principles*) is the informal name given to the *Non-Legally Binding Authoritative Statement of Principles for a Global Consensus on the Management, Conservation and Sustainable Development of All Types of Forests* (1992), a document produced at the United Nations Conference on Environment and Development (UNCED), informally known as the Earth Summit. It is a non-legally binding document that makes several recommendations for conservation and sustainable development forestry.

Free or capillary water water in cell lumina.

FSC, Forest Stewardship Council international non-profit, multi-stakeholder organization established in 1993 to promote responsible management of the world's forests. The FSC does this by setting standards on forest products, along with certifying and labeling them as eco-friendly.

gamma diversity diversity of the entire landscape (regional species pool). The number of species in a large geographic area.

grain refers to the direction of the axial elements of the wood in relation to the long axis of the log, or, when applied to converted timber, of an individual plank. The appearance of wood (and to some extent its other properties) may be referred to three groups of characteristics; its grain, its texture and its figure. The grain may be e.g. straight, spiral, interlocked (esp. in tropical woods). Grain can be determined by the type of cleavage produced when wood is split. If the plane of cleavage is flat, the grain is said to be straight. If the face of cleavage is wavy, the wood is curly- or wavy-grained. (Panshin &de Zeeuw1980:34)

grand piano modern pianos come in two shapes, the »grand« and the »upright«. In the wing-shaped »grand piano«, strings and soundboard are contained in a horizontal case, and the hammers strike the strings from below. (Randel 2003:652)

Green Climate Fund (GCF) (Cancun, 2010) is a fund established within the framework of the UNFCCC as an operating entity of the Financial Mechanism to assist developing countries in adaptation and mitigation practices to counter climate change. (Wikipedia)

green wood wood which has the original moisture present in the standing tree and has not been dried below the *fiber saturation point*; generally wood whose MC is higher than FSP.

growth/ inner stresses originate in the cambial zone due to the cristallisation of the celllose, or incrustation of liginin in the last phase of cell wall differentiation or apical intrusive growth of fibres. These stresses lead to warping and twisting of boards as they are relieved when sawing the log.

Guaiacum sanctum L. , Zygophyllaceae, guayacán, Guayacán Real, holywood. This tree is one of two species which yield the valuable Lignum vitae wood, the other being *Guaiacum officinale.* Its timber is highly valued and the species has been logged and traded for a long period. It is now listed under CITES Appendix II and trade of the species has significantly declined in recent years. The species is threatened by habitat loss, deforestation and fragmentation. IUCN, »Red list«: »near threatened«, also in CITES Appendix II, *Guaiacum* was a particularly popular cure for syphilis in the sixteenth century, if not a particularly effective one. It is regarded to be both the heaviest and hardest wood commercial wood in the world with the relative density/ "specific gravity" 1.05-1.26.

guyacán →*Guaiacum sanctum*

hach winik **»real people**«, this is how Lacandons call themselves

habitat the environment of an organism; the place where it is usually found.

habitat corridors connect protected areas allowing species dispersal to take place. They are particularly important in maintaining known migration routes. (Primack 2008)

hardwood a term commonly applied to the wood of magnoliid or eudicot tree wood

harpsichord a keyboard instrument shaped usually in the wing form of grand piano and played by means of a similar keyboard, but producing its notes by plucking the strings with plectra, not striking them with hammers.

Haematoxylon campechianum, Fabaceae sp. *tinte* or *palo de Campeche* ; Itza and Lacandón Maya *ek'*. Swamp forest legume tree that grows in dense stands in seasonally inundaded areas (*tintales* or *bajos*). The tree was of great economic importance from the 17th century to the 19th century, when it was commonly logged and exported to Europe for use in dyeing fabrics. Logwood trees played a major role in the history of Belize, for it was the abundance of logwood that prompted British loggers to colonize the Belizean coast, leading to a British challenge to Spanish rule of the area that eventually would become British Honduras and later Belize. It remains an important source of haematoxylin, which is used in histology for staining. The bark and leaves are also used in various medical applications. The extract was once used as a pH indicator. (cf. Torelli 2001; Nations 2006:106).

heartwood the inner layers of wood, which, in the growing tree, have ceased to contain living cells and in which the reserve materials (e.g. starch) have been removed or converted into low-molecular heartwood substances. It is generally darker in color than sapwood, though not always clearly differentiated: trees with obligatory colored heartwood, trees with light heartwood, trees with retarded formation of heartwood and species without heartwood (»sapwood trees«)..

herb a plant that consists only of primary tissues; lacking wood; it often lives for less than a single year (beans, corn, wheat)

high-performance *milpa* (Wilken 1971) sophisticated, intensive agroforestry. It was widely practiced by Mesoamerican farms). In its high-performance mode, the Maya milpa is a form of restoration agriculture as defined by Shepard Restoration Agriculture. Each cycle of production results in abundant products for family subsistence, trade and tribute. The system also prevents erosion and compaction, increases soil fertility, and builds long-term carbon reserves in the soil and in enriched woodland vegetation. A dialogue of scientific and traditional farmer knowledge is desperately needed to construct productive conservation landscapes for the future of the tropics worldwide. (Ford and Nigh 2015, pp. 68-69, 71, 59)

high grading the removal of the most economically profitable trees in a forest, (i.d. selective felling) often disregarding the future of the residual stand. The stunted, slow growing or poorly formed trees that are left as residuals will, if ecological conditions permit, reseed the space that has been created. Over time the practice of high grading can therefore give rise to forest stands containing stems of less value in terms of timber quality. Opposite to *selecting cutting (see)*

hause/ home garden, Lacandon *kolil nah* (cf. Cook 2016:39) a garden with plants for daily use.

humidor humidity-controlled box or room used primarily for storing cigars, cigarettes, or pipe tobacco.

interlocked grain the grain which spirals around the axis of the tree, but reverses its direction for periods of years resulting in alternating directions of the spiral grain. On quartersawn surfaces the change in grain direction creates a ribbon stripe figure.

invasive tourism archaeologists have expressed concerns that tourism encourages particular ways of seeing and knowing the past. When archaeological sites are run by tourist boards, ticket fees and souvenir revenues can become a priority, and the question remains whether a site is worth opening to the public or remaining closed and keeping the site out of harm's way. Damage to irreplaceable archaeological materials is not only direct, as when remains are disordered, altered, destroyed, or looted, but often the indirect result of poorly planned development of tourism amenities, such as hotels, restaurants, roads, and shops. These can drastically alter the environment in ways that produce flooding, landslides, or undermine ancient structures. (Archaeological tourism 2017)

ITTO International Tropical Timber Organization, an intergovernmental organization promoting the conservation and sustainable management, use and trade of tropical forest resources. Its members represent about 80% of the world's tropical forests and 90% of the global tropical timber trade.

