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TROPICAL TIMBER 2050

An analysis of the future supply of and demand for tropical timber and its contributions to a sustainable economy

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INTERNATIONAL TROPICAL TIMBER ORGANIZATION

TROPICAL TIMBER 2050

An analysis of the future supply of and demand for tropical timber and its contributions to a sustainable economy

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The International Tropical Timber Organization (ITTO) is an intergovernmental organization promoting the conservation and sustainable management, use and trade of tropical forest resources. Its members represent the bulk of the world's tropical forests and of the global tropical timber trade. ITTO develops internationally agreed policy documents to promote sustainable forest management and forest conservation and assists tropical member countries to adapt such policies to local circumstances and to implement them in the field through projects. In addition, ITTO collects, analyzes and disseminates data on the production and trade of tropical timber and funds projects and other actions aimed at developing sustainable forest industries at both the community and industrial scales. Since it became operational in 1987, ITTO has funded more than 1200 projects, pre-projects and activities valued at more than USD 430 million. All projects are funded by voluntary contributions, the major donors to date being the governments of Japan and the United States of America.

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Cover image: Tropical forest above a floor made of tropical timber. © POND5/foto76

CONTENTS

Tables

Figures

FOREWORD

ITTO undertakes a wide range of work on incentives to promote sustainable forest management in tropical countries. Recently, this has included the development of models for forecasting trends in tropical timber supply and demand with a view to predicting regional surpluses and deficits of timber supply that appropriate incentives might help address. Such models can be crucial tools for planning policies at the national and international levels, as well as for forecasting likely recovery times from shocks to the sector—such as that caused by the ongoing COVID-19 pandemic.

This report, an output of ITTO's Biennial Work Programme activity on legal and sustainable supply chains, describes a model developed to forecast trends in tropical timber supply and trade to 2050. It analyzes a number of potential scenarios and examines previous economic and non-economic shocks to estimate the likely time required for the sector to recover to pre-pandemic levels.

The model and this report are part of an ongoing effort by ITTO to provide knowledge and learning experiences on potential frameworks for incentivizing investments in natural tropical forests and the sustainable production of the wood and non-wood products arising from them. The wealth of information herein will help engage both governments and private-sector players more prominently in climate-change mitigation and REDD+ processes linked to tropical forests.

The work summarized in this report took place in parallel with a related activity that examined existing and potential incentive schemes for sustainable forest management in tropical countries, based on eight detailed case studies in the three main tropical regions. ITTO published that report in April 2021 as *Fiscal and Non-fiscal Incentives for Sustainable Forest Management* (Technical Series No. 48).

ITTO is grateful to the authors of the present report—Christian Held, Eva Meier-Landsberg and Verónica Alonso from the Germany-based company, Unique Forestry and Land Use—for their tireless work on the model and this report. Alain Karsenty, the lead consultant who oversaw the work in the parallel study referred to above, also provided many insights to this report. Finally, we thank the Government of Germany in particular and also the governments of the United States of America and Japan for making funding available to carry out this important study, which I commend to all ITTO members and stakeholders.

Steve Johnson
ITTO Officer-in-charge
Yokohama, July 2021

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The authors thank ITTO for its support, flexibility and constructive reviews, as well as for making ITTO data and market insights available on tropical timber producer countries.

Thanks are also due to the Government of Germany (through the Federal Ministry of Food and Agriculture) for providing the grant to ITTO that allowed this study. Alain Karsenty, who led a parallel study on incentives for sustainable forest management, provided valuable feedback in addition to coordinating and providing results from his research.

Since this was a desk-based exercise, it is important to acknowledge the work on reliable statistics on timber production and wood products carried out across the globe by national statistics offices, which frequently work in difficult environments and still come up with much useful information. Considerable progress has been made, and the quality of information available in international forest products statistics has improved substantially for many countries. In addition to ITTO's databases, FAO's forest products database is of great value for understanding global timber production and trade trends.

The authors extend their thanks to the many researchers who work on basic research and innovative topics to advance the role of timber as a sustainable material, while highlighting the need to bring together the environmental and societal requirements of modern silviculture and forest management.

Finally, many thanks are due to Alastair Sarre, whose editing contributed greatly to the readability of this report, and to Claudine Fleury and Claudia Adan, who produced the French and Spanish translations, respectively.

ABBREVIATIONS AND ACRONYMS

CBFM	community-based forest management
CLT	cross-laminated timber
EU FLEGT	European Union Forest Law Enforcement, Governance and Trade
FAO	Food and Agriculture Organization of the United Nations
GDP	gross domestic product
GFPM	Global Forest Production Model
Gt	gigatonne(s)
ha	hectare(s)
IRW	industrial roundwood
ITTO	International Tropical Timber Organization
m	metre(s)
MSMEs	micro, small and medium-sized enterprises
RWE	roundwood equivalent
SFM	sustainable forest management
SMEs	small and medium-sized enterprises
SSP	shared socioeconomic pathway
UN	United Nations
USD	United States dollar(s)

EXECUTIVE SUMMARY

Tropical timber supply and demand in 2050

Production of roundwood in tropical producer regions

The overall production of roundwood in tropical producer regions will decline due to decreasing woodfuel consumption (270 million m³ less woodfuel in 2050 than in 2015). Nevertheless, total woodfuel production in 2050 (718 million m³) will be higher than industrial roundwood (IRW) production in that year.

IRW production in sub-Saharan Africa, Latin America and Southeast Asia will grow by 24% by 2050 (to 533 million m³) compared with 2015. The three regions will be net exporters of IRW in that year, producing 19% of global IRW production.

Plantation forestry will be the main source of IRW in tropical producer regions in 2050. With limited expansion possibilities for large-scale plantations, smallholders and agroforestry systems will be increasingly important for production. All production systems need further improvements in productivity and timber quality. Private equity capitalization and incentives for small to large plantation-based enterprises will be key for stimulating sector growth.

IRW production in natural forests will remain fairly stable. To maintain market share for tropical timber derived from natural forests, sustainable forest management will need to be more competitive by expanding the range of commercial species and including revenue streams from carbon and ecosystem services. Industrial concessions and communities will need to improve their silviculture and obtain third-party certification of legality and sustainability.

Production and consumption of tropical timber products

The production of tropical primary-processed wood products will be 36% higher in 2050 (at 476 million m³ roundwood equivalent) than in 2015, comprising 12% of global production. The share of global consumption of primary-processed wood products in tropical producer regions will be 12%, which is disproportionately low considering that 38% of the world population will live in these regions by 2050.

The forest industry in tropical producer regions will have to modernize and invest more than USD 40 billion by 2050 in the expansion of processing capacities. Employment in forest industries in tropical producer regions will grow by 1.3 million jobs by 2050, to 7 million.

Meeting future employment needs in the wood-processing industries in tropical producer countries will require a well-trained workforce, which still needs to be developed. Forest enterprises face several challenges in enhancing productivity and value-adding, especially informality, restricted access to capital, and a lack of business development support. These challenges need to be overcome to ensure global competitiveness and an adequate timber supply for future employment and sustainable growth in producer countries.

Transformative public and private investments in the tropical timber industry will be required to overcome the abovementioned challenges. Public investment would facilitate the raising of private investments at scale and is needed to stimulate sustainable growth. Any effort aimed at enhancing tropical timber industries must be harmonized with the actions required to achieve the widespread adoption of sustainable forest management for tropical timber production.

Synthesis of tropical timber in the sustainable economy of 2050

Economic growth will lead to a net increase in global material use of nearly 100% by 2050. The vast majority of these materials will be non-renewable, and their use is closely linked to negative externalities such as greenhouse-gas emissions, biodiversity loss and public health issues.

As tropical low- and middle-income countries rapidly grow their economies, building a sustainable and resilient future requires finding strategies to mitigate the negative effects of material use and resource extraction.

Tropical timber can play a major role in slowing biodiversity loss, ecosystem degradation, social inequality and other negative externalities related to the extraction of natural resources in tropical regions.

The enhanced use of tropical timber should be based on the following complementary strategies and key actions:

- increasing resource efficiency, such as reducing waste through technical improvements in production processes and the digitization of value chains, using side-streams and byproducts and, where feasible, applying cascade use;
- changing consumption patterns, such as that projected for the declining use of woodfuel, and allocating freed resources to new processing pathways;
- developing regional processing industries to reduce export volumes and increase domestic value-added;
- improving forest management, for example by expanding certification and improving management planning. Production systems will need to be modified to enable higher harvesting rates, improve forest health and produce higher-value assortments; and
- exploring opportunities and striving for timber-focused investments in natural capital—green investments, investments in nature-based solutions such as tropical rainforest conservation and landscape restoration, and subsidies or tax reductions for "green" products will be incentives for increasing natural capital and economic efficiency.

ITTO's role in the tropical forest-sector transition and modernization

The present study identifies future opportunities and challenges for the tropical forest sector. In view of these, ITTO can take a leading role in guiding the tropical forest sector's transition and modernization in the decades to come. The study concludes with a set of activities that could be accommodated or strengthened in ITTO's work programme, as set out in the following table.

Future fields of activity in the tropical-forest-sector transition and modernization

Focus area	Proposed fields of future activities
1 Sustainable forest management: managing and conserving tropical forests	Develop innovative business models and multiple revenue streams for natural forest management, including "concessions 2.0"
	Develop concepts to provide the raw materials of the future: high-quality raw materials for modern industries from productive plantations that are resilient to climate change
2 Economics, statistics and markets: improving the transparency of—and expanding international markets for—tropical timber	Support international initiatives that promote timber trade, legality and transparency through data analytics and impact monitoring
	Analyse current and future market requirements and understand the transitions required for tropical timber supply and value chains
3 Sustainable forest industries: developing efficient and value-adding tropical forest-based industries	Promote innovation and digitalization in tropical timber sectors, from forest information systems and timber production to wood-product processing and consumer requirements
	Develop incentive and capitalization schemes for tropical forest-sector small and medium-sized enterprises
4 Climate-change mitigation and adaptation: addressing climate change	Promote the substitution of non-renewable materials with sustainable timber to mitigate greenhouse-gas emissions and other negative externalities associated with the use of non-renewable materials
	Cooperate with initiatives that address deforestation and degradation and promote reforestation for commercial purposes
5 Capacity building: raising the capacity of forest stakeholders to manage and benefit from their resources	Promote diversity in tropical timber production to enable broad participation, ownership and benefit-sharing in sustainable forest management, including in small to large enterprises and between private and public actors, genders and generations
	Facilitate knowledge transfer and provide training and education to meet future silvicultural and industry labour requirements

1 GENERAL APPROACH

Key points

- The study uses the Global Forest Product Model and publicly available data to provide projections to 2050 for tropical timber supply and demand and trends in tropical timber resources, products and industries.
- In making its projections, the study assumes the "middle of the road" shared socioeconomic pathway.
- The study discusses the potential impact of economic fluctuations on timber production based on an analysis of global and regional data for gross domestic product and tropical wood-product production and consumption.
- It also analyzes global material use and the potential of tropical timber to provide sustainable substitutes for non-renewable materials.

This study summarizes the status of tropical timber production and presents projected future developments in tropical timber supply and demand to 2050. The forecast data used in the study rely mainly on the following publicly available resources:

- Food and Agriculture Organization of the United Nations (FAO) data on forest area and forest product production and trade, as contained in the FAOSTAT database (FAO 2020).
- Projections generated by the Global Forest Production Model (GFPM) (Buongiorno et al. 2003; Buongiorno 2015) for forest products and forest area (mid-case scenario).
- United Nations (UN) and World Bank/ International Finance Corporation data and forecasts for population and gross domestic product (GDP).
- National statistical data on forest-sector employment and forest industries.
- Studies and scientific papers.

Figure 1 summarizes the main work packages in this study.

Tropical producer regions

This study focuses on three tropical timber-producing regions: Latin America and the Caribbean, Southeast Asia and sub-Saharan Africa. For the purposes of the study, these regions are referred to generally as tropical producer regions. The full list of countries, by region, is in Annex 1.

To ensure a full picture of future timber supply and demand, the study compares the situation in the tropical producer regions with other regions (Table 1), with a focus on China, Europe and North America; various other regions are included but discussed only in certain contexts.

Tropical timber production and product classification

In this study, tropical timber is defined as any wood produced in tropical producer regions (see above).[1] This includes:

- tropical hardwoods (typically from natural forests);
- plantation hardwoods (e.g. *Eucalyptus*, *Acacia*, teak, *Gmelina* and sandalwood); and
- plantation softwoods (e.g. pines, cypress).

Consequently, the consumption of tropical timber equals the production of wood in tropical producer regions. On the other hand, the consumption of timber in these regions includes wood products imported from non-tropical producer regions. Thus, the data presented in this report require careful reading to avoid confusion.

Tropical timber products are defined here as comprising all wood-based products in the FAO products definitions produced in tropical timber producer regions.[2] This definition is adopted due to limitations in production and trade statistics, which do not allow reliable differentiation between tropical and temperate species in individual countries, particularly when dealing with processed products. On the other hand, using this definition creates sources of error. For example, it includes Brazil and South Africa, which are not wholly located in the tropics.

1 The terms "timber" and "wood" are generally used interchangeably in this report.
2 www.fao.org/forestry/statistics/80577/en

Figure 1: Work packages

Key parameters and database	• Specification of tropical producer regions • Definition of product groups • Forest area and timber resources • Validation of GFPM database
Status of tropical timber supply and demand	• GFPM-based projections of tropical timber supply and demand • Status of and trends in tropical timber resources • The structure of forest industries and tropical timber resources
Tropical timber in a sustainable economy	• Analysis of global material use and the future role of the tropical regions • Description of new markets for wood products in tropical producer regions

Table 1: Regions used in the study

Tropical producer regions[a]	Other regions
Latin America and the Caribbean	China
Southeast Asia[b]	Europe
Sub-Saharan Africa	North America
	Northern Africa/Western Asia
	Oceania
	Rest of Asia (Central and East Asia)
	South Asia

Notes: [a] Non-tropical countries such as Argentina, Chile and South Africa are included in these groups because they have subtropical zones. [b] Southeast Asia comprises Brunei, Cambodia, Indonesia, the Lao People's Democratic Republic, Malaysia, Myanmar, the Philippines, Singapore, Thailand, Timor-Leste and Viet Nam. South Asia comprises Afghanistan, Bangladesh, Bhutan, India, Iran, Maldives, Nepal, Pakistan and Sri Lanka.

Figure 2 shows the wood-product categories examined in this study. The main product groups are woodfuel; industrial roundwood (IRW); saw/veneer-log-based products (sawnwood, veneer and plywood); and wood-fibre-based products (particleboard/fibreboard and woodpulp).

If not specifically mentioned, the wood-product volumes presented in this study are roundwood equivalent (RWE). Primary-processed wood products are converted to RWE to allow comparisons and to indicate the raw-material volumes involved in production and processing. Conversion coefficients for RWE are available in Annex 2.

Figure 2 shows the estimated sources of raw material for the various product groups in tropical producer regions. The estimates assume that wood-fibre-based products are sourced primarily from plantations and that total IRW production in the tropical producer regions comprises 60% plantation timber (Payn et al. 2015) (the remaining volume shares are attributed to natural-forest production).

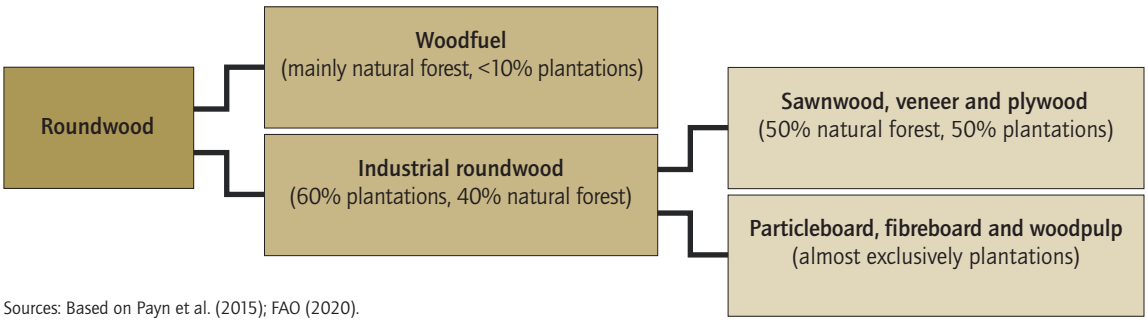
The Global Forest Product Model

The forecasts of tropical timber consumption and supply in 2050 presented here are based largely on projections obtained from the GFPM (Buongiorno 2015; Annex 3).

The GFPM is a dynamic economic model of worldwide production, consumption and trade of forest products. It is a general-equilibrium model, which, for every year and country, simulates changes in forest area, stock, production, consumption and trade.

The model entails scenarios of projected socioeconomic global change called "shared socioeconomic pathways" (SSPs), of which five exist; they are used widely to derive scenarios of greenhouse-gas emissions for policymaking purposes. The Sixth Assessment Report on climate change by the Intergovernmental Panel on Climate Change (IPCC), due to be published in 2021, will use SSPs. The GFPM and the IPCC both use SSP 2—the

Figure 2: Tropical timber product groups and estimated sources of raw material



Sources: Based on Payn et al. (2015); FAO (2020).

"middle of the road" scenario—as their mid case. In SSP 2, "The world follows a path in which social, economic, and technological trends do not shift markedly from historical patterns. Development and income growth proceeds unevenly, with some countries making relatively good progress while others fall short of expectations. Global and national institutions work toward but make slow progress in achieving sustainable development goals. Environmental systems experience degradation, although there are some improvements and overall the intensity of resource and energy use declines. Global population growth is moderate and levels off in the second half of the century. Income inequality persists or improves only slowly and challenges to reducing vulnerability to societal and environmental changes remain" (Riahi et al. 2017).

On the supply side, the GFPM projections are based on assumptions regarding forest-area loss due to the expansion of agricultural land and the increasing role of plantations as the main source of supply (Daigneault 2018).

A shortcoming of the GFPM model is that it lacks a clear attribution of timber sources (e.g. the volumes coming from plantations versus natural forests). The GFPM's baseline projections for primary-processed wood products reflect moderate development paths and consider foreseeable megatrends.

Minor edits were made to the GFPM's generic output numbers, but only when we discovered obvious data bugs—for example when a country showed zero production or zero consumption by 2050 (e.g. Nigeria, which was showing zero woodfuel production and consumption). Where indicated by plausibility, an average annual growth rate based on historical data was applied.

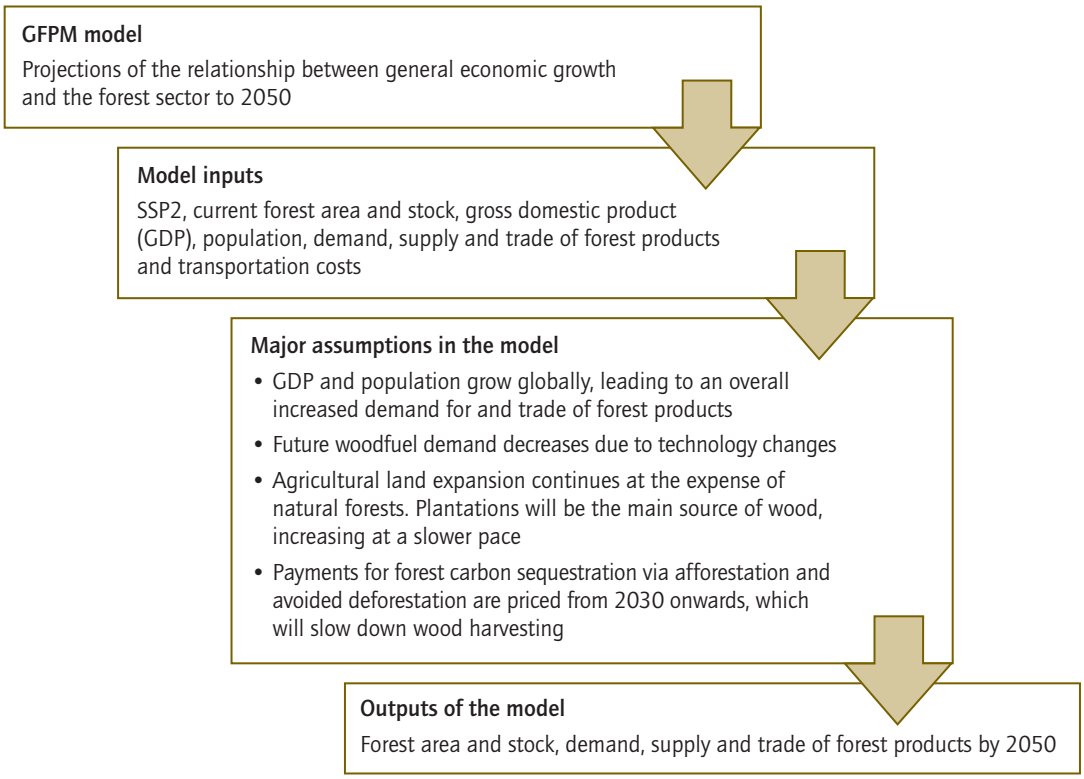
Like every model, GFPM has its limitations in reflecting real-world dynamics. It should be understood as a strong reduction of a complex reality in order to enable the envisioning of certain aspects of the future. Developments in emerging markets are especially difficult to anticipate. Nonetheless, the GFPM is currently the only model that enables wood production and consumption projections at the country level while factoring in reciprocal effects of the resource base and market demand and considering global megatrends.

The most recent version of the GFPM has been calibrated for the base year of 2015 and draws on historical FAO production and consumption data. Hence, the analysis and presentation of the GFPM-derived forecast data compare 2015 and 2050. FAO data were used for the analysis and presentation of historical time series.

Because this study comes at a time of global economic turmoil due to the COVID-19 pandemic, the forecasts herein need to be contextualized carefully. The model configuration does not integrate 2020 production and consumption data and therefore does not take into account the impacts of the pandemic. The study discusses the potential impact of economic fluctuations on timber production based on a historical analysis of global and regional GDP data in relation to the production and consumption of wood products in tropical producer regions.

Figure 3 illustrates the key parameters and assumptions made by the GFPM.

Figure 3: The GFPM model—inputs, trends and outputs



The impact of informal and illegal timber production on model forecasts

Historical data and projection figures in this report draw on the GFPM, which relies on FAO-reported data. As widely acknowledged, FAO is the most comprehensive and reliable source of data on forests and wood-product production and consumption. It is also known, however, that roundwood and wood-product volumes may go unreported when informally or illegally produced. Significant deviations in real product volumes from those reported could seriously affect projections. This is especially true for countries in tropical regions where governance structures and reporting procedures may be relatively less developed.

To assess the magnitude of potential deviations in harvested and processed wood volumes, data from case studies on illegal and informal forest operations were compared against FAO-reported information (see Annex 4). This comparison produced a highly heterogeneous picture, ranging from the underreporting of total volumes in FAO data, to exact matches between FAO data and those from case studies, to overestimates. Nevertheless, the weighted average of 109 million m³ of IRW production derived from case studies in eight tropical countries is only 4% higher than that derived from FAO data. There was wider deviation in sawnwood production, with the weighted average of 7.5 million m³ for sawnwood production in ten countries indicating that FAO data underreported by 27% compared with the case studies.

The input assumptions for the GFPM projections seem reliable for IRW production within the given range of uncertainties for any forecast model. Projections for tropical sawnwood show less accuracy, but there were no systematic deviations and the case studies were therefore considered unrepresentative of the entire tropical forest sector. Hence, the authors did not alter the GFPM's projected numbers to maintain the integrity of model.

2 TROPICAL TIMBER SUPPLY AND DEMAND TO 2050

Key points

- Total global production of roundwood will increase by 13% by 2050, to 4.3 billion m³. The total production volume of roundwood in tropical timber producer regions in 2050 is projected at 1.3 billion m³, of which woodfuel will account for 57%.
- Global woodfuel production will decrease from 1.8 billion m³ in 2015 to 1.5 billion m³ in 2050, a decline of 21%. The decrease will mainly be due to reduced consumption in sub-Saharan Africa.
- Global industrial roundwood production is projected to grow by 45% by 2050, to 2.8 billion m³, but tropical production will increase by only 24%, to 533 million m³.
- All tropical timber producer regions will be net exporters of industrial roundwood by 2050.
- Tropical industrial roundwood will increasingly be supplied by plantations, with natural forests projected to account for 27% of the volume in 2050, down from 35% in 2015.
- To maintain market share, timber production in tropical forests needs to become more competitive by expanding the range of commercial species and including revenue streams from carbon and ecosystem services.
- Industrial concessions and communities will need to improve silviculture and obtain third-party certification of legality and sustainability.
- With limited expansion possibilities for large-scale plantations, smallholders and agroforestry systems will become important producers. Both need further improvements in productivity and timber quality.
- Private-equity capitalization and incentives for small-to-large plantation-based enterprises will be crucial for stimulating sector growth.

This chapter summarizes key numbers in the supply of, and demand for, roundwood in tropical producer regions to 2050, as projected by the GFPM. It discusses: the impacts of global GDP fluctuations on tropical roundwood production and how these might alter GFPM results; actual and future production systems of tropical roundwood; and challenges for tropical roundwood production given changing societal and economic demands. The chapter concludes with a set of key actions for shaping the role of tropical roundwood production in 2050.

Production

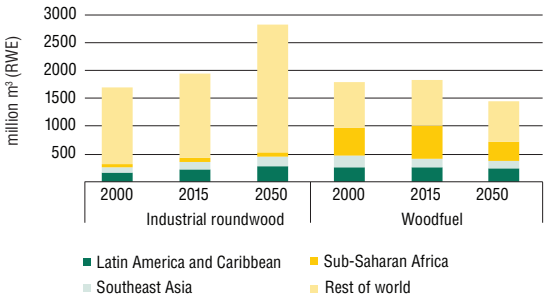
Global production of all roundwood will grow by 13% by 2050, to 4.3 billion m³, driven by increasing demand for IRW. The increase in global IRW production to 2.8 billion m³ (45%) in 2050 will occur mainly in Europe and North America. The forecast data show that IRW production in tropical producer regions will grow by 24%, from 429 million m³ in 2015 to 534 million m³ in 2050 (Figure 4). Southeast Asia is expected to grow its production by 26%, from 136 million m³ to 173 million m³. Production will increase in Latin America and the Caribbean by 25% (from 227 million m³ to 283 million m³) and in sub-Saharan Africa by 19% (from 65 million m³ to 78 million m³).

Woodfuel production will decline by 21% in 2050 (to 1.4 billion m³) (Figure 4), due mainly to a decline in consumption in sub-Saharan Africa. Sub-Saharan Africa will remain the major woodfuel-consuming region, however, and there will still be a shortfall in production of 18 million m³ (Figure 5).[3,4]

The consumption of modern biomass (e.g. wood pellets and woodchips) is not directly reflected in and cannot be extracted from the GFPM; volumes are indirectly included in IRW volumes. Demand for modern biomass is projected to grow substantially, especially in industrialized economies (OECD 2018).

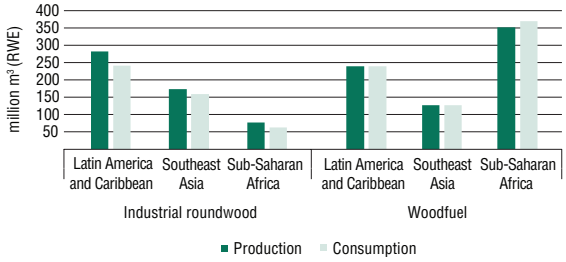
3 Detailed forecasts for world regions are available in annexes 3 and 9.
4 Annex 5 discusses the accuracy of long-term woodfuel consumption projections for sub-Saharan Africa. A comparison of historical forecast studies shows that the GFPM has been fairly accurate in projecting woodfuel consumption in Africa. Other forecast approaches overestimated woodfuel consumption by more than 20%.

Figure 4: Industrial roundwood and woodfuel production, 2000, 2015 and 2050



Sources: FAO (2020); GPFM, corrected/adjusted by the authors.

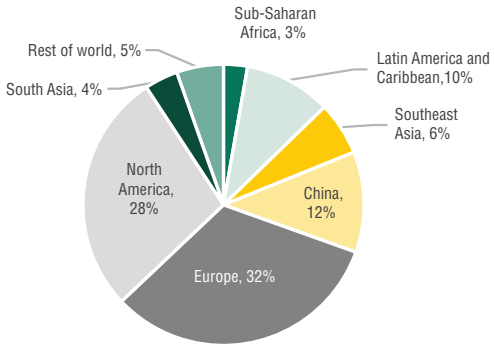
Figure 5: Projected production and consumption of industrial roundwood and woodfuel in tropical producer regions, 2050



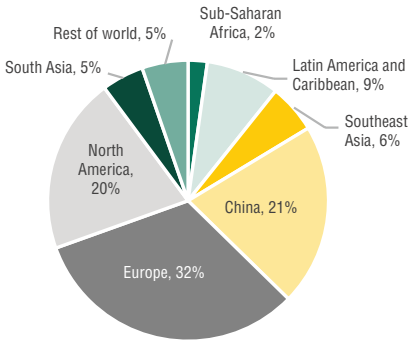
Sources: FAO (2020); GPFM, corrected/adjusted by the authors.

Figure 6: Projected global industrial roundwood production and consumption in 2050, by selected world region

Industrial roundwood production, 2050



Industrial roundwood consumption, 2050



Source: GPFM, corrected/adjusted by the authors.

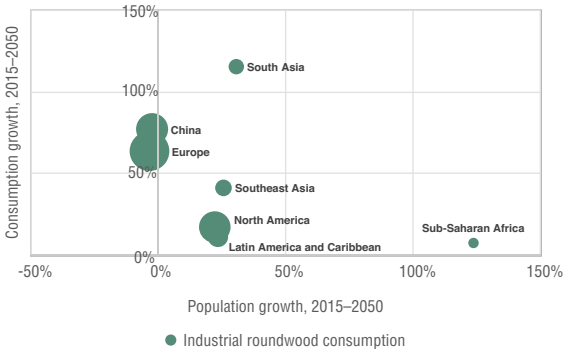
Consumption

The moderate growth in IRW production in tropical producer regions to 2050 (24%) compared with global growth rates (45%) is explained mainly by the relatively low rate of growth in consumption projected for the tropical producer regions. Only a 20% increase is anticipated by 2050 due to relatively low growth in demand for primary-processed wood products in these regions as well as to bottlenecks in industrial processing and limitations posed by IRW production systems. These aspects are discussed later.

In general, the domestic uptake of IRW is projected to be comparatively low in tropical producer regions. Thirty-eight percent of the global population will live in tropical producer regions by 2050 but only 17% of global IRW will be consumed there (Figure 6). Wood consumption in those economies will not catch up with industrialized economies by 2050, despite population growth and the considerable potential for growth in market demand (Figure 7). This won't change unless wood-product consumption increases in the construction and manufacturing sectors in tropical producer regions.

More positively, woodfuel consumption is projected to drop substantially, notably in sub-Saharan Africa, where per-capita consumption will decline from 0.6 m³ in 2015 to 0.2 m³ in 2050 (Figure 8). Nevertheless, given the large increase in population projected in sub-Saharan Africa over the period, the region's woodfuel demand will still be the highest of all the world regions (Figure 4).