IUCN the International Union for Conservation of Nature (IUCN; officially International Union for Conservation of Nature and Natural Resources) is an international organization working in the field of nature conservation and sustainable use of natural resources. It is involved in data gathering and analysis, research, field projects, advocacy, and education. IUCN's mission is to "influence, encourage and assist societies throughout the world to conserve nature and to ensure that any use of natural resources is equitable and ecologically sustainable". The IUCN Red List of Threatened Species (also known as the IUCN Red List or Red Data List), founded in 1964, is the world's most comprehensive inventory of the global conservation status of biological species.

jungle the word *jungle* originates from the Sanskrit word *jangala,* meaning uncultivated land. "Jungle" is the term often applied to secondary forest with dense ground growth, but it is also applied to some tropical moist forests where seasonal variations permit thick ground growth. One of the most common meanings of *jungle* is land overgrown with tangled vegetation at ground level, especially in the tropics. Typically such vegetation is sufficiently dense to hinder movement by humans, requiring that travelers cut their way through. This definition draws a distinction between rainforest and jungle, since the understorey of rainforests is typically open of vegetation due to a lack of sunlight, and hence relatively easy to traverse. Jungles may exist within, or at the borders of, rainforests in areas where rainforest has been opened through natural disturbance such as hurricanes, or through human activity such as logging. The successional vegetation that springs up following such disturbance of rainforest is dense and impenetrable and is a 'typical' jungle. Jungle also typically forms along rainforest margins such as stream banks, once again due to the greater available light at ground level.

jurup che in Lacandon description of plant community succession, the second fallow shrub stage (2-3 years). Together *robir* and *jurup che* were previously identified by the local Spanish term *acahual***.**

juvenile wood forms the central cylinder or core (hence core wood) of the stem and branches (»crown wood«). The juvenile rings have shorter cells, larger microfibrillar angle with the pronounced axial shrinkage, more reaction wood and internal/growth stresses, lower crystallinity and cellulose content in comparison to the »normal« adult wood that is produced later. The transition between juvenile and juvenile wood is taken to occur at an age of 12-20 years.

k'ax Lacandon "primary forest"

kol Yucatek milpa; a form perennial, multi-cropping swidden cultivation centered on maize *(Zea mays L.);* crucial element in managing the neotropical woodlands of Maya area. It has shaped and conserved forest ecosystems and provided the bulk of the crops used for local consumption. Between 40 and 50 different crops are grown in both active and fallow milpa at any time. Also "high-performance milpa", (Ford and Nigh 2015:41; Cook, 2016:39).

kolil nah Lacandon "house garden", small section of the property reserved for kitchen garden with demarcated beds of cabbages, radishes, carrots and letuce, ki je podoben našim zelenjavnim vrtovom /vegetable garden.(cf. Cook 2016:39)

kor in Lacandon description of plant community succession, the herbaceous stage, previously identified by the local Spanish term *milpa***.**

kux che in Lacandon description of plant community succession, the second forest stage (5-20 years).

Lacandon forest (Selva Lacandona) as a part of the *Maya tropical forest* stretches from Chiapas, Mexico, into Guatemala and into the southern part of the Yucatán Peninsula (Lacandon Jungle 2018). The heart of this rainforest is located in the Montes Azules Biosphere Reserve in Chiapas near the border with Guatemala in the Montañas del Oriente region of the state. Although most of the jungle outside the reserve has been partially or completely destroyed and damage continues inside the Reserve, the Lacandon is still the largest montane rainforest in North America and one of the last ones left large enough to support jaguars. It contains 1,500 tree species, 33% of all Mexican bird species, 25% of all Mexican animal species, 44% of all Mexican diurnal butterflies and 10% of all Mexico's fish species. The Lacandon in Chiapas is also home to a number of important Mayan archeological sites including Palenque, Yaxchilan and Bonampak, with numerous smaller sites which remain partially or fully unexcavated. This rainforest, especially the area inside the Biosphere Reserve, is a source of political tension, pitting the EZLN or Zapatistas and their indigenous allies who want to farm the land against international environmental groups and the Lacandon Maya, the original indigenous group of the area and the one who has legal title to most of the lands in Montes Azules.

Lacandon Maya agroforestry, the milpa forest garden cycle.

LCA Life cycle assessment, also known as **life cycle analysis**, is a methodology for assessing environmental impacts associated with all the stages of the life cycle of a commercial product, process, or service. For instance, in the case of a manufactured product, environmental impacts are assessed from raw material extraction and processing (cradle), through the product's manufacture, distribution and use, to the recycling or final disposal of the materials composing it (grave).

An LCA study involves a thorough inventory of the energy and materials that are required across the industry value chain of the product, process or service, and calculates the corresponding emissions to the environment. LCA thus assesses cumulative potential environmental impacts. The aim is to document and improve the overall environmental profile of the product.

LIA see little ice age.

little ice age, LIA, a period of cooling that occurred after the Medieval Warm Period. Although it was not a true ice age, the term was introduced into scientific literature by François E. Matthes in 1939. It has been conventionally defined as a period extending from the 16th to the 19th centuries, but some experts prefer an alternative timespan from about 1300 to about 1850. The last glacial period, popularly known as the Ice Age, was the most recent glacial period, which occurred from c. 110,000 – c. 11,700 years ago.

logwood →*Heamatoxylon campechianum* ***Manilkara zapota*** (L.) v. Royen, Sapotaceae, tree native to southern Mexico, Belize and northeastern Guatemala. Most abundant, anthropogenically fostered tree species. Widely cultivated in Maya forest for its fruit, exceptionally durable wood and *chicle*-tapping. Chicle is white gummy sap exuding from liwing inner bark. (see text!) C*hicleros,* cut zigzag gashes in the tree trunk and collect the sap in bags. The collected material is boiled until it reaches the correct thickness and is then molded into blocks. These are exported, chiefly to the United States, for use in making chewing gum. (Long ago, the Mayas and Aztecs would boil its 'chicle' sap, mold it into thick blocks and cut them into small pieces to chew. They were making the first chewing gum).In 1999, the *Rainforest Alliance* certified chicle production in the Yucatán as its first non-timber forest product, helping to relieve pressure on forests while still allowing the local people to earn a living.

Maya forest garden the traditional Maya orchard plot that evolves from the milpa. Like the milpa, it uses a polyculture and permaculture system of cultivation, and is managed with local, organic resources rather than chemical fertilizers and pesticides. Though it mostly focuses on the cultivation of perennial plants, a few annuals and herbs are still grown, providing for a diverse array of household needs. It will eventually cycle back into a hardwood forest.

The traditional milpa and forest garden is an unplowed, multi-crop field that sustains biodiversity and animal habitat while producing plants for food, spice, shelter, medicine, ornament and profit. It can be fertilized by household refuse (compost), organic material (dead weeds), ashes from kitchen fires, and manure, enriching the soil and increasing productivity without the use of chemically manufactured fertilizer.

Maya forest gardener a traditional Maya farmer who cultivates the cycle of milpa, forest garden, and forest using extensive traditional knowledge and practices that promote the ecology, biodiversity, and growth of the ecosystem. This includes nurturing the plants, providing for animals and insects, as well as serving for household needs.

Maya tropical forest a lowland forest region of the modern teritorries of eastern Chiapas (Mexico),Guatemala's Department of Petén, the seouthern part of the Yucatán Peninsula, and all of the nation of Belize.The Lacandon forest (Selva Lacandona) is a part of the *Maya tropical forest* which stretches from Chiapas, Mexico, into Guatemala and into the southern part of the Yucatán Peninsula (Lacandon Jungle 2018).

MCPFE The Ministerial Conference on the Protection of Forests in Europe (synonym of the *Helsinki Process)* and, from November 2009, of FOREST EUROPE) is a pan-European ministerial level voluntary political process for the promotion of sustainable management of European forests. Through this process, guidelines, Criteria & Indicators of Sustainable Forest Management and other instruments for the promotion of sustainable forest management (SFM) are developed.

MFM miltiple-use forest management.

mehen kol Lacandon »house garden«.

mehen che in Lacandon description of plant community succession, the first forest stage (10 years)

MEM see multiple-use forest management.

Mesoamerica (proposed by Kirchhoff in 1943) area of Mexico and Central America in which the common presence of certain pre-Hispanic culture traits permits the classification of the separate culture within the area as one civilization. Gographically, Mesoamerica can be marked in the north along the Sinaloa, Lerma, and Pánuco rivers, separating the nomadic tribes of the northern desert from the agricultural population of Mesoamerica. It includes central and southern Mexico, Yucatán peninsula, Guatemala, El Salvador, parts of Honduras and Nicaragua, and northern Costa Rica. The southern boundary runs from Caribbean mouth of the Motagua River, Guatemala in a southernwestern line through through Central Aerica, passing Lake Nicaragua, to the Gulf of Nicoya, Costa Rica (Muser, 1978, p.99).

milpa polyculture based on maize and intercropped with tens of other plants domesticated . The milpa entails a rotation of annual crop with a series of managed and enriched intermediate stages culminating in the reestablishment of the forest on the once-cultivated parcel (Hernandez Xolocotzi, Bello Baltazar, and Levy Tacher, 1995; Nations and Nigh 1980; Teran and Rasmussen, 1994; cited in Ford and Nigh, 2010:183, 184). The milpa is the foundation of the forest garden. It shoud be stressed that the *milpa* system is associated with the Mesomerican smallholder.

***milpa*, conventional** as opposed with highly sophisticated sustainable tradicional milpa, milpa commonly practiced today in the Maya region. Often ends with pasture and cattle breeding.

***milpa,* traditional** traditional Mesoamerican and Maya agricultural field that employs a system of land use. This system cycles from closed forest canopy to a field dominated by annual crops to an orchard garden, and from an orchard garden back to the closed canopy. It uses a polyculture and permaculture system of cultivation, and is managed with local, organic resources rather than chemical fertilizers and pesticides. Annuals dominate the milpa in the first years and farmers select from a suite of more than 70 crop species. Traditionally, several kinds of maize, beans, squash, and root crops are cultivated amidst a complex agroecology of herbs. At the outset, forest gardeners will begin to plant perennials so the milpa cycles into the forest garden. Also called "high performance milpa" by Wilken (1971). Traditional Lakandon milpa is an intensive agroforestry system that enhanced soil fertility ("black carbon", port. "terra preta"!) and encouraged the rapid development of secondary forest after maize cultivation (Nigh 2008:240).

milpa cycle The traditional Maya agricultural cycle that advantages the ecology and microclimate of the natural environment, encouraging biodiversity. It is more accurate to think of the milpa cycle as a rotation of annuals with successional stages of forest perennials during which all phases receive careful human management. The cycle begins with the clearing and burning of a piece of mature forest. The cleared milpa is planted with annuals that require full sun. From the milpa, the field cycles into a forest garden, with a greater emphasis on perennials. Eventually, the farmer will plant hardwoods that will mature and look much like the forest that was there before it was cleared. It is the milpa cycle that is the axis of the resilient Maya resource management system. (Altieri 2002; Ford and Nigh 2009, Teran and Rasmussen 1994, quoted in Ford and Nigh 2010:183). The milpa cycle is the conservation method of farming and managing the Maya forest. It goes through four main stages over the course of approximately 20 years: from the forest to the milpa; from the milpa to the forest garden; and from the forest garden back to the forest (El Pilar Forest Garden Network 2017)

modulus of elasticity, E relates the stress applied along one axis to the strain occurring on the same axis.

moisture content, MC (wood) The ratio of the mass of water and the mass of the oven dried material, expressed in percent, %.

mollisol one of the world's agriculturally mos timportant and naturally productive soils, particularly under conditions of rain-fed cultivation (Fedick 1996, quoted in Nigh and Diemont 2013).

monoculture the practice of growing one crop on an agricultural field. Monoculture, embedded in the industrial agricultural system, makes it possible for mechanized farming and all its attendant capital.

movement /wood wood is normally dried to a moisture content approximating its anticipated mean EMC in use. However, since invironmental conditions are rarely constant, the EMC is and the moisture content continually changing of the wood under normal exposure conditions is seldom equa to its EMC. Concurrent dimensional changes are also taking place. These have been called *movement* by Stevens (1963), to distinguish them from the initial shrinkage associated with drying the green wood.

multiple-use forest management (MEM) represents a common and prime management objective under SFM paradig. It is a concept of forest management that combines two or more objectives not only production of wood and (Sabogal *et al*. 2013) is important because it maintains the delicate and necessary ecosystems of forests while still allowing populations to meet the rising demand of products yielded from them (Nix 2017). Under right coditions, MFM could diversify forest use, broaden forest productivity and provide incentives for managing forest cover… (FAO).

Munsell color system method of designating colours based on a colour arrangement scheme developed by the American art instructor and painter Albert H. Munsell. It defines colours by measured scales of hue, value, and chroma, which correspond respectively to dominant wavelength, brightness, and strength or purity. (Enc. Britannica).