Figure 7: Population growth, consumption growth and total consumption of industrial roundwood, 2015–2050, by selected world region



Note: Europe = approx. 0.9 billion m³ (RWE).
Sources: GPFM, corrected/adjusted by the authors; UN (2020a).

will be a net exporter of 14 million m³ of IRW per year, supplied mainly by Malaysia, Viet Nam and the Lao People's Democratic Republic (in descending order by volume). Latin America will also be a net exporter of IRW in 2050, at 42 million m³, with Brazil and Chile contributing 22 million m³ and 17 million m³, respectively. Sub-Saharan Africa's net trade surplus will reach 15 million m³ in 2050, almost exclusively because of net exports from South Africa of 14 million m³. IRW exports in 2050 will mainly target markets in Asia, especially China and South Asia. North Africa will also be an important importer of IRW. East Africa, the Caribbean, Peru and the Philippines will experience significant IRW supply gaps by 2050.

Figure 8: Per-capita consumption of industrial roundwood and woodfuel in 2015 and 2050, by selected world region

Sources: GPFM, corrected/adjusted by the authors; UN (2020a).

Trade

Along with domestic consumption, exports will be a main driver of IRW production growth in tropical producer regions. For example, around 75% of the projected growth in IRW production in Latin America and the Caribbean to 2050, and 38% of growth in Southeast Asia, can be explained by increasing IRW exports.

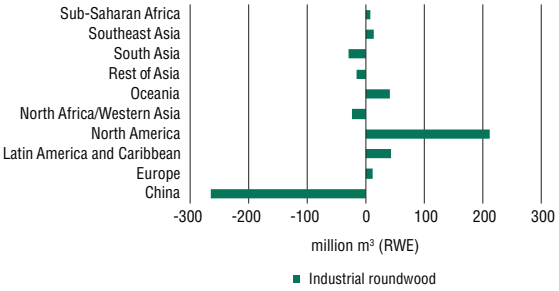
By 2050, all tropical producer regions will be net exporters of IRW[5](Figure 9; Annex 9), mainly consisting of plantation roundwood. Southeast Asia

5 Note that the net export volume projected by the GFPM indicates the trade balance, and exports and imports may be higher. Further, net exporters and net importers will still be importing and exporting.

Effects of GDP fluctuations on tropical timber production

Recent decades have shown that global economic fluctuations affect global and tropical timber production, with economic shocks resulting in substantial production declines. Typically, tropical IRW production has recovered within three to five years after economic shocks—more dynamically than the global average. In general, GDP fluctuations do not have a strong effect on woodfuel consumption, the exception being in Latin America, where the share of industrial woodfuel consumers is relatively high, and consumption patterns suggest a modest relationship with GDP.

Figure 9: Trade balance of industrial roundwood in 2050, by selected world region



Source: GPFM, corrected/adjusted by the authors.

Industrial roundwood

The GFPM projections presented above indicate moderate development paths and consider foreseeable megatrends. But timber is a vital raw material for global industries, and its consumption is directly related to short-term economic dynamics. Here, we examine historical developments in the global economy and draw lessons for understanding the potential impacts of GDP fluctuations on the projections.

Past decades have seen several economic fluctuations with significant impacts on global timber consumption patterns—some of global magnitude, others more regional in scale. Experts and science suggest that the frequency of such events will increase in the future (OECD 2010; Zseleczky and Yosef 2014).

At the time this report was produced, the COVID-19 pandemic was causing a unique shock to the global economy, resulting in a drop of global GDP of 4.4% in 2020 (IMF 2020). The crisis is likely to have affected timber production in 2020. Although the impact on timber production could not be quantified at the time of writing, the drop may be similar to previous economic shocks. The highest reduction in timber production in recent decades occurred during the global financial crisis of 2009, when global IRW production fell by more than 6% for two consecutive years.

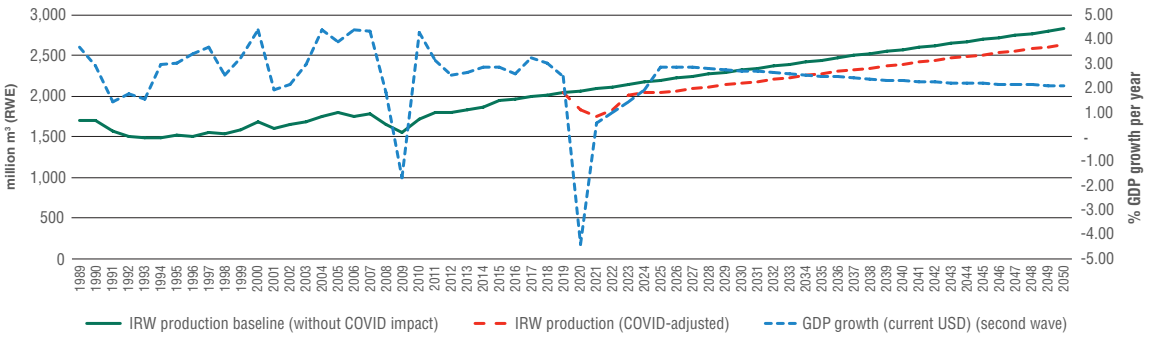
Global timber production recovered within three to five years after economic downturns in 2001 and 2009 to reach pre-crisis production levels (Figure 10). But history also shows longer recovery periods; for example, global timber production took more than ten years to recover after the collapse of the socialist economies in the 1990s.

Assuming that the world economy will recover from the impacts of the pandemic by the end of 2021 (according to the International Monetary Fund's scenario of June 2020), it seems reasonable to assume that global timber production will reach pre-crisis levels by 2026. This will affect GFPM forecasts of timber consumption. The pre-crisis configuration of the GFPM projected a global demand for IRW of around 2.9 billion m³ by 2050. Factoring in a pandemic-induced five-year recovery period, the consumption volume in 2050 will be around 2.6 billion m³ (Figure 10).

In light of the pandemic, the annual growth rate of IRW production will drop from 1.1% to 0.9% between 2020 and 2050, still higher than the growth rate of 0.7% achieved in the 30-year period between 1989 and 2019.

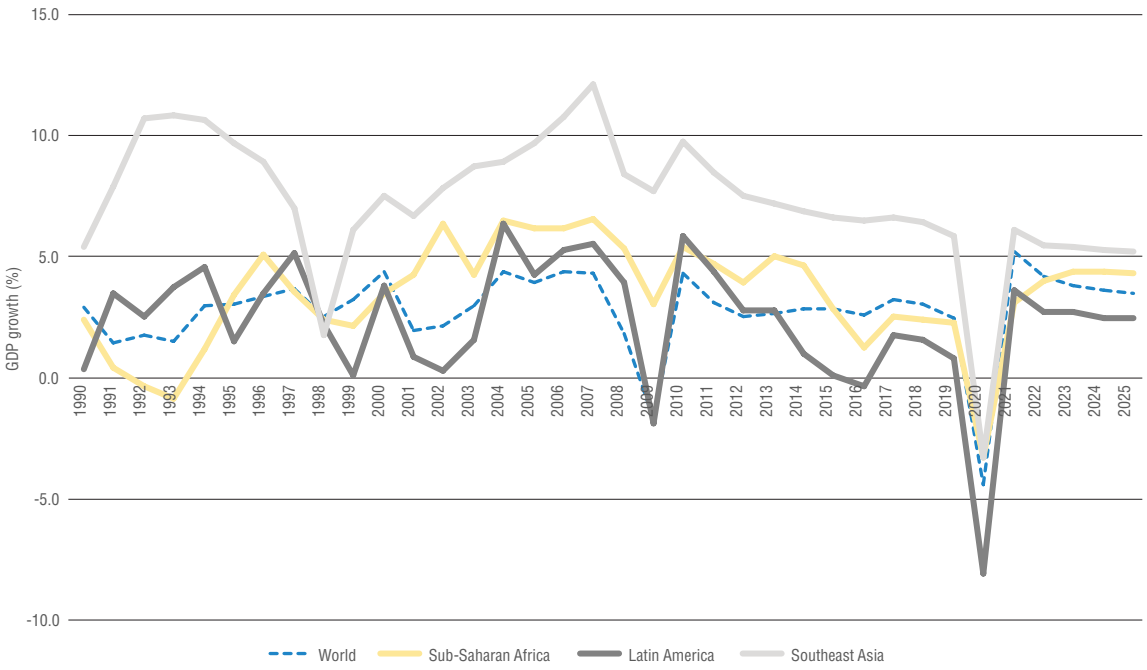
Timber production in the tropical producer regions of sub-Saharan Africa, Latin America and the Caribbean and Southeast Asia has reacted in different ways in the past to global economic shocks

Figure 10: Global industrial roundwood production and GDP growth, 1989–2050



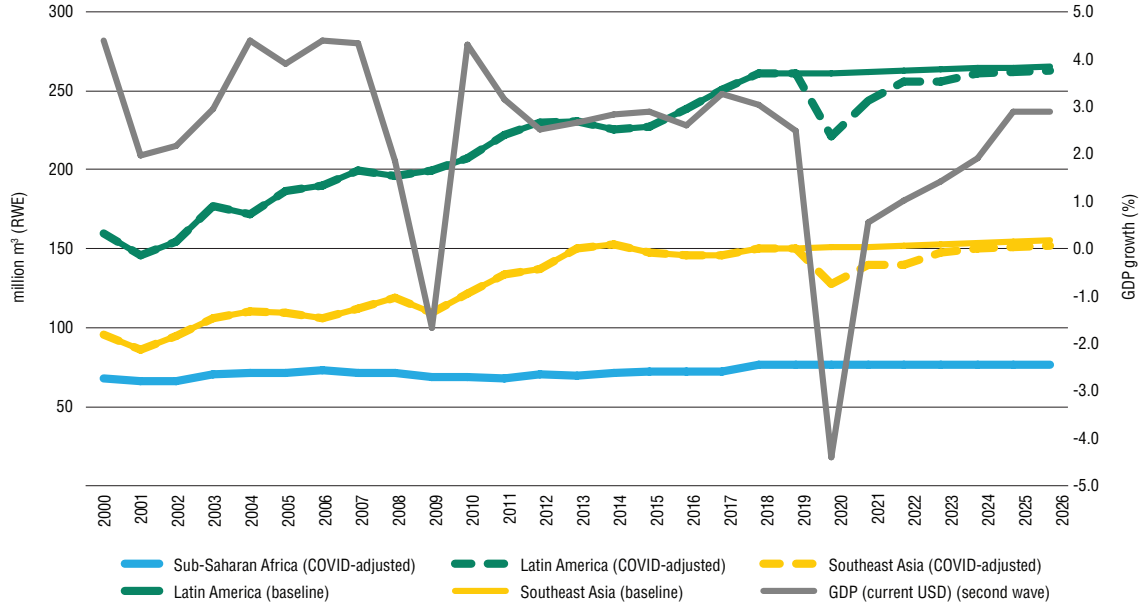
Sources: FAO (2020) (baseline years 1989–2019); GFPM (baseline years 2020 to 2050); World Bank (2020) for GDP 1989–2019; IMF (2020) for GDP 2020–2050; authors' elaboration for COVID-19-adjusted IRW production.

Figure 11: GDP growth rates, tropical producer regions and world, 1990–2025



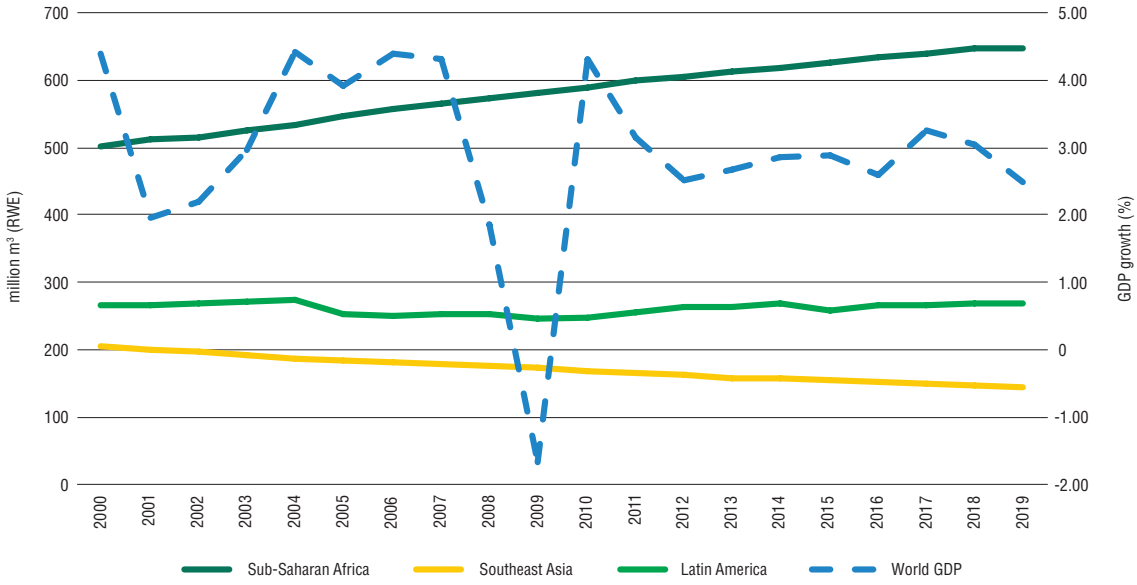
Sources: World Bank (2020) for GDP 1990–2019; IMF (2020) for GDP 2020–2025.

Figure 12: Industrial roundwood production in tropical producer regions and World GDP growth, 1990–2026



Sources: FAO (2020) (baseline years 1989–2019); GFPM (baseline years 2020–2026); World Bank (2020) for GDP years 1990–2019; IMF (2020) for GDP 2020–2026; authors' own elaboration for COVID-19-adjusted IRW production.

Figure 13: Woodfuel consumption in tropical producer regions, and world GDP growth, 2000–2019



Sources: FAO (2020); World Bank (2020).

and depressions. Since the early 2000s, however, economies in the tropical timber producer regions have become increasingly connected to global economic development, and regional GDPs have more or less followed fluctuations in global GDP (Figure 11).

Timber production in Latin America and Southeast Asia clearly dropped in reaction to the GDP fluctuations in 2001 and 2009 (Figure 12) but, in both regions, production had mostly recovered to pre-crisis levels within three years. Notably, in both regions, IRW production showed impressive growth in the years after the economic shocks, temporarily overcompensating for the losses incurred during the crises.

Timber production in sub-Saharan Africa has been largely disconnected from global economic fluctuations and has barely reacted to drops in global GDP. This may not be the case, however, for those countries in the region with a high dependency on wood-product exports.

All three regions are experiencing massive recessions due to the COVID-19 pandemic (IMF 2020). Latin America will likely be affected hardest, with a negative GDP of more than 8% in 2020. Regional GDP growth is expected to be around 3% in both sub-Saharan Africa and Southeast Asia in 2020, which is less of a drop than the predicted global average of 4.4%.[6]

The impact of the pandemic on tropical forest sectors may be stronger than during previous events because of the magnitude of the economic shock and the greater integration of tropical forest sectors in global value chains. Given this, it may take longer for timber production in tropical producer regions to reach pre-crisis levels.

Figure 12 shows projected timber production assuming a conservative five-year recovery phase in Latin America and Southeast Asia, with production in sub-Saharan Africa largely unaffected. Note that the production drop in 2020 in the figure is only to visualize the impact of the recession. An exact quantification of production losses is not yet possible.

Woodfuel

Previous fluctuations in global GDP have had a less noticeable impact on woodfuel consumption in tropical producer regions than on IRW. One reason for this is the lack of reliable data on woodfuel consumption, which is commonly based on estimates.

FAO-recorded woodfuel consumption in sub-Saharan Africa and Southeast Asia has not changed in the past in reaction to GDP fluctuations (Figure 13). In both regions, woodfuel is a major source of primary energy required for daily subsistence and is usually available at low or without any direct cost; consumption to meet daily needs is not subject to macroeconomic

6 Scenario of the IMF, October 2020 (www.imf.org/en/Publications/WEO/weo-database/2020/October).

impacts. Temporary increases in consumption due to the re-migration of part of the urban labour force to rural areas during economic recessions could not be identified in the data. Such a phenomenon may have a significant impact on woodfuel consumption at the local level but has not tended to affect regionally aggregated consumption volumes.