***Musa* spp.** are native to tropical Indomalaya and Australia, and are likely to have been first domesticated in Papua New Guinea, there is no sharp distinction between "bananas" and "plantains". Almost all modern edible parthenocarpic (seedless) bananas originate from two wild species – *Musa acuminata in Musa balbisiana.* Bananas are in the forth place in the world in therms of production quantity, after wheat, rice and milk. Bananas on the western market are *almost exclusively Cavendish varieties.*

mycorrhiza mycorrhizal symbiosis refers to the association of fungi with plant roots. This relationship is predominantly mutualistic, that is, with both partners benefiting from the association. More than 90% of all plant families studied (80% of species) in both agricultural and natural environments form mycorrhizal associations and they can be essential for plant nutrition.

Na Bolom, the House of the Jaguar was the home of archeologist Frans Blom and his wife, Gertrude Duby Blom, the documentary photographer, journalist, environmental pioneer, and jungle adverturer. It is in San Cristóbal de las Casas, Chiapas, Mexico and today, *Na Bolom* operates as a hotel, museum and research center run by Asociación Cultural Na Bolom, a non-profit organization dedicated to the protection of the Lacandon Maya and the preservation of the Chiapas rain forest.

nah colil the main felling and cultivation period. Farmers obsere the flowerin of certain forest trees to guide their agricultural activities. These indicator species signal the foot of the agriculturalcycle. (Nations and Nigh, 1980, p. 11)

Nicotiana tobacco tobacco. Research is ongoing into its ancestry among wild *Nicotiana* species, but it is believed to be a hybrid of *Nicotiana sylvestris*, *Nicotiana tomentosiformis*, and possibly *Nicotiana otophora*. In their great first voyage to the New World, Christopher Columbus and his expedition were introduced to a plant whose smoke was called *tobacco* by the natives of Hispaniola. The Maya used tobacco extensively for recreation and rituals alike. Varieties of tobacco used by the Maya differed from tobacco that used in modern cigarettes and other related products. The Maya smoked the leaves to scare away snakes and spirits. Besides smoking the dried leaves, the Maya also consumed their tobacco by making tea out of it and ingesting the liquid. (Entheogenics and the Maya 2017)

NLBI Non-Legally Binding Instrument on All Types of *Forests*, adopted in 2007, by the United Nations Forum on Forests (UNFF), commonly known as the "Forest Instrument". The adoption of the Forest Instrument proved an important step in promoting sustainable forest management globally. The Member States of the UN agreed on a series of policies and measures at the international and national levels to strengthen forest governance, technical and institutional capacity, policy and legal frameworks, forest sector investment and stakeholder participation, within the framework of national forest programmes (NFPs).

normal climate after DIN EN 310, 1993, climate 20 ± 2) ^{0}C for air temperature and (65 ± 5) % for relative humidity. (Holzlexikon 2003:856)

Ochroma pyamidale Cav. Ex Lam.; sin. *O. lagopus Sw.,* Malvaceae large, fast-growing tree that can grow up to 30 m. Balsa wood is a very lightweight material with many uses. Balsa trees are native to southern Brazil and northern Bolivia, up to southern Mexico. It is a pioneer plant, which establishes itself in clearings in forests, either man-made or where trees have fallen, or in abandoned agricultural fields. Used in mylpa system in Selva Lacandona Lacandon to assist soil fertility regeneration and restoration (cf. Diemont *et al.* 2006:208, Ford and Nigh 2015:62, 63).

organic foods that are grown without the use of petrochemical pesticides and artificial fertilizers, free from contamination by industrial waste, and processed without ionizing radiation or food additives. Livestock are reared without the routine use of antibiotics and growth hormones, foraging on the landscape. Generally, organic produce may not be genetically modified.

orthotropic having unique and independent properties in three mutually orthogonal (perpendicular) planes of symetry; 3 special case of anisotropy.

pak che kol (Lacandon) is variously interpreted (cf. Cook, 2016, p.39) as a "milpa without tree" fallow milpa that has beome old or "planted tree milpa" and "tree gardens". A better interpretation would be "an old milpa that is undergoing or has attained second-growth regneration. These tree gardens serve as a fallow area between milpa and primary forest. Lacandons call these regenerating plots *pak che kol* ("planted tree gardens"). See also ***acahuales***

paleoecology the ecology of the past using geological and biological evidence from fossil deposits to investigate the past occurrence,

palynology the study of pollen. It can be used to reconstruct past vegetation (land plants) and marine and freshwater phytoplankton communities, and so infer past environmental (palaeoenvironmental) and palaeoclimatic conditions.

paraphrase in the 19th century, a solo work of great virtuositly in which popular mellodies, usually from operas, where elaborted (as in Liszt's *Rigoletto: Paraphrase de concert.* 1860). Paraphraes were produced in large numbers by composers of salon music; the catalog of Liszt's works shows 78 such pieces. (Randel 2003:632.)

pathological rotation (age) the point where annual increment growth is equal to the loss of wood due to decay.

perennials plants that have a life cycle lasting more than two growing seasons, either dying back or growing continuously (eg. trees).

permaculture a form of agriculture in which a plot of land is maintained in cultivation and constantly in production by relying on renewable resources and a self-sustaining ecosystem. Milpa cycle is regarded to be ancient Mayan permaculture.

PEFC The Programme for the Endorsement of Forest Certification schemes (PEFC) is a certification system confirming that wood comes from forests that are responsibly managed from an environmental, social and economic perspective.

Persea americana, Lauraceae tree, long thought to have originated in South Central Mexico, classified as a member of the flowering plant family Lauraceae. Recent archaeological research produced evidence that the avocado was present in Peru as long as 8,000 to 15,000 years ago. Mexico is by far the world's largest avocado growing country, producing several times more than the second largest producer.

pet kol tall, managed tree garden, created in favorable ecological niches (Gomez-Pompa e tal. 1987) developed on on sites of 19 000-24 000 m^2, where particularly useful plants were cultivated, forming a kind of nursery within a protected forest ecosystem.Intensively managed woodland patches have probably been important in shaping the structure and composition of the Maya forest (Nigh and Diemont 2013).

phanerophytes Raunkiær's plant life form. Shoot apical meristems are borne more than 25 cm above the soil surface. Examples of phaneropytes are thus all trees and a great many shrubs, including primarily tropical, arboreal monocots such as palms. Mechanically dependant species that remain rooted in the soil, such as climbers, lianas, or vines, could be considered phanerophytes. Arguably, however, mechanically dependant species that are not rooted at ground level, warrant a class of their own, i.e. should be classified as epiphytes.

phloem the portion of vascular tissues involved in conducting sugars and other organic compounds, along with some water and minerals. Alternative: *xylem*.

plantains are members of the banana family, but they are starchier and lower in sugar, which means that when they are ripe, they will still be green in color. While a banana makes a great, raw on-the-go-snack, plantains aren't usually eaten raw because of the high starch content. Native to India and the Caribbean, plantains serve an important role in many traditional diets.

primary forest refers to untouched, pristine forest that exists in its original condition. This forest has been relatively unaffected by human activities. Primary rainforest is often characterized by a full ceiling canopy and usually several layers of understory. The ground floor is generally clear of heavy vegetation because the full canopy allows very little light, necessary for plant growth, to penetrate. Occasionally, when a canopy tree falls, a temporary "light gap" is opened in the canopy, allowing growth of floor and understory species. Primary forest is the most biologically diverse type of forest.

polyculture a form of agriculture imitating the diversity of natural ecosystems by cultivating multiple plants (crops and trees) together in the same plot. Techniques include crop rotation, multi-cropping, intercropping, companion planting, beneficial weeds, and alley cropping. Polyculture requires considerable human skill, and has many benefits: building biodiversity, sustainability, and healthier soil, preventing erosion, and decreasing susceptibility of crops to disease and pests.

production forestry practice of forestry with object of producing maximum quantity of timber, fuel wood and other forest produce. The production forestry can be further classified into (a) commercial forestry aiming to get maximum production of timber, fuel wood and other forest products as a business enterprise and (b) industrial forestry aiming at producing raw material required for industry. In production forestry, there is a greater concern for the production and economic returns.

protected area is an area of land or sea dedicated by law or tradition to the protection of biodiversity and associated natural and cultural resources (WRI 2003). Protecting areas that contain healthy, intact ecosystems is the most effective way to preserve overall biodiversity. IUCN has developed a system that classsifies protected areas according to their use by humans, ranging from minimal to intensive. Categories I-V can be defined as true protected areas, because their habitat is managed primarily for biodiversity (Primack 2008).

Pteridium aquilinum, Pteridophyta, Polypodiopsida/Pteridpsida, Polypodiales, Dennstaedtiaceae found throughout the world in temperate and tropical regions. Bracken is an aggressive colonizer of open ground and readily invades pastures and fields. Causes stagnation in forest succession in many parts of the world.

raised fields in raised fields platforms of earth are lifted from low, damp, or seasonaly inundated soil, so that the water runs in drainage canals around the fields (Benson 1977:61).

ramon → *Brosimum alicastrum*

ray a ribbon-like aggregate of cell extending radially in the xylem and phloem.

reaction wood a term applied to certain of "abnormal" wood, which is characteristically present in branches and leaning trunks. It forms as a response to gravity. Reaction wood in hardwoods is called tension wood and is formed on the upper part of the leaning trunks and branches; reaction wood in softwoods is called compression woood and is formed on the lower part of the leaning trunks and branchesse to gravistimulus. It forms on the slopes where crowns are asymetric and generally after felling.

Red list see **IUCN**

REDD+ stands for countries' efforts to reduce **e**missions from **d**eforestation and forest **d**egradation, and foster conservation, sustainable management of forests, and enhancement of forest carbon stocks.

repartimiento sp. distribution, partition, or division, was a colonial forced labor system imposed upon the indigenous population of Spanish America (and the Philippines).

restoration ecology returning an ecosystem to a desired, more natural state after human disturbance.

retention forestry/approach the unifying feature of retention forestry is that during harvest, important structures and organisms are intentionally retained on site for the long term. A portion of the original stand is left unlogged to maintain the continuity of structural and compositional diversity. Retention forestry is applicable to all forest biomes, complements conservation in reserves, and represents bottom-up conservation through forest manager involvement (e.g. Gustaffson. *L. et al.* 2012). Maintenance of some structures and organisms from the preharvest forest ecosystem has several specific objectives, including (a) maintaining and enhancing the supply of ecosystem services and the provisioning of biodiversity (e.g., MA 2005); (b) increasing public acceptance of forest harvesting and the options for future forest use (e.g., McDermott *et al.* 2010); (c) enriching the structure and composition of the postharvest forest (e.g., Franklin *et al.* 1997); (d) achieving temporal and spatial continuity of key habitat elements and processes, including those needed by both early- and late-successional specialist species (e.g., Bauhus *et al.* 2009, Gustafsson *et al.* 2010); (e) maintaining connectivity in the managed forest landscape (e.g., Kouki *et al.* 2001); (f) minimizing the off-site impacts of harvesting, such as on aquatic systems (e.g., Clinton 2011); and (g) improving the aesthetics of harvested forests (e.g., Shelby *et al.* 2005, quoted in Gustafsson *et al.* 2012).

RIL reduced impact logging. Intensively planned and carefully controlled implementation of timber harvesting operations to minimise the environmental impact on forest stands and soils (ITTO). The biological objective is to preserve as much ecological integrity as possible of the logged stand, including, most importantly, protecting already-established seedlings, saplings, and subadults of commercial species that, in theory, would form the next crop of trees. The methods developed are known collectively as RIL and, in tests, have proven effective the world over in reducing collateral damage to the residual stand by 20%–50% (reviewed by Putz *et al*. 2008, quoted in Zimmerman and Kormos 2012) RIL is defined as intensively planned and carefully controlled timber harvesting conducted by trained workers in ways that minimise the deleterious impacts of logging (Putz *et al.* 2008). RIL techniques are thought to protect forest biodiversity and critical forest functions, while maintaining a sustainable and financially viable flow of timber (Fredericksen 1998).

robir in Lacandon description of plant community succession, the first fallow shrub stage (2-3 years).

tension wood reaction wood in hardwood tree species (angiosperms) formed on the upper part of the leaning trees. See reaction wood.

resilience the ability of an ecosystem to return to its original state following disturbance. (Primack 2008)

resistance ability of an ecosystem to remain in the same state even with ongoin disturbance. (Primack 2008)

restoration agriculture explains how we can have all of the benefits of natural, perennial ecosystems and create agricultural systems that imitate nature in form and function while still providing for our food, building, fuel and many other needs — in your own backyard, farm or ranch. (Shepard 2013)

retention approach an approach modeled on natural processes, where a portion of the original stand is left unlogged to maintain the continuity of structural and compositional diversity. (cf. Gustafsson *et al*. 2012)

rubber →*Castilla elastica*

sapwood the peripferial portion of the wood that in the living tree cointains living (parenchyma) cells and reserve materials.

secondary forest is rainforest that has been disturbed in some way, naturally or unnaturally. Secondary forest can be created in a number of ways, from degraded forest recovering from selective logging, to areas cleared by slash-and-burn agriculture that have been reclaimed by forest. Generally, secondary forest is characterized (depending on its level of degradation) by a less developed canopy structure, smaller trees, and less diversity. "Jungle" is the term often applied to secondary forest with dense ground growth, but it is also applied to some tropical moist forests where seasonal variations permit thick ground growth.