Woodfuel consumption has shown volatility in response to GDP fluctuations in Latin America, however. Although not statistically significant, data suggest that decreasing GDP growth in that region has resulted in a reduction in woodfuel consumption. The reason for this might be the higher share of consumption accounted for by industrial consumers (e.g. in the manufacture of steel); their usage is likely to decline during economic downturns as they reduce production due to decreased demand.

Sources of future tropical roundwood supply

Overall demand for roundwood harvested in natural forests in tropical producer regions will decline to 2050 due to decreasing woodfuel consumption. Demand for IRW from these regions will increasingly be met by plantation-grown timber, with IRW production in natural forests remaining fairly stable.

The GFPM projects a total production volume of roundwood in tropical producer regions of 1253 million m³ in 2050, of which woodfuel will account for 57% (719 million m³). The GFPM projects a total IRW production volume of 534 million m³ in 2050 (43% of total roundwood production).

There is high uncertainty in the share of natural-forest timber production in total production in 2050. This is mainly because tropical hardwoods and plantation-grown timber can substitute for each other in numerous market segments (Figure 14). Moreover, the competitiveness of natural-grown tropical hardwoods is constrained by high production costs and limited versatility in final applications. Natural-grown tropical hardwoods are expected to maintain a long-term advantage over plantation-grown timber in only a few core market segments, such as outdoor applications, furniture and high-end interior works (Turner 2010). No identifiable trend suggests a substantial increase in for tropical timber from natural forests to 2050. Figure 14 presents a range for tropical hardwood production from natural forests of up to 149 million m³ in 2050 but indicates that exact volumes cannot be projected and the range is more likely to be lower than higher.

Primary wood-product specifications in future markets will directly affect raw-material requirements. Fibre-based wood products will increase market share, triggering timber production in high-productivity, short-rotation plantations. Sawlog-based wood products will increasingly be used as inputs for engineered wood products and mass timber, requiring strict compliance with quality and product standards. The total volume of plantation-grown IRW in 2050 is estimated at 327 million m³, with an unknown portion destined for use as woodfuel.

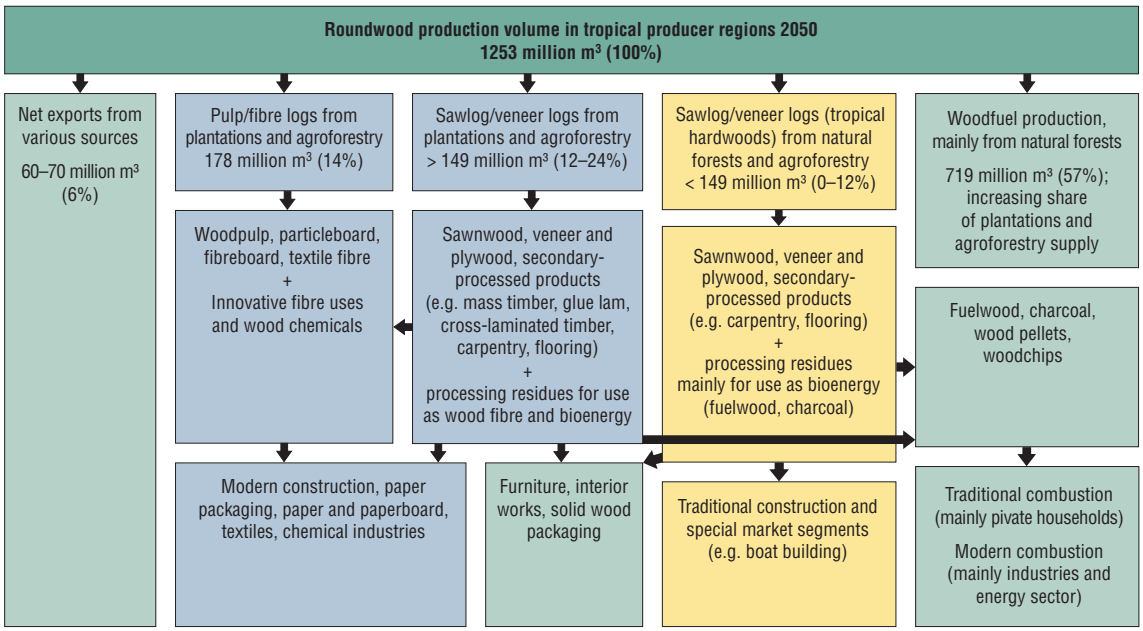
Woodfuel and modern biomass

Woodfuel will account for 57% (719 million m³) of total roundwood production in tropical producer regions in 2050. Private households will still rely heavily on natural forests and woodlands as their main resource base, but woodfuel plantations, agroforestry systems and woodlots established by households and communities will increasingly address demand. Globally, only about 7% of woodfuel consumption was supplied from plantations in 2010, and natural forest is still the dominant source of woodfuel in tropical regions (Penna 2010). The share of plantation-grown woodfuel is hard to estimate, and the rate of future substitution of plantation-grown biomass for natural-forest woodfuel will depend on national policies promoting woodfuel planting, the dissemination of knowledge and materials, and funding for these efforts.

The production of modern biomass (e.g. wood pellets, woodchips for large-scale biomass plants, and retort-produced charcoal) will predominantly use plantation-grown biomass and wood-industry residues. Some tropical producer countries have already established supply chains to feed modern biomass-based industries. In Brazil, the world's largest charcoal producer, for example, about 70% of charcoal is derived from plantation-grown timber for industry end users (Bailis et al. 2013).

Notably, only a small proportion of regional modern biomass production (as of 2015) is consumed in the tropical producer regions, and significant shares are exported to industrialized economies (e.g. wood pellets and woodchips from Viet Nam to Japan and the Republic of Korea). Nevertheless, biomass plays a crucial role in the sustainable-energy strategies of several tropical countries (IRENA 2014), indicating that regional demand will grow for plantation-grown biomass.

Figure 14: Indicative flow of roundwood in tropical producer regions in 2050



Notes: Dark-green boxes present the roundwood mix from various sources; blue boxes present roundwood flow from planted sources; yellow boxes present natural forest roundwood flows; and light-green boxes present roundwood flows that include planted and natural sources.

Source: Authors' own elaboration based on GFPM projections.

Industrial roundwood

The GFPM projects a total IRW production volume of 534 million m³ in 2050 (43% of total roundwood production). Of this, the share supplied by natural forests will decline from around 35% in 2015 to 27% in 2050, although the total production volume of tropical hardwood IRW will decrease only slightly, with a production volume of up to 149 million m³ in 2050 (down from 150–160 million m³ in 2015). The projected stagnation of tropical hardwood IRW production continues a historical trend since 1990: tropical hardwood production volume has been relatively stable (at 150–170 million m³ per year; Figure 15) over the last three decades. Although overall IRW production has grown by more than 60% in tropical producer regions since 1990, the share of tropical hardwoods has declined from 58% to 35%.

Production volumes have changed substantially over time in individual countries. For example, Peru's formal tropical timber production declined between 2007 and 2019 due to the decreasing availability of commercial species and changes in the concession system. On the other hand, Cameroon's production has generally increased since 2000 due to the expansion of concession areas and increased log exports (Figure 16).

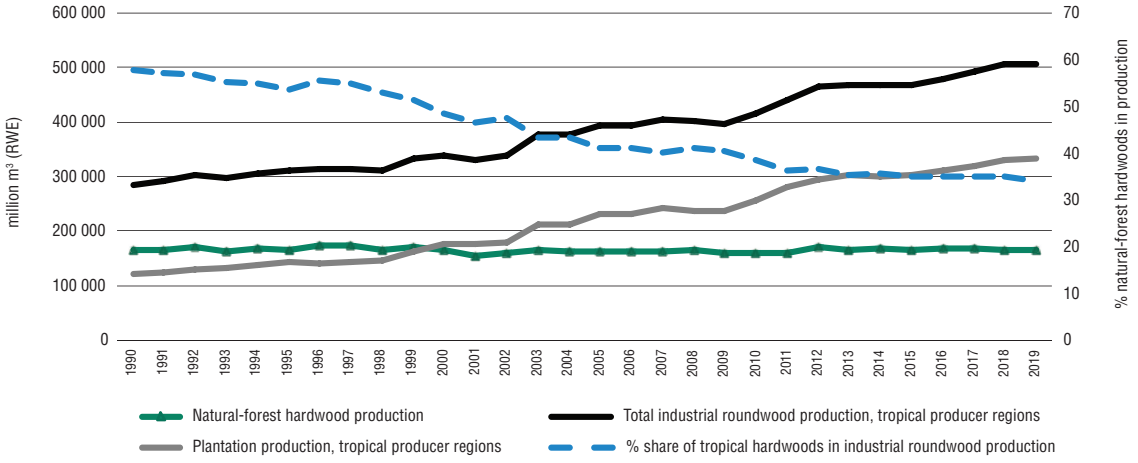
Projections of production indicate increasing demand for plantation-grown pulp and fibre logs and sawlogs. Production volumes of plantation-grown IRW is estimated at 389 million m³ in 2050, representing 73% of total IRW production in tropical producer regions (Table 2). The actual share of plantation-based production is estimated at around 65% (Payn et al. 2015; Nepal et al. 2019).

The growing demand for plantation timber is triggered by market requirements that increasingly favour standardized and highly versatile raw materials to feed large-scale industrialized primary processing. Moreover, applications of wood products in key markets are undergoing fundamental changes; for example, the construction sector, which is the main market for sawnwood products, will increasingly consume high-performance engineered wood products for mass timber construction, a trend driven by the development of sustainable construction solutions in increasingly urbanized societies.

Challenges in topical timber production in natural forests and plantations

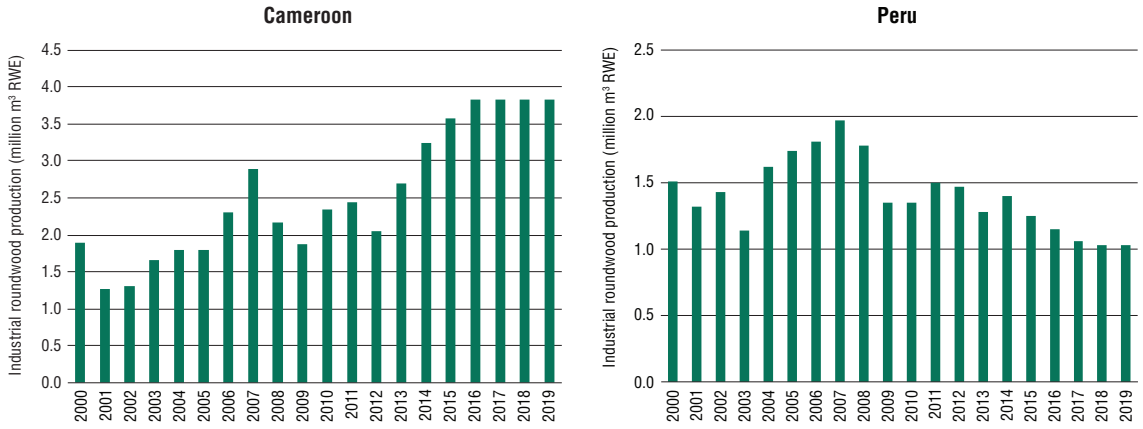
The production of tropical timber in natural forests will face increasing competition from planted forests to 2050. To maintain market share, sustainable forest

Figure 15: Total and natural-forest industrial roundwood production in tropical producer regions, 1990–2019



Source: ITTO (2020), corrected for pulplogs and plantation volumes in Southeast Asia.

Figure 16: Industrial roundwood production, Cameroon and Peru, 2000–2019



Source: FAO (2020).

Table 2: Industrial roundwood production in 2050 from natural forests and plantations in tropical producer regions

Tropical producer region	Industrial roundwood (IRW) production (1000 m³)[a]	Natural-forest hardwood production (1000 m³)[b]	% natural-forest hardwood production as percent of total[b]	IRW plantation production (1000 m³)[b]
Sub-Saharan Africa	78 049	39 025	50	39 025
Latin America and the Caribbean	282 664	28 266	10	254 398
Southeast Asia	173 206	77 943	45	95 263
Total	**533 919**	**145 234**	**27**	**388 686**

Sources: [a] Projections of the GFPM; [b] estimate based on Nepal et al. (2019).

management (SFM) in tropical forests will need to become more competitive by expanding the range of commercial timber species and including revenue streams from ecosystem services, including carbon sequestration. Industrial concessions and communities will need to improve their silviculture and obtain third-party certification of legality and sustainability.

Plantation forestry will be the main supplier of future timber markets in tropical producer regions. With limited expansion possibilities for large-scale plantations, smallholder and agroforestry production will become increasingly important. Both systems need further improvements in productivity and timber quality. Private-equity capitalization and incentives for plantation-based enterprises, large and small, will be key for stimulating sector growth.

Natural forests in future tropical timber supply

Future tropical timber production in natural forests will have to consider multiple societal demands and provide proof of sustainability. Net deforestation has been substantial in tropical producer regions in recent decades. Latin America and the Caribbean and Southeast Asia have both lost 5% of their forest cover since 2000, and sub-Saharan Africa has lost 7%; overall, these three regions lost 108 million ha between 2000 and 2015 (FAO 2016). GFPM projections indicate a slowdown in net deforestation in Latin America and the Caribbean and Southeast Asia, with about 1% additional forest-cover loss to 2050, but sub-Saharan Africa is projected to lose another 8% of its forest. The main drivers of deforestation will be land-use change to agriculture, pasture, infrastructure, settlement and mining.

The consequences of deforestation are felt at the local to global scales. Deforestation affects the livelihoods of local communities, reducing their supply of forest products (e.g. woodfuel and non-wood forest products) and ecosystem services. It also degrades the natural capital stock of countries and contributes to biodiversity loss and greenhouse-gas emissions.

Ongoing deforestation and weak forest governance in tropical producer regions have led to stagnating market demand for tropical timber in industrialized countries. Overall, the commercial use of timber produced in natural tropical forests is perceived negatively in international forest policies and in national timber procurement (Turner 2010), and many tropical timber consumer countries prioritize the conservation of natural forests and the maintenance of ecosystem services. Although there is evidence that SFM that includes timber production can be compatible with conservation objectives, multipurpose management remains challenging to implement and monitor (Grulke et al. 2016). Appropriate SFM approaches will result in tradeoffs in both economic returns and conservation. The voluntary certification of SFM, and international initiatives like the European Union Forest Law Enforcement, Governance and Trade (EU FLEGT) programme, are crucial instruments for the future of timber production in natural tropical forests.

The sustainability of timber production in natural tropical forests is limited by a lack of management planning. Timber is produced in tropical countries by a variety of actors, such as rural households, micro-scale operators, industrial concessionaires and community-based forest managers. The latter two in particular are crucial for SFM in tropical forests and supply substantial volumes of good-quality timber (although data do not clearly indicate the production share).

Despite the significant areas under community-based forest management (CBFM) and industrial concessions, only 191 million ha of natural tropical production forests (11% of the total natural tropical forest area) had forest management plans in 2015, indicating difficulties for the sustainable supply of natural tropical timber (MacDicken et al. 2015).

Globally, the area of natural forest in tropical producer regions (1.7 billion ha, of which 123 million ha consists of industrial concessions and 716 million ha is under CBFM; see Figure 17) should be sufficient to sustainably supply the projected 149 million m^3 of IRW and a substantial share of the projected 719 million m^3 of woodfuel demand in 2050. Supply gaps could arise at the national and subnational levels, however, in the face of population pressure, resource depletion and poor governance (see the national-level GFPM projections in Annex 9).

Industry concessions in natural forests will need to explore new business models and silvicultural concepts. Forest concessions cover about 123 million ha across the three tropical regions (Figure 17). The situation is heterogeneous, with some countries terminating their concession systems and others modernizing theirs. Among the most important challenges facing concessions are the complexity of natural-forest management; the increasing area

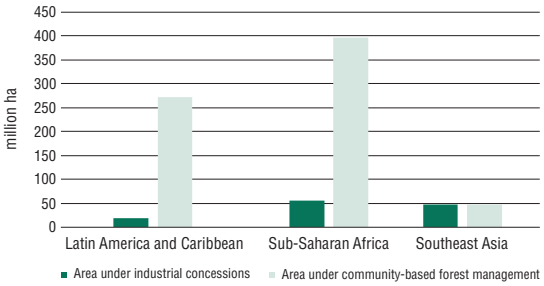
of secondary forests and logged-over concessions; the requirements for complying with environmental and social safeguards; the often poor forest governance systems in tropical countries; the narrow market for only a few of the many tree species in natural tropical forests; competition from informal and partly illegal actors, which undercuts domestic market prices as well as some international markets (e.g. in Asia); and conflicts in large-scale concessions between enterprises and communities, often because of the longstanding neglect of participatory processes during the planning and execution of concession management (FAO 2018).

In the face of increasing demands on tropical forests for their multiple goods and ecosystem services, SFM-oriented timber production must become an accepted tool for forest conservation while ensuring benefits for a wide range of actors, from small to large scale and from communities to industrial players. Industrial concessions need new business models, moving away from timber-dominated approaches towards diversified models aimed at producing multiple goods and ecosystem services (Karsenty and Vermeulen 2016). In the course of this development, new silvicultural strategies will need to be explored and adopted.

CBFM will need more support to overcome capacity gaps and to participate successfully in the timber markets of the future. The total area of forest subject to CBFM across the three tropical producer regions is estimated at 716 million ha (Figure 17). There is evidence that, when population pressure is not too high, community-managed forests are more effective than centrally managed forests at preventing forest degradation (FAO 2018), but integrating CBFM schemes into value chains remains challenging. Frequently, for example, CBFM is subject to conflicts over land tenure; communities lack management plans and technical and financial capacity and require significant support to build this; market access is poor; and communities must often rely on service providers to execute forest operations (Gilmore 2016).

A lack of community capacity and appropriate management planning is restricting the participation of CBFM operations in timber value chains. Although several countries have made substantial progress, there is still a need to revise legislation and improve the enabling environment. Flexibility is needed in forest regulations to reflect the wide range of forest conditions and actors in CBFM.

Figure 17: Industrial concession areas and areas under community-based forest management in tropical regions, 2015



Note: The area given for concessions in sub-Saharan Africa includes only Central and West Africa.

Sources: FAO (2018); Gilmore (2016).

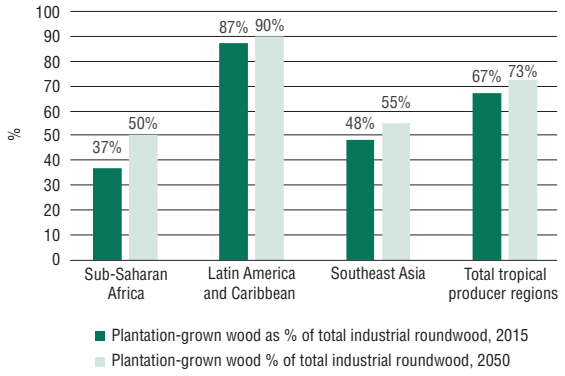
Forest plantations in future tropical timber supply

Plantations will supply future tropical timber demand from diversifying production systems. The area of natural forests is declining in the tropics and the area of forest plantations is increasing. The total area of forest plantations in the three tropical producer regions is estimated at more than 40 million ha (FAO 2016)—although part of this is designated for protection and conservation purposes. Plantations produced an estimated 67% of IRW supply in the tropical regions in 2015, and this proportion is projected to increase to 73% by 2050 (Figure 18).

The biggest increases in forest plantation area to 2050 are projected to be in Southeast Asia and Latin America, with only minor increases in Africa (Indufor 2012; d'Annunzio 2015).

No comprehensive information is available on the structure of plantation ownership and enterprises in the tropics. FAO (2016) estimated that 50% of the global plantation estate was owned publicly in 2005. Since then, however, there has been substantial private-sector investment in tropical plantations, and huge internationally funded smallholder promotion programmes have been implemented. At the same time, several countries (e.g. the United Republic of Tanzania and Zambia) have partly privatized publicly owned plantation estates. Hence, the ownership structure may look quite different today.

Figure 18: Industrial roundwood production in forest plantations in tropical producer regions, 2015 and 2050



Note: See Table 2 for volumes.

Sources: Based on Payn et al. (2015); Nepal et al. (2019).

Plantations will receive increasing interest from financial and industrial investors, but investment opportunities need to develop. Large-scale plantations are operated by both public and private enterprises. Commonly, these operations are integrated units or profit centres of a corporation's processing activities. Significant plantation estates in the tropics supply huge pulp industries, sawmills and particleboard/fibreboard producers.

Large investors in commercial plantations generally raise their own public or private finance for their forestry investments. Even so, there are several ways they can increase the attractiveness of their investment while also reducing risks to the business, including by making strategic and operational choices based on good market research, careful site–species–market matching, and the adoption of appropriate management practices to ensure optimum growth and quality.

Many large-scale plantations in the tropics have failed financially without industrial integration. The capital intensity of such operations is substantial, and dealing with global commodity market dynamics and local risks in developing countries is complex. Nevertheless, increasing interest among institutional investors in forests as an asset class has prompted the establishment of numerous forest funds in recent years with substantial investments in large-scale plantations in tropical regions; examples include New Forests in Southeast Asia, Criterion African Partners in sub-Saharan Africa, and the Arbaro Fund in Latin America and Africa.

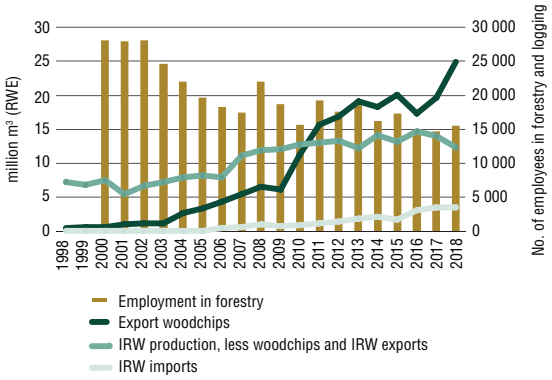
Plantation-sector investors are particularly active in Asia and Latin America, where there is significant market and economic growth and forest companies are looking to obtain market share and secure access to resources as part of their global strategies. On the other hand, few international companies have invested significantly in sub-Saharan Africa outside South Africa, despite rapidly increasing demand driven by population growth. The pre-maturity of timber and forestry markets, difficult access to land, and the green-field nature of most investment opportunities have tended to deter international investors (ITTO/IMM 2019).

Smallholders and outgrowers will be crucial for timber production to 2050 but face technical and financial constraints. Triggered by growing market demand and increasing timber prices, smallholder plantations and woodlots have grown in significance in tropical regions. Some farmers and communities are planting trees independently as individuals or in groups and others are organized under the umbrellas of donor-funded programmes (e.g. the originally European Union-funded and now FAO-operated Sawlog Production Grant Scheme in Uganda and the Participatory Forest Programme in the United Republic of Tanzania). In Latin America, many countries provide incentives for smallholders, such as the Certificado Incentivo Forestal in Colombia and the highly successful Chilean incentive scheme (now phased out).

Large-scale forest companies are also operating outgrower schemes to enable them to draw on smallholder woodlots as a means of supply and risk management. This model is receiving increasing interest because access to large portions of land for industrial plantations is becoming more difficult and expensive in many tropical countries.

In general, smallholders face restrictions on their access to high-quality seeds and seedlings, and many lack silvicultural knowledge and the financial capacity to bridge the time lag in obtaining returns on investment. Thus, opportunity costs and technical support often determine the potential for scaling up smallholder activities; the need of smallholders for early returns tends to favour the production of short-rotation, low-quality timber. In Viet Nam, for example, smallholders produce more than 20 million m^3 annually, but the impact of this on the development of the domestic wood sector remains limited. A large proportion of the raw material is exported as woodchips, despite a desperate need among

Figure 19: Forestry employment and industrial roundwood production and trade, Viet Nam, 2000–2018



Sources: FAO (2020); Viet Nam annual statistical yearbooks (2001–2019) published by the General Statistics Office of Viet Nam.

domestic enterprises for sawlogs. In fact, Viet Nam is importing increasing quantities of sawlogs for domestic processing. Given the dispersed nature of the production system, increases in domestic timber production have not resulted in large gains in employment in the formal forest sector (Figure 19).

Plantations are facing risks and restrictions. Planted forests are increasingly threatened by pests and diseases, either introduced accidentally or adapted to new host trees. Managing this threat requires innovative solutions and a global approach (Wingfield et al. 2015). There is an ongoing need to develop, test and mass-produce "new" plantation species and clonal varieties. Different techniques need to be tried and adopted, such as in terms of spacing, crop management and the wider use of alternative production models (e.g. silvopastoral systems).

Increasing competition for fertile land and a focus on rehabilitating degraded land also bring challenges for commercial tree-planting. Important considerations include better identifying sites that will support productive tree growth; the careful matching of species to such sites (including the use of indigenous species, where appropriate); and adopting techniques to ameliorate site conditions, such as site-specific fertilization and cultivation.

Agroforestry and tree-crops in future tropical timber supply

Exotic species from "modern" agroforestry systems increasingly contribute to timber supply, but traditional production systems will continue to be largely subsistence-driven. Agroforestry is a form of land use in which woody perennials (such as trees, shrubs, palms and bamboos) and agricultural crops and animals are produced on the same parcel of land in some form of spatial and temporal arrangement (FAO 2019b). Some agroforestry systems traditionally grow and make use of native species, and others mix exotic tree species with agricultural production and animal husbandry. Thus, agroforestry systems can be sources of both exotic and indigenous tree species.

Another important source of timber in tropical producer countries are trees outside forests, although this resource cannot clearly be separated from agroforestry, and the two frequently overlap (FAO 2002). Generally, trees outside forests are characterized by lower tree densities per hectare, and they are not necessarily linked to an agricultural production system. There is no comprehensive source of data on timber production from trees outside forests at a regionally aggregated scale, and this section, therefore, refers only to areas that can be clearly identified as agroforestry production systems where tree canopies cover more than 30% of the surface area in a given portion of land.

Globally, there is an estimated 209 million ha of agroforestry systems in tropical producer regions with tree cover of more than 30% (Zomer et al. 2014) (Figure 20). Despite this large area, however, the role of agroforestry in IRW production has not been analyzed systematically, although data from case studies indicate that it could be substantial in some countries and regions. In India, for example, agroforestry and trees outside forests provide more than 90% of domestic IRW production (Shrivastava and Saxena 2017; Dev et al. 2018). There are also examples of agroforestry systems in Latin America and Africa that provide sawlogs and biomass for industrial uses (Somirraba et al. 2012; Iiyama et al. 2014). In Indonesia, homegarden systems supply tropical hardwood sawlogs to domestic processors (Irawanti et al. 2017; Rahman et al. 2016).

Nevertheless, the vast majority of the land under agroforestry is used for subsistence and to supply artisanal industries, and few national forest policies take agroforestry fully into account as a potential sustainable resource base. Increasing the participation of agroforestry systems in timber value chains is often restricted by institutional frameworks that neglect the character of such systems and apply general forest-sector licensing regulations to them, which are challenging to meet for occasional timber producers.

In the case of natural-forest-based agroforestry systems, licensing procedures and insecure land tenure are serious constraints (FAO 2019b).

The area of agroforestry systems that purposefully produce commercial IRW and woodfuel is increasing, in which exotic hardwood species are commonly intercropped or planted on short rotations. In Latin America, for example, silvopastoral systems are gaining increasing interest in the supply of timber for wood-based industries, pulp producers and biomass at a large scale (FAO 2019a). The areas of such systems, and their contributions to overall timber supply, are unknown. In Africa, agroforestry systems have become an important source of woodfuel; Iiyama et al. (2014) suggested that such systems have substantial potential in sub-Saharan Africa if widely adopted at the landscape scale as an integrated strategy.

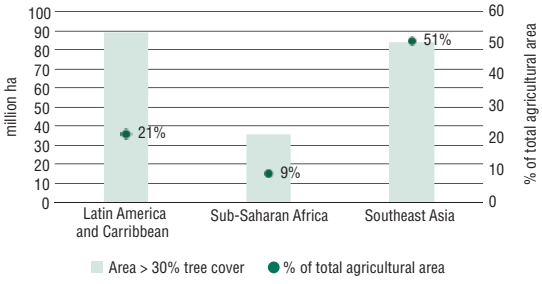
Interest in agroforestry is likely to continue increasing among policymakers and agricultural investors in view of the need for agricultural approaches that are resilient to climate change and which enable the carbon-neutral production of agricultural commodities (Reppin et al. 2020).

The potential of tree plantations to supply tropical timber markets in the future will depend on improvements in timber quality and increased knowledge on wood properties. Tree-crop plantations (e.g. rubber, oil palm, coconut and horticultural) have significant potential for IRW production in tropical regions. In Southeast Asia, rubberwood is already an important source of IRW: in Viet Nam, for example, rubberwood production exceeds 3 million m³ annually, which is 15% of domestic IRW production (Forest Trends 2018). There is about 11.4 million ha of rubber plantations globally, of which 8.8 million ha is in Southeast Asia. Because the quality of rubberwood stands varies, the actual volume entering wood industries is unknown. Case studies suggest a commercial volume of 50–100 m³ per ha at the end of the rubber-tapping cycle (ITTO 2008).

Due to the price volatility of natural rubber, timber sales from rubber plantations have become important for stabilizing cash flows and generating positive returns. Traditionally, rubberwood has been used in furniture production, but research indicates that it is also suitable for structural construction (Eufrade et al. 2015). There is increasing interest in improving the silvicultural management of rubber plantations to place more emphasis on timber production. Thus, the rubberwood resource will continue to supply timber markets in the future.

The industrial potential of the wood standing in more than 30 million ha of oil-palm plantations has not been fully explored. Experts estimate that, over the course of replanting oil-palm plantations in Asia, Africa and South America, 100–120 million m³ of logs could be available annually.[7] It appears, however, that no significant volumes are currently entering wood-processing value chains. Research is ongoing,[8] but a significant market presence of palm wood seems unlikely in the near future.

Figure 20: Estimated area of land under agroforestry in tropical producer regions, 2014



Source: Zomer et al. (2014).

Key actions to support tropical timber production

Multilevel efforts are required to maintain and enhance tropical timber production. These include making progress in forest governance, enhancing the competitiveness of timber production and establishing new business models. Timber production in natural forests will have to comply with increasing societal demands for proof of sustainability and the integration of ecosystem services. Plantations and agroforestry production must attract sufficient capital to professionalize production systems and produce high-quality timber for innovative wood-product markets.

Develop enabling forest governance systems. Investment in large-scale production in plantations and natural forests requires reliable and transparent forest policies and an enabling environment for investment. At the same time, small producers and communities need fair and equitable access to resources.

7 www.wbpionline.com/features/oil-palm-wood-an-untapped-resource-6012167

8 E.g. the international research and development programme PalmwoodNet (2015–2018), which combined actors from timber processing, palm-oil producers and timber consumers.

Hence, support for national efforts to improve forest policies and governance should be prioritized. Going beyond the analytical scope of this study, ongoing initiatives such as the EU FLEGT programme and those of FAO and the World Bank emphasize that clear, certified sustainable production, equitable laws on forest resource tenure and access, and effective law enforcement are instrumental for promoting forest-sector development.

Support the development of new business models for natural forest management and plantations. Tropical timber production can generate revenues from timber, non-timber forest products and ecosystem services (e.g. carbon storage and watershed protection) and thereby contribute to economic and social development. Such a blend of revenue streams, if realized, would provide leverage for commercial timber production where otherwise it would be economically restricted. Such blended business models must be further explored for natural forests, plantations and agroforestry.

Mobilize capital and incentives for smallholder tree-planting and communities. Smallholders and communities often lack access to capital for commercial activities. This is because most traditional financers see forestry as a high-risk investment and are deterred by the long length of time before the main income streams materialize. Forestry typically requires the vast majority of its finance in the early phase, and small actors often require financial incentives to kickstart their businesses. Such incentives could be in the form of soft loans or grants that are conditional on performance. Distributing free seedlings often does not have the desired result because growers do not value them sufficiently. Governments can offer direct and indirect incentives to attract investments in forest management and tree-planting, such as sound technical support (e.g. applied research and practical training facilities), infrastructure improvements and a favourable taxation environment that takes into account the peculiar timing of most forestry investments.

Resolve market constraints for smallholders and communities. The existence of accessible markets for products is crucial for the viability of smaller growers and communities. These actors often have weak market linkages and poor access to market information. They also lack the economies of scale and understanding of quality standards that are vital for accessing certain markets. Such constraints can be at least partly offset by assisting producers to consolidate into groups or clusters, which act to create an enabling environment by providing, among other things, technical support and market information.

Ensure adaptability to climate change, which will be crucial for maintaining forest productivity. Climate change is affecting timber production in various ways. Where temperatures are increasing and droughts becoming more frequent, trees are increasingly stressed and vulnerable to pests, diseases and wildfire, ultimately meaning reduced growth and often tree mortality. Silviculture must continually evolve to meet such challenges.

Research and development should be enhanced to continually adjust the silviculture of natural forests in light of changing biophysical and societal conditions, including the management of secondary and logged-over forests, adjusting to climate change, and the combined production of timber, non-timber forest products and ecosystem services. Other research topics should focus on increasing productivity in plantations and agroforestry. With a view to timber markets in 2050, emphasis should also be placed on obtaining a better understanding of wood properties to match future market demand in innovative products. Opportunities should be assessed for the greater use of lesser-known species in natural forests, timber from tree-crop plantations, and increasing the versatility of plantation species in multiple uses in the construction sector.

3 PRODUCTION AND CONSUMPTION OF TROPICAL WOOD PRODUCTS IN 2050

Key points

- Global production of primary wood products is projected at 3.7 billion m³ (roundwood equivalent) in 2050, an increase of 61% compared with 2015. Tropical production of primary wood products will increase by only 36%, however, to 476 million m³.
- The production increase in tropical producer regions will be driven partly by exports: net export volumes will contribute 23% to production growth to 2050 in Latin America and 30% in Southeast Asia.
- The domestic consumption of primary wood products will be relatively low in tropical producer regions in 2050, at 12% of global consumption, even though 38% of the world population will be living in those regions.
- Low domestic market demand in the tropical producer regions will constrain wood-industry development by deterring investments in modern, capital-intensive wood-processing industries.
- Forest industry employment in the tropical producer regions is projected to grow by 1.3 million jobs, to 7 million full-time-equivalent employees in 2050.
- Future employment in the forest sector, especially in wood-processing industries, will require a well-trained workforce, which still needs to be developed.
- The forest industry in tropical producer regions will need to modernize in the lead-up to 2050 and invest more than USD 40 billion in the expansion of processing capacities.
- Transformative public and private investments in the tropical timber industry will be required to overcome the tropical timber sector's challenges. Public investments would facilitate the raising of private investments at scale and are needed to stimulate sustainable growth.
- The wood-processing sector will need to overcome structural barriers that hinder enterprise development.

This chapter summarizes key numbers on the future supply of and demand for primary-processed wood products in the tropical producer regions. It discusses the impact of fluctuations in global GDP on primary wood-product production and trade and describes factors that influence the vulnerability and resilience of tropical wood-sector industries. The chapter also reviews the challenges facing tropical wood-processing industries under changing market requirements and concludes with a set of actions to consider for enhancing tropical wood-processing industries to 2050.

Production

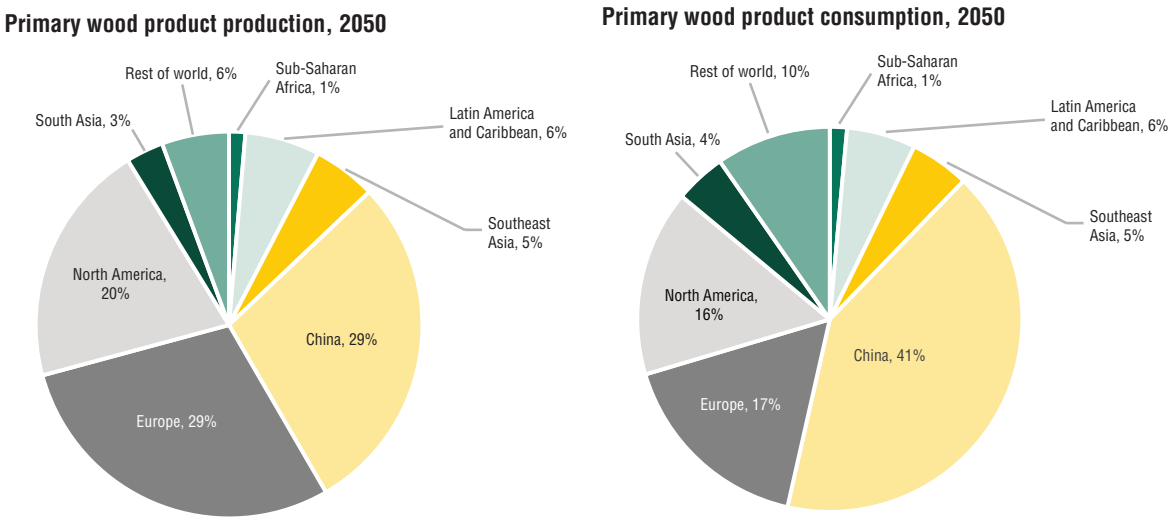
The projected global production volume of primary-processed wood products in 2050 will amount to 3.7 billion m³ RWE (+61% compared with 2015).[9] The tropical producer regions will contribute 12% of this (Figure 21).

Sawnwood will be the most important primary-processed wood product globally in 2050 (1.2 billion m³ RWE), but the greatest increase in production is expected to be in veneer/plywood and wood-based panels. Combined, the output of these latter two product groups will surpass 1.6 billion m³ RWE in 2050. Global woodpulp production will be an estimated 760 million m³ RWE in 2050 (Figure 22).

Production in tropical producer regions will increase by a total of 36% (RWE) across all product groups. Among the regions, Southeast Asia will be the major producer of log-based products (i.e. sawnwood, veneer and plywood) (Figure 23), and Latin America will be the most important producer of fibre-based products (particleboard, fibreboard and woodpulp). Nevertheless, woodpulp production will decline significantly in Latin America and Southeast Asia (Figure 24). Although production in sub-Saharan Africa will increase by more than 60%, the total production volume of primary wood products will remain relatively small, at 50 million m³ RWE.

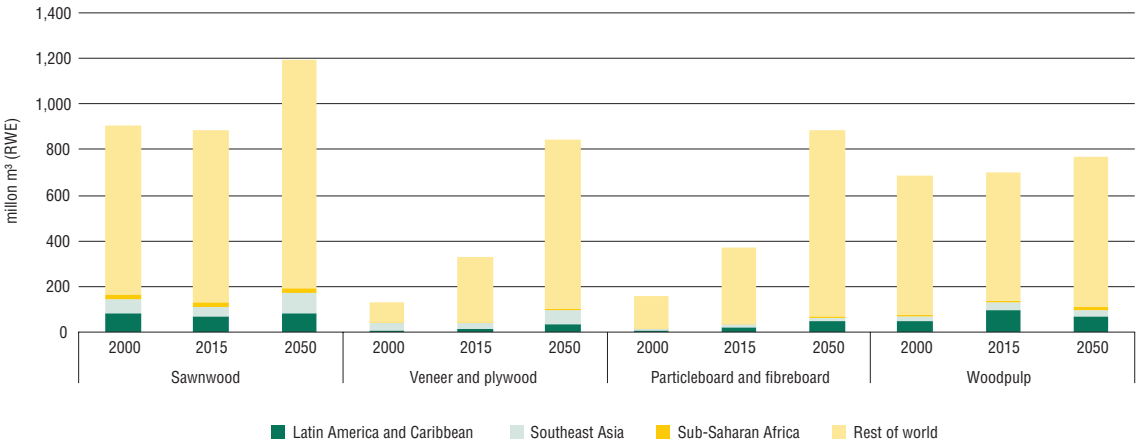
9 Detailed projections for world regions are available in annexes 3 and 9.

Figure 21: Participation of selected world regions in the production and consumption of primary wood products, 2050



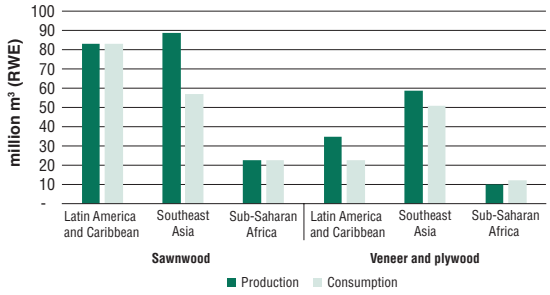
Source: GPFM, corrected/adjusted by the authors.

Figure 22: Primary wood-product production, 2000, 2015 and 2050



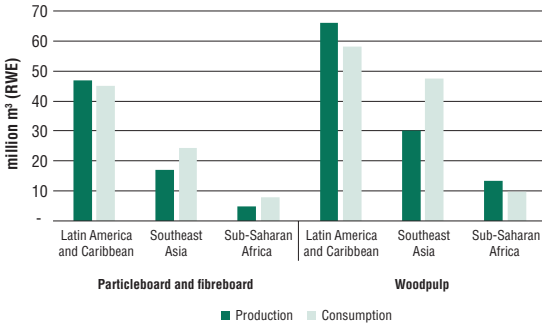
Source: GPFM, corrected/adjusted by the authors.

Figure 23: Production and consumption of sawnwood, veneer and plywood in tropical producer regions, 2050



Source: GPFM, corrected/adjusted by the authors.

Figure 24: Production and consumption of particleboard/fibreboard and woodpulp in tropical producer regions, 2050



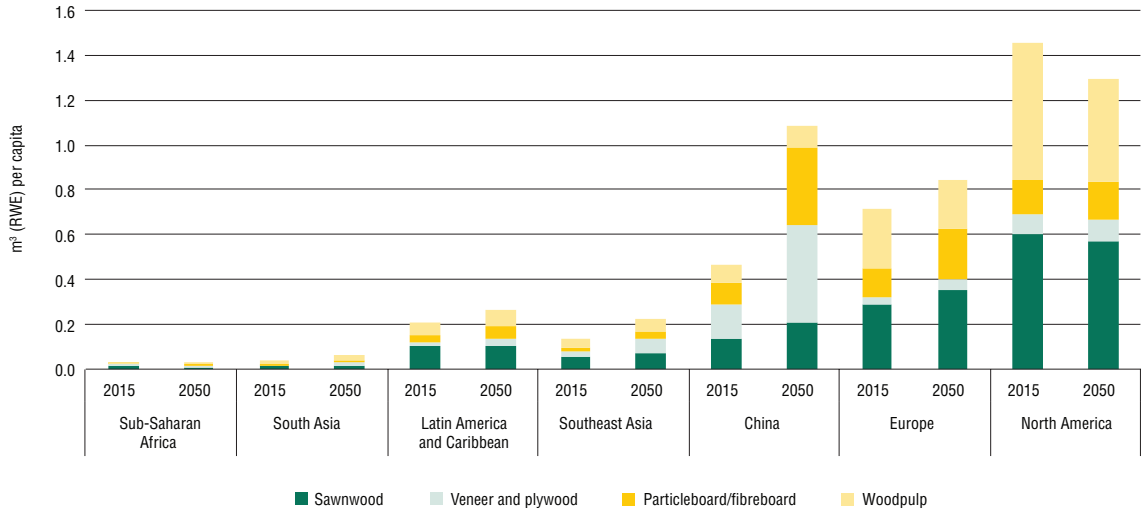
Source: GPFM, corrected/adjusted by the authors.

Consumption

Primary wood-product consumption growth in tropical producer regions to 2050 will be higher than the global average, at +76%. Growth will be mainly in Southeast Asia (+108%), followed by sub-Saharan Africa (+76%) and Latin America (+ 56%). In volume terms in the three regions, the largest consumption of primary wood products in 2050 will be in Latin America, at 209 million m³ RWE; Southeast Asian consumption will be around 180 million m³ RWE and sub-Saharan consumption will be about 52 million m³ RWE.

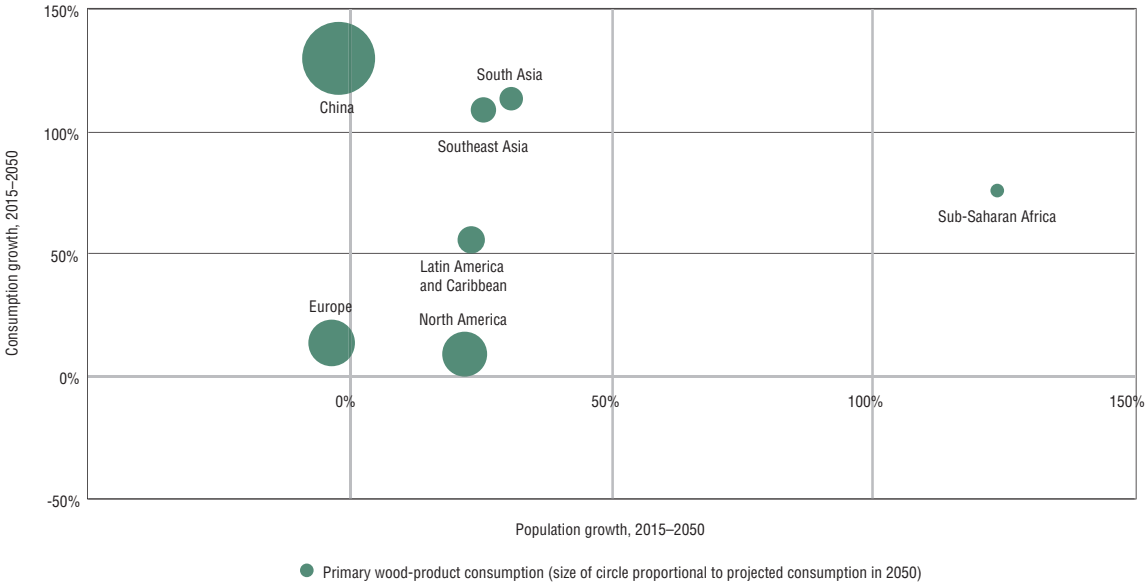
Despite decent growth rates in tropical producer regions to 2050, the relative share of these regions in global primary wood-product consumption will be disproportionate to the size of the population. The per-capita consumption of primary wood products will remain consistently low in tropical producer regions (Figure 25); industries and households in tropical producer regions will consume 12% of primary wood products globally in 2050, despite representing 38% of the world population (Figure 26). Consumption will be higher in Latin America and Southeast Asia than in sub-Saharan Africa, due mainly to consumption by secondary-processing and manufacturing sectors in those regions.

Figure 25: Per-capita consumption of primary wood products in selected world regions, 2015 and 2050



Sources: GPFM, corrected/adjusted by the authors; UN (2020a).

Figure 26: Regional population growth, consumption growth and total consumption of primary wood products, 2050



Sources: GPFM, corrected/adjusted by the authors; UN (2020a).

Trade

The production increase in tropical producer regions will be driven partly by exports: net export volumes will contribute 23% to production growth in Latin America and 30% in Southeast Asia. The trade in primary wood products will vary between producer regions (Figure 27). Latin America will be a net exporter across all primary wood-product groups, exporting mainly wood-based panels and pulp. Sub-Saharan Africa's trade balance will be slightly positive for sawnwood and woodpulp but strongly negative for particleboard/fibreboard and veneer/plywood: dependency will be high on imports for particleboard and fibreboard, with almost 40% of regional consumption originating outside the region. Southeast Asia will become a major exporter of sawnwood, veneer and plywood but will require imports of wood-based panels and woodpulp to meet regional demand.

Globally, China will be the largest consumer of primary-processed wood products in 2050 and heavily dependent on imports. Other important export destinations will be other Asian subregions and North Africa.

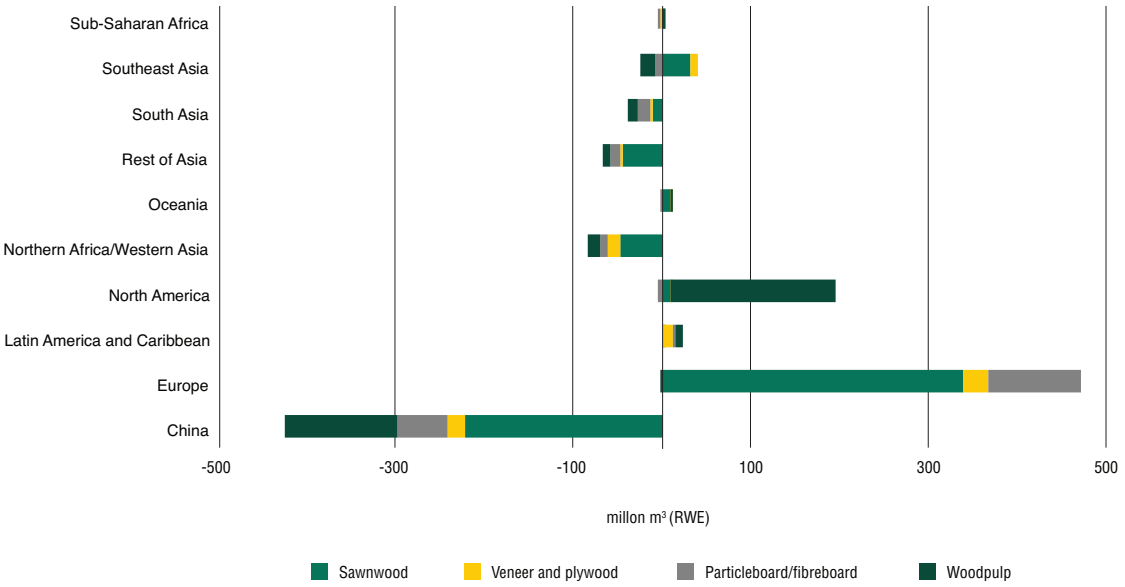
Effects of GDP fluctuations on processing and trade of tropical wood products

Tropical wood-processing industries have coped comparatively well with recent global economic shocks, although the full magnitude of the impacts of the COVID-19 pandemic is yet to be assessed. Experience suggests that certain factors make the tropical forest sector resilient to economic fluctuations. In the aftermath of the most recent shock, the sector will need to stimulate domestic consumption, promote domestic value-adding and participate in international value chains with value-added products rather than raw materials. The export of low-value-added products is a risk factor, although tropical hardwood exports show high resilience.

Exports from tropical producer regions have been more seriously affected than domestic consumption by past economic crises, especially sawnwood and wood-based panels (Figure 28) (on the other hand, woodpulp exports have been relatively robust in the face of economic shocks, see Figure 32).

There was a massive drop in exports of sawnwood and wood-based panels from Latin America and Southeast Asia during the 2008/2009 global financial crisis, and volumes have not yet recovered to pre-crisis levels. A major export destination of Latin America had been the North American construction sector,

Figure 27: Trade balance of primary wood products in selected world regions, 2050



Source: GPFM, corrected/adjusted by the authors.

which was "ground zero" for that crisis and which has recovered only slowly. Southeast Asia's recovery phase was more positive, but export destinations, mainly in East Asia, have increasingly been served by other suppliers, challenging the competitiveness of Southeast Asian production.

In sum, the export of low-value-added primary wood products increases vulnerability to economic shocks, and the strong export dependency for unprocessed wood products should be re-considered to enhance the tropical forest sector's resilience.

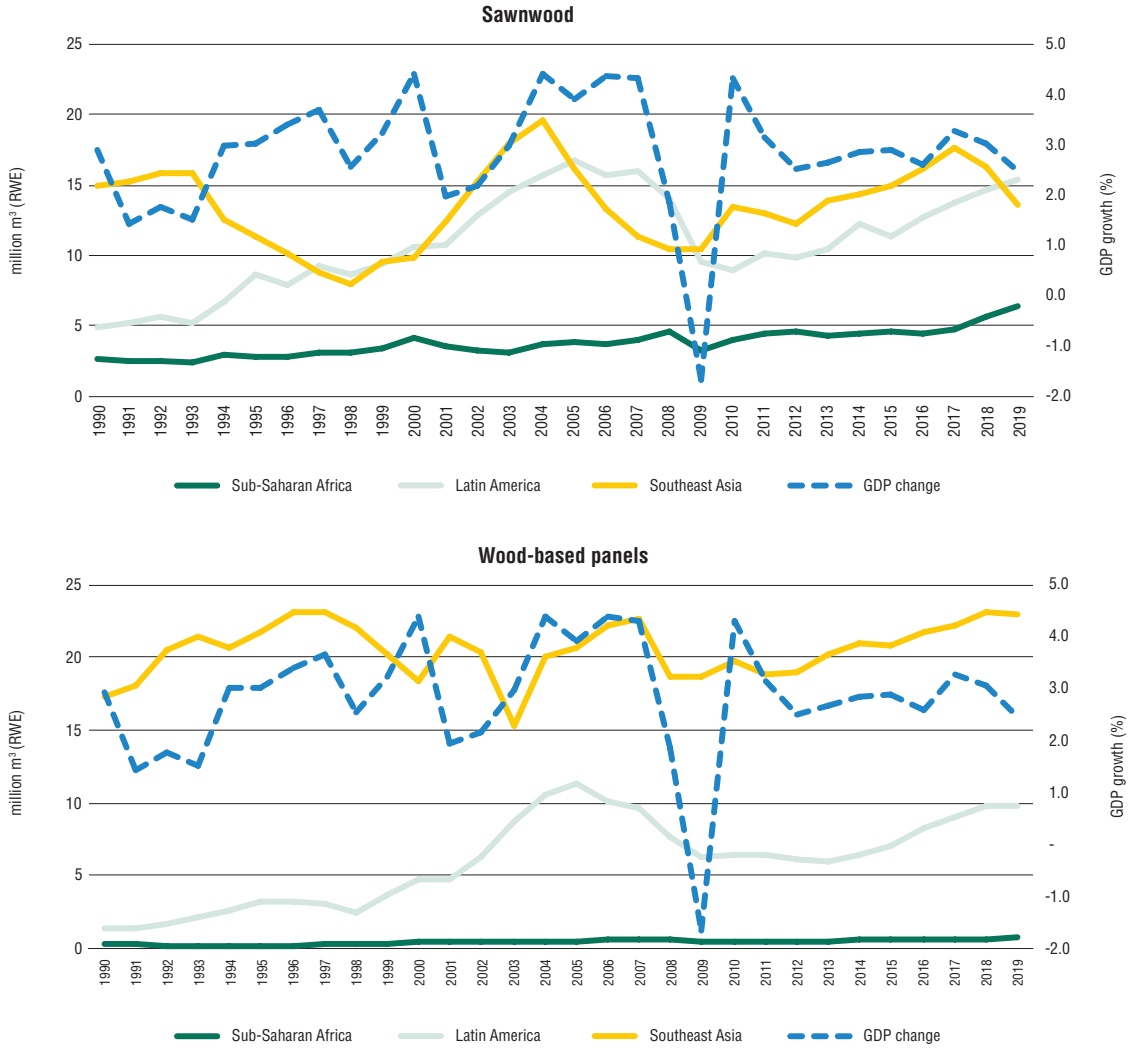
Tropical hardwood exports are an exception, with volumes relatively stable over time. In Cameroon, for example, hardwood exports have recovered immediately after past economic shocks; in Peru, such exports increased in volume during the 2008/2009 global financial crisis (Figure 29).

Domestic consumption and value adding are stabilizing factors. Domestic consumption has proved to be a stabilizer for tropical timber production in previous economic crises. Production declines in sawnwood and wood-based panels recovered relatively quickly in tropical producer regions after the 2008/2009 global financial crisis, with the exception of sawnwood consumption in Latin America (Figure 30).

Latin America's long-term and Southeast Asia's temporary severe reduction in sawnwood consumption also resulted from structural changes in both production and demand. Although market demand in tropical producer regions increasingly draws on standardized and engineered sawnwood products, the sawmilling industry in the tropics still faces innovation and investment bottlenecks. Moreover, the substitution of sawnwood by wood-based panels and non-wood products is negatively affecting sawnwood consumption. The 2008/2009 global financial crisis had a catalytic effect on sawnwood industries in tropical regions, resulting in a reduction in production capacity (e.g. in Latin America), although the overall consumption of wood products was stable. This trend will most likely continue post-2020.

Domestic demand, driven by strong population growth, was the most likely reason for the stable volumes—and fast recovery in the consumption—of sawnwood and wood-based panels in sub-Saharan Africa after the 2008/2009 global financial crisis, albeit from a low base. The stabilizing effect of domestic consumption in Southeast Asia and Latin America arises from the intake by manufacturing industries, which use sawnwood and panels as inputs for secondary wood processing. Exports of the derived products have been shown to be relatively stable in the face of GDP fluctuations, with short recovery periods after economic shocks (e.g. in Peru and Viet Nam—Figure 31).

Figure 28: Exports of sawnwood and wood-based panels in tropical producer regions, and world GDP growth, 1990–2019



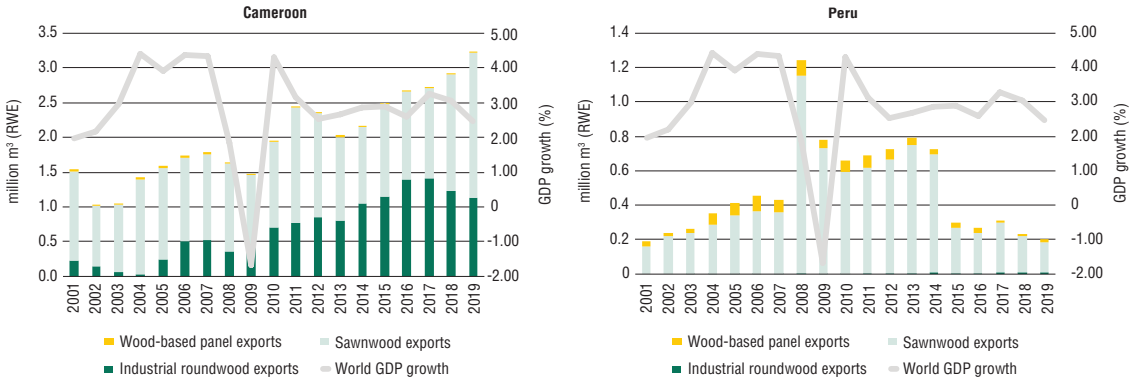
Sources: FAO (2020); World Bank (2020).

Pulp and paper will continue to drive timber production in tropical producer regions. In the past, woodpulp production has largely been robust in the face of economic shocks (Figure 32), and tropical producer regions maintained stable growth trajectories during the 2008/2009 global financial crisis. Woodpulp production may be a winner in the COVID-19 pandemic due to temporary increases in mail-order packaging and increased demand for hygienic paper products. The woodpulp market is highly internationalized, with opportunities to diversify markets. The consumption and export of woodpulp may help timber production stabilize in tropical producer regions and return to its pre-crisis growth trajectory. Given that large volumes of woodpulp are exported from tropical regions without further processing, however, this might mean less opportunity to enhance value-adding.

Challenges for tropical timber-processing industries

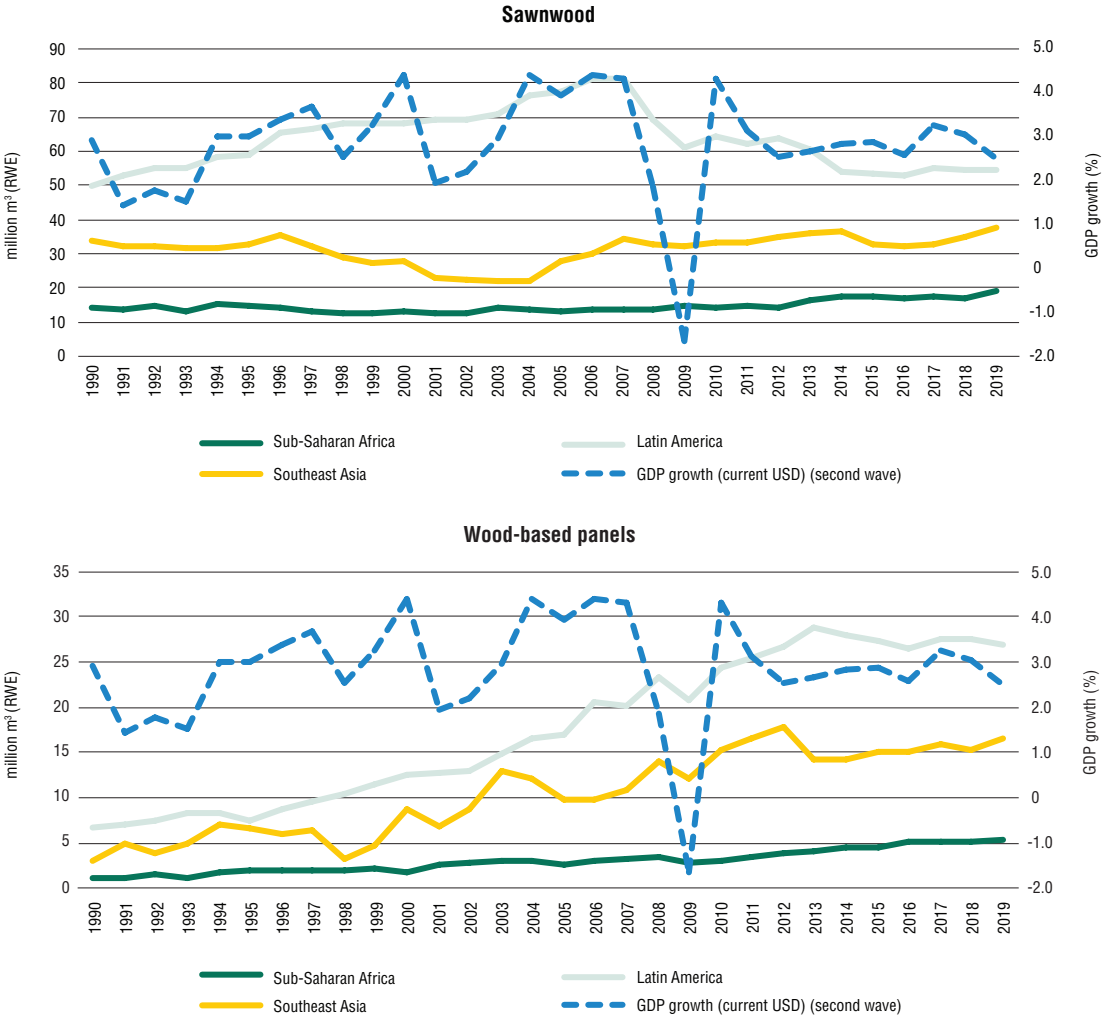
The forest industry in tropical producer regions will need to modernize in the lead up to 2050 and invest more than USD 40 billion in the expansion of processing capacities. Forest industry employment in the tropical producer regions is projected to grow by 1.3 million jobs by 2050, to 7 million full-time-equivalent employees. In the future, the forest sector, especially the wood-processing industries, will require

Figure 29: Exports of tropical roundwood, sawnwood and wood-based panels, Cameroon and Peru, and world GDP growth, 2001–2019



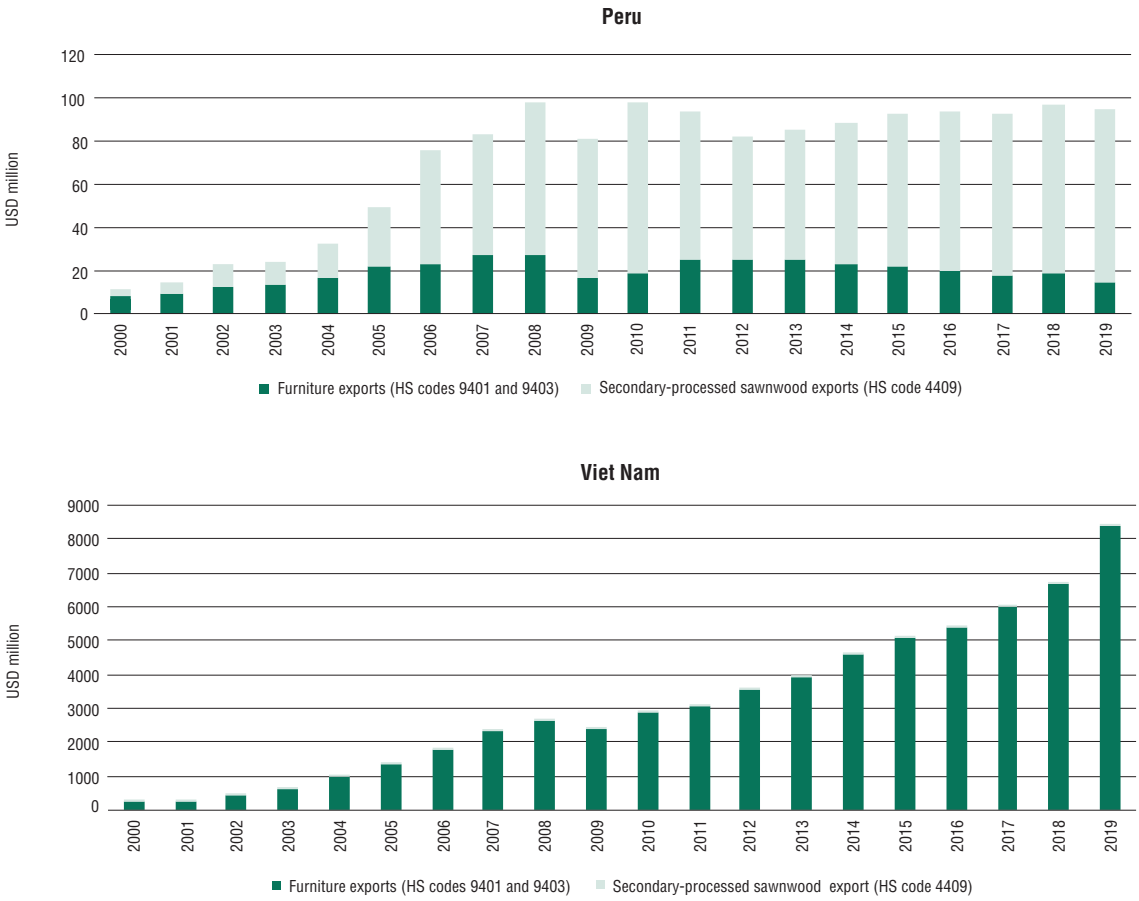
Note: The low volume of Peruvian log exports in 2015–2019 was caused by changes in national forest policies on concessions and timber extraction.
Sources: FAO (2020); World Bank (2020).

Figure 30: Consumption of sawnwood and wood-based panels in tropical producer regions and world GDP growth, 1990–2019



Sources: FAO (2020); World Bank (2020).

Figure 31: Exports of secondary wood products from Peru and Viet Nam, 2000–2019



Source: UN Comtrade (2020).

a well-trained workforce, which still needs to be developed. Forest-sector enterprises face several other challenges in increasing productivity and value-adding due to the informality of large parts of the sector in many tropical countries, restricted access to capital, and a lack of business development support. These challenges need to be overcome to ensure global competitiveness and an adequate timber supply.

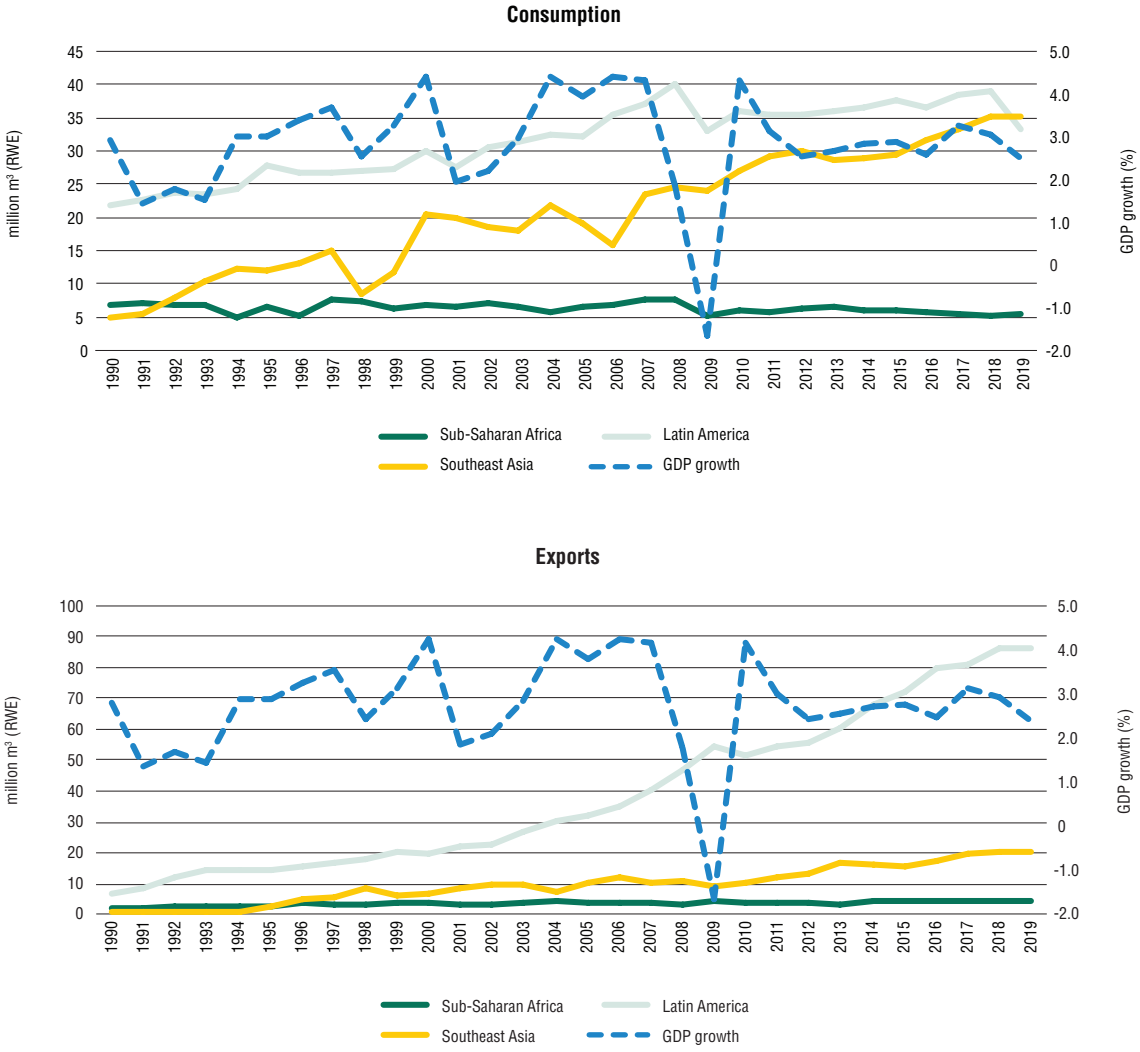
Low domestic market demand will constrain wood-industry development. The consumption of primary wood products is commonly driven by domestic market demand in construction. However, wood consumption in tropical producer regions has traditionally been low in urban construction, and construction in rural areas is increasingly based on concrete and bricks; therefore, domestic wood consumption is relatively low in many tropical countries.

Household purchasing power will increase in tropical producer regions, but it won't catch up with industrialized economies by 2050. Hence, private domestic demand for secondary-processed wood products (e.g. paper and furniture) will remain a limiting factor for market opportunities. Low domestic demand is deterring investment in modern, capital-intensive wood-processing industries.

Many countries are stuck in a negative feedback loop, in which a lack of knowledge about modern timber products constrains demand and hence the development of a modern processing industry, which in turn reduces the incentive to invest in timber production and processing. Consequently, growing demand for advanced wood products is met by imports, with negative effects on the wood industry's participation in national economies; this is the case, for example, in Peru (Figure 33).

Since the 1960s, the construction sector in tropical countries has had a general preference for concrete in high-rise buildings and bricks in rural housing. The sector is neglecting the increasing versatility and

Figure 32: Consumption and exports of woodpulp in tropical producer regions and world GDP, 1990–2019



Sources: FAO (2020); World Bank (2020).

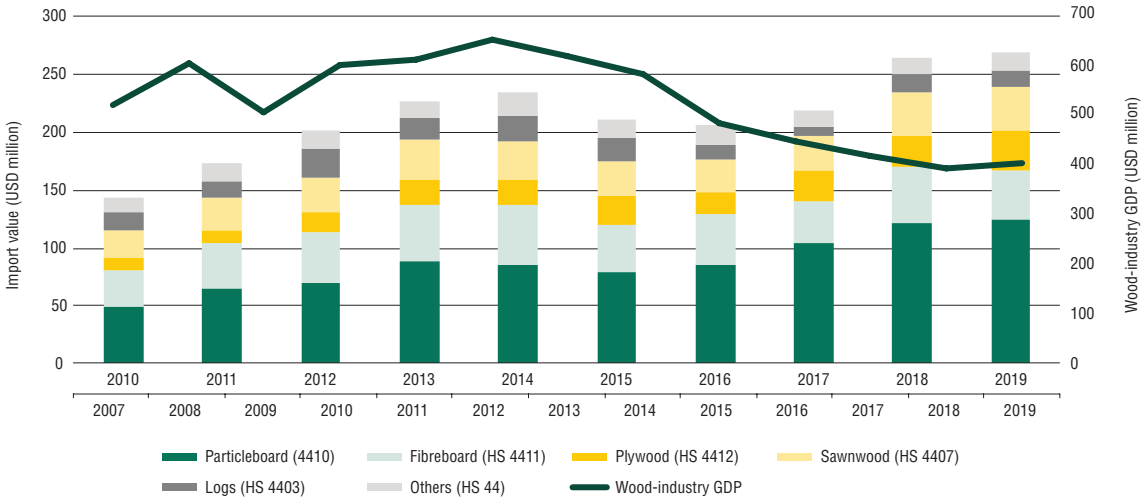
performance of modern mass timber products[10] that have evolved in the last 20 years; modern timber construction is basically non-existent in tropical countries. The positive effect of using timber products instead of conventional materials in construction has been widely acknowledged (World Bank 2017), but tropical countries have not yet translated this into clear policies to promote timber construction, such as in public procurement (GlobalABC 2020).

Being correlated with per-capita income, paper and tissue consumption will remain below the global average in tropical regions to 2050. The industrial use of wood fibre (e.g. for packaging and textiles) is also expected to remain low in tropical regions, despite substantial growth due to technical innovations in clothing and demand from logistics. Industrialized regions are increasingly exploring wood fibre as a raw material in the bioeconomy (Hetemäki and Hurmekoski 2016), such as for textile fibre, plastics substitutes and chemicals, but most investment in tropical countries is still in conventional production.

With limited domestic markets, the export of low-value-added wood products is an increasingly important factor in production growth in tropical producer regions. However, export dependency on primary-processed wood products causes vulnerability to global economic fluctuations. Moreover, international markets are highly competitive and are dominated by actors from North America and Europe.

10 Mass timber is a new category of wood product comprising multiple solid wood panels nailed or glued together.

Figure 33: Wood-product imports and wood-industry GDP growth, Peru, 2007–2019



Sources: Peru national statistical office; FAO (2020).

The wood-processing sector will need to overcome structural barriers that hinder enterprise development. The lack of a competitive wood industry is caused partly by a lack of suitable IRW supply, but more importantly it is rooted in structural challenges that cause deficits in investment and innovation.

The situation of today's tropical timber-processing sector presents a divided picture. A wide array of economic actors and enterprises process timber in the tropics. In many countries, parallel structures of highly professional formalized industries exist alongside informal artisanal value chains.

Thus, permeability between segments is poor. Micro enterprises rarely grow to become small or medium-sized enterprises (SMEs) because of restrictions imposed by their informal character and their lack of technical and financial capacity. SMEs rarely become large players because of a lack of financial possibilities and limited access to international markets. They rarely attract foreign equity because they cannot produce bankable information.

In the absence of a vibrant SME sector, large-scale enterprises are crucial for competitive forest sectors in the tropics. These are very capital-intensive, however, and require a high level of technical and managerial skill to operate in emerging economies. Most commonly, large wood companies operate their own forest resources (e.g. concessions or plantations). They frequently form part of international corporations, and their operations benefit from economies of scale. Large wood-based enterprises in the tropics are found mainly in the pulp-and-paper subsector and in particleboard/fibreboard production in Latin America and Southeast Asia (Figure 34).

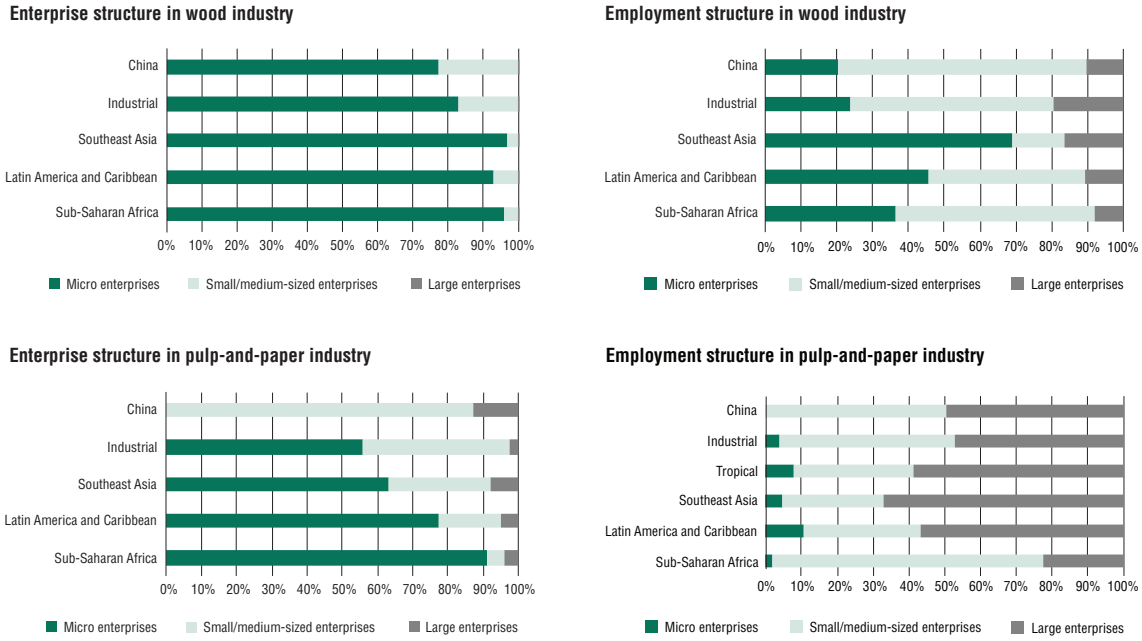
Frequently, such large entities operate in isolation of domestic value chains. In some cases, SMEs supply the large enterprises with pre-fabricated products, but ecosystem-type clusters of SMEs and large corporations like those in Europe and North America are rare in the tropics. More often, large companies operate as competitors for raw materials and market share and further restrict the development potential of SMEs.

Tropical wood industries will require a shift from micro