secondary milpa or orchards abandoned, fallowing fields. (Kashanipour and McGee 2004:49)

selection cutting/harvest system (ger. *Plenterwald)* a silvicultural system used in uneven-aged forests. Periodic (eg. every 5-20 years) harvests of trees of various sizes are done to yield timber and to maintain a desired age and size class structure and species mixture in the forest. Cutting of trees selected individually or in small groups while protecting those that are free of deformities and disease. Its purpose is to ensure that the forest contains trees of all ages. It also improves the health of the stand and releases space for young trees to grow. Often (sometimes deliberately) confused with "*selective*" cutting, a term synonymous with the practice of *highgrading* (the removal of the most economically profitable trees in a forest, often with a disregard for the future of the residual stand). A silvicultural system used in uneven-aged forests. (cf.Selection cutting 2018)

selective/select cutting/harvest system generally a system in which periodic (e.g. every 30-50 years) harvests are made of all or only a certain selected species or type of trees are cut down to some minimum diameter. Often called "diameter-limit cutting". It frequently leads to "high-grading",also known as "cutting the best and leaving the rest", i.e.. removing of the most economically trees, often disregarding the future development of the residual stand. Most times, trees that are highly valued – like mahagony – are more likely to be cut down. Select cutting removes the largest and highest quality trees of the most desirable species. It leaves trees that are approximately the same age as those taken, but of no particular value. Since these unwanted trees left standing capture most of the available sunlight and growing space, they prevent high quality stems of more desirable species from becoming established. Select cutting is an economic practice, not a forestry one.

Not considered to be an acceptable harvest system in sustainable forest management in many types of forests (cf.Kimmins 2004:533). Very poor choice for sustaining the benefits of the forest.

A forest that is harvested by select cutting appreciates very little in value over time and is less suitable for wildlife than diverse and vigorous stands of high quality trees. A high-graded forest gradually deteriorates from old age, disease and logging damage. Eventually, only complete removal of all the large trees can return these areas to a young, healthy condition. At that point, the cost of removing the trees may not cover the cost of planting new trees after the harvest. (cf. Virginia Departmemt of Forestry, 2018)

selva alta perennifolia tropcal forest with dominant trees higher than 30 m, normally with strong buttresses; below 1500 m.

Selva Maya the Spanish term for the Maya tropical forest.

Selva Lacandona an area of tropical forest which stretches from Chiapas, Mexico, into Guatemala and into the southern part of the Yucatán Peninsula.; part of Selva Maya.

Sequestration see **carbon sequestration.**

ser-climax a case of arrested succession where the plant community of an early stage "captures" the site by developing sufficient root and/or foliage mass to monopolize soil moisture and nutritiens, and light. Early seral shrub or herb communities that develop unimeded because of an initial lack of invasion by later seral species may remain stable and resistent subsequent invasion by these speciexs for many decades or even centuries. (Kimmins 1997:533)

seral stage the identifiable stages in the development of a sere, from an early pioneer stage, through various early and mid-seral, to late seral, subclimax, and climax stages. The stages are identified by different plant associations (different species composition and/or community structure), different ages of dominant vegetation (usually related to differences in structure), and by different microclimatic, soil and forest conditions (Kimmins 1997:533)

SFM Criteria and indicators are the basic tools for defining and promoting sustainable forest management by providing relevant information for forest policy development and evaluation, national forest policies, plans and programmes and as a basis for cross-sectoral forest related data collection and communication to the sector and to the broad public. Through them it is also possible to monitor, assess and report progress towards sustainable forest management at regional and national levels in the Pan-European region.

shifting cultivation see **swidden**

slash and burn see **swidden**

specific gravity (symbol SG, G) or density index (Panshin and de Zeeuw (1980) correctly: relative density (symbol *d*) is the ratio of the oven-dry mass of a wood specimen to the mass of water displaced by the bulk specimen at a given moisture content. Since it is a ratio of masses, it is dimensionless. Specific gravity is numerically equal to oven-dry mass divided by moist volume, mainly oven-dry volume (i.e. metric units if expressed in specific gravity, volume when oven-dry or specific gravity, volume when green). See also density. The density and relative density are numereically equal under oven-dry conditions. As moisture contdent increases, density becomes numerically greater than relative density (Siau 1984:25,26).

sound board (ger. Resonanzboden; it. piano armonico, tavola armonica). On the piano and related string instruments, thin sheet of wood over which the strings pass and that is largely responsible for transmitting the vibrations of the strings to the surrounding air. The analogous part of the violin and related instruments is termed the belly or table (Rendal 2003:811).

stela columnar stone monument erected to record historic and religion. (Muser 1978:147)

subsistence farming the production of sufficient food and other necessities to meet the requirements of a farm unit, leaving no surplus for sale and little for storage. (Kemp 1998)

succession the gradual and sequential change in species composition, vegetation structure, and ecosystem characteristics following natural or human-caused disturbance. It progresses through distinct stages until the so-called climax community is attained, with the complete sequence from the initiation of the community to the climax referred to as a sere. The climax community represents the ecosystem that is best suited to the environmental conditions at the site. (Kemp, 1998, p.386)

succession, primary begins when a community is established on a previously unvegetated site – eg., a lava flow or mud-flats exposing by falling water levels.

succession, secondary begins in an environment that has already been more o less modified by a period of occupancy by living organisms. Forest clearcuts and abandoned agricultural fields both undergo secondary succession. As opposed to the primary succession, secondary succession is a process started by an event (e.g. forest fire, harvesting, hurricane) that reduces an already established ecosystem (e.g. a forest or a wheat field) to a smaller population of species, and as such secondary succession occurs on preexisting soil whereas primary succession usually occurs in a place lacking soil. (Kimmins, p. 400; Kemp. 1998, p.386)

sustainability an integral part of all natural systems, however, maintained by the controlled flow of matter or energy through the system. Current sustainability issues cover a very broad spectrum, with the concept of sustainable yealds applied to agriculture, energy, fishing, forestry and resource development in such a way that the economic factors are integrated with environmental concers as far as possible. (Kemp, 1998, p.391)

sustainable forest management (SFM) the management of forests according to the principles of sustainable development. SFM has to keep the balance between three main pillars: ecological, economic and socio-cultural. Successfully achieving sustainable forest management will provide integrated benefits to all, ranging from safeguarding local livelihoods to protecting the biodiversity and ecosystems provided by forests, reducing rural poverty and mitigating some of the effects of climate change. Sustainable forest management should ensure that components of biological diversity are used in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs of present and future generations. "Sustainable forest management should take an ecosystem approach ... comprising such elements as forest composition, natural regeneration, patterns of ecosystem variation, ecosystem functions and ecosystem processes over time" (CBD 2001, p. 331)

> The concept of sustainable forest management is based on the principle of ecological sustainability and sustainable yield. Sustainable forest management integrates consideration of biodiversity, ecosystem health and vitality, ecological productivity, and socio-economic sustainability within a framework of intergenerational equity and a precautionary approach to forest management. Biodiversity provides the essential underpinning for ecological, social and economic sustainability (Cork 2002) typically provided in the form of ecosystem services. The concept of ecosystem services is incorporated within the principles of sustainable yield; whereby the production of goods, provision of regeneration and stabilising processes for ecosystems, life-fulfilling functions and preservation of opportunities to generations of human societies are implied and assumed.
>
> Ecosystem vitality is an important consideration for ecological sustainability as it refers to the ability of a system to respond to and/or recover from a disturbance. Components of the forest ecosystem (including ecosystem processes) respond to management activities as an integrated functioning whole. Maintaining forest ecosystem vitality under different management regimes requires consideration of the viability of the components of the forest ecosystem such that the functioning whole is not compromised or jeopardised over the foreseeable future.
>
> Sustainable yield is a key element of ecological productivity. It is concerned with maintaining a capacity for the continual flow of products, such as timber and water, and services from a forest ecosystem in ways that ensure the functioning of the forest system as a whole is maintained in perpetuity. The flows of products change over time within defined bounds depending upon the balance and emphasis of sustainable use objectives given environmental and societal needs (Chikumbo *et al. 2001, Turner et al. 2002, quoted in* Davey, S.M., Hoare J.R. L and Rumba, K,E. 2003).
>
> Definition of the United Nations Forum on Forests (UNFF): »Sustainable forest management as a dynamic and evolving concep which aims to maintain and enhance the economic, social and environmental value of all types of forests«.
>
> Definition developed by the Ministerial Conference on the Protection of Forests in Europe (FOREST EUROPE), and adopted by the Food and Agriculture Organization (FAO) defines sustainable forest management as: »Stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfill, now and in the future, relevant ecological, economic and social functions, at local, national and global levels, and that does not cause damage to other ecosystems«.
>
> The objectives of SFM have been defined differently by various organizations. The UNFCCC does not define SFM and creates some confusion by using the term *sustainable management of forests* (SMF) rather than the more common SFM (UNFCCC 2008). The UN's Food and Agriculture Organization (FAO) and UN Forum on Forests (UNFF) have each offered interpretations of the term SMF. The FAO has suggested that SMF refers to the "application of forest-management practices for the primary purpose of sustaining constant levels of carbon stocks over time" (FAO 2009), noting that SMF would not require that other forest values also be sustained. This narrow, carbon-focused approach reflects the FAO and International Tropical Timber Organization (ITTO) definitions of SFM (ITTO 2005, FAO 2010), which give forest managers the discretion to decide which forest values to sustain.
>
> In contrast, the UNFF (2009) cites the NLBI as the relevant authority. The NLBI uses SFM and SMF interchangeably and defines SFM holistically, requiring SFM operations to maintain the full complement of a forest's ecological integrity. The NLBI was developed by the UNFF, the international body tasked with achieving consensus on international forest policy, and was endorsed by the UN General Assembly. Absent a global treaty on forests, the NLBI currently represents the strongest international consensus on SFM.
>
> The discretionary approach proposed by the ITTO and FAO also appears inconsistent with the ITTO's own criteria and indicators for SFM (developed with the FAO), which state that all of its SFM criteria are "essential elements" and are not prioritized (ITTO 2005). The Forest Stewardship Council (FSC), the leading SFM certifier in the tropics, also adopts a holistic approach (FSC 2002), as does most of the literature. The consensus definition of SFM, therefore, encompasses sustaining timber yields while maintaining a forest's full complement of ecosystem services and societal values, which we refer to as *ecological integrity*. However, the SFM objectives listed by different organizations do not yet explicitly require that a forest's structure and composition be maintained. Here, we review scientific findings from forests that are in the tropics and receive more than 1000 millimeters of rainfall annually. (quoted in Zimmerman, B.L. and Kormos, C. (2012)**;** Sustainable forest management (2017) .

Presently, SFM procedures rely on government-mandated cutting cycles, minimum felling diameters, per-unit-area harvest intensities and seed-tree retention rates applied in combination with proven techniques for reducing damage to the residual stand during logging operations (*reduced-impact logging*, RIL).

swidden is an agroforestry system in which woody vegetation is regenerated after a period of annual cropping. Associated with most forested areas of the tropical world. Swidden is often blamed for deforestation but it also plays a role in forest conservation. See also milpa traditional. The term "swidden" derives from the Old Norse "svithinn" meaning "clearing in the forest to be burned" Here we prefer the term to alternative names for this kind of agroforestry, such as "slash-and burn" or "shifting cultivation" that invoke an image of a primitive scorched earth operation, carried out by by shady cultivators who wander randomly through the forest. Swidden, an ancient form of horticulture, rotates crops and woodlands; milpa as practices by ancient and Modern Maya, shapes woodland ecology. Succession is carefully managed to contribute to soil fertility and biodiversity. Low-temperature burning sequesters carbon as persistent biochar. Traditional Maya milpa management supports forest ecosystem services. (Nigh and Diemont 2013)

tension wood reaction wood in angiosperms. It is formed on the upper side of the leaning stem or branches. In dressed temperate hardwoods it can have a silvery shine, in tropical woods it appears as darker streaks, while in green sawn timber the fibres get pulled out, resulting in a wooly surface. Individual tension wood fibres tend to be less heavily lignified than nomal, principally becaue these cells are characterized by the presence of a gelatinous (G) layer which usually replaces the S3 (Walker 1993:186).

terra preta owes its characteristic black color to its weathered charcoal content, and was made by adding a mixture of charcoal, bone, and manure to the otherwise relatively infertile Amazonian soil. A product of indigenous soil management and slash-and-char agriculture, the charcoal is very stable and remains in the soil for thousands of years, binding and retaining minerals and nutrients.

> Terra preta is characterized by the presence of low-temperature charcoal residues in high concentrations;of high quantities of potsherds; of organic matter such as plant residues, animal feces, fish and animal bones and other material; and of nutrients such as nitrogen (N), phosphorus (P), calcium (Ca), zinc (Zn), manganese (Mn).Fertile soils such as terra preta show high levels of microorganic activities and other specific characteristics within particular ecosystems. (Terra preta, 2008)

According to a study led by Dirse Kern of the Museum Goeldi in Belem,

> Terra Preta is "not associated with a particular parent soil type or environmental condition", suggesting it was not produced by natural processes. As a rule, Terra Preta has more plant-available phosphorus, calcium, sulfur, and nitrogen than is common in the rain forest. The soil is specifically well-suited for "tropical fruits". Corn, papaya, mango and many other foods grow at three times the rate than in the "normal" tropical soil. Fallows on the Amazonian Dark Earths can be as short as six months, whereas fallow periods on Oxisols are usually eight to ten years long. Only short fallows are presumed to be necessary for restoring fertility on the dark earths. However, precise information is not available, since farmers frequently fallow the land due to an overwhelming weed infestation and not due to declining soil fertility. In 2001, James B. Petersen reported that Amazonian Dark Earths in Açutuba had been under continuous cultivation without fertilization for over forty years. Bruno Glaser has found that *Terra Preta* is rich in charcoal, i.e. incompletely burnt wood. Terra Preta contains up to 64 times more of it than surrounding red earth. He believes that it acts to hold the nutrients in the soil and sustain its fertility from year to year. (cit. in Coppens)
>
> What's more: the soil behaves like a living organism; it is self-renewing. It acts more like a super-organism than an inert material. It is even more remarkable when it was discovered that it was most likely created by pre-Columbian Indians, between 500 BC and 1500 AD, and abandoned after the invasion of Europeans (other dating suggests 800 BC to 500 AD). Dating of the soil samples has shown that cultivation stopped in 1500, at the time of the Spanish Conquest. Francisco de Orellana, of the Spanish Conquistadors, reported that as he ventured along the Rio Negro, hunting a hidden city of gold, his expedition found a network of farms, villages and even huge walled cities. When later Spanish settlers arrived, none could find the people of whom the first Conquistadors had spoken. Had they been lured here with a lie? And if the farms did not exist, a "city of gold" seemed to have been an even bigger lie. Later, scientists were sceptical of Orellana's account, as in their opinion, the Amazonian soil could not support such big communities. Of course, these scientists were speaking at a time when terra preta was not yet identified. (P. Coppens n.d.)

texture (wood) determined by its cellular construction and refers essentially to the uniformity or otherwise of the cells of the wood, in their size and thickness of their walls. The texture may be very fine, fine, medium, coarse and very coarse.

Theobroma cacao cacao also called the cacao tree and the cocoa tree, small (4–8 m tall) evergreen tree in the family Malvaceae, *T. cacao is widely distributed from southeastern* Mexico to the Amazon basin. There were originally two hypotheses about its domestication; one said that there were two loci for domestication, one in the Lacandon Jungle area of Mexico and another in lowland South America. The flowers are produced in clusters directly on the trunk and older branches; this is known as cauliflory. Cacao beans constituted both a ritual beverage and a major currency system in pre-Columbian Mesoamerican civilization.

tracheary elements the principal water coducting elements of the xylem, mostly vessel element (hardwoods) and tracheids (softwoods).

traditional ecological knowledge (TEK) refers to the evolving knowledge acquired by indigenous and local peoples over hundreds or thousands of years through direct contact with the environment. This knowledge is specific to a location and includes the relationships between plants, animals, natural phenomena and the landscapes that are used for lifeways, such as hunting, fishing, trapping, agriculture, and forestry. TEK is an accumulating body of knowledge, practice, and belief, that encompasses the world view of indigenous people which includes ecology, spirituality, human and animal relationships and more. TEK has become increasingly recognized as being valuable for natural resource management, including adaptation to climate change.

TEK is an important source of ideas, inspiration and designs to help our profession meet this challenge. TEK refers to ecological knowledge and practices of indigenous and local cultures. Because these practices originated and evolved prior to the era of fossil-fuel dominance, they were designed and have continuously adapted to utilize renewable energies and resources. TEK is also well suited to sustainable design due to philosophical differences with Western science and culture. While Western culture views society as apart from and controlling ecosystems, indigenous cultures routinely see themselves as embedded within ecosystems. Because TEK has declined as the influence of Western culture has spread, there is an urgent need to identify and apply this knowledge for future benefit. Collaboration with scientists can help raise the social standing of indigenous people and of TEK within their own communities, thus contributing to cultural survival while maintaining this information. Engineering including water management and agriculture in the Americas are highlighted. (Martin JF Roy, ED, Diemont SAW and Ferguson BG. 2010).

transcription the adaptation of a composition for a medium other than its original one. (Randel 2003:902)

tree a highly compartmented, perennial, woody, shedding plant that is usually tall, single-stemmed and long-lived. Phanerophyte that bears its perennating buds more than 25 cm above the level of the soil.

UNCED United Nations Conference on Environment and Development (UNCED), Earth Summit. 1992

UNFF United Nations Forum on Forests In 2006, at its sixth session, UNFF agreed on four shared Global Objectives on Forests which seek to:

> a. Reverse the loss of forest cover worldwide through sustainable forest management (SFM), including protection, restoration, afforestation and reforestation, and increase efforts to prevent forest degradation;
>
> b. Enhance forest-based economic, social and environmental benefits, including by improving the livelihoods of forest-dependent people;
>
> c. Increase significantly the area of sustainably managed forests, including protected forests, and increase the proportion of forest products derived from sustainably managed forests; and
>
> d. Reverse the decline in official development assistance for sustainable forest management and mobilize significantly increased new and additional financial resources from all sources for the implementation of sustainable forest management.

Usumacinta river the seventh largest river in the world based on volume of water.

uyanchunil kol "the first milpa" made in March before the rain begins and the ground is still made. Originally, uyanchunil kol referred to a milpa cut from virgin/primary forest. But since the area was decreed a protected site in the 1990', this practice is infrequent. Instead, fallow milpas are rotated and reverted back into cultivation. So today, the uyanchunil kol refers to a milpa cut from secondary forest. (Cook, 2016, p. 41)

wood *secondary xylem,* a cetripetal derivative of the vascular cambium; the complex of differently oriented tissues (anisotropy). Due to the well-defined anisotropic nature of wood, its properties are typically oriented.

woody plant a plant that undergoes secondary growth by means of a vascular cambium which produces secondary xylem (wood) and secondary phloem. Alternative is an herbaceous plant.

WWF's Global 200 is the list of ecoregions identified by WWF, the global conservation organization, as priorities for conservation. It is a first attempt to identify a set of ecoregions whose conservation would achieve the goal of saving a broad diversity of the Earth's ecosystems. These ecoregions include those with exceptional levels of biodiversity, such as high species richness or endemism, or those with unusual ecological or evolutionary phenomena. The WWF assigns a conservation status to each ecoregion in the Global 200: critical or endangered; vulnerable; and relatively stable or intact. Over half of the ecoregions in the Global 200 are rated endangered. (Global 200 2018)

yum ik' ob (Yucatec) wind tender controls milpa fires

xylem the water- and mineral-conducting portion of the vascular tissues, containing either tracheids or vessel elements or both; parenchyma, fibers, and sclereids are also frequent components of xylem. Alternative *phloem*.

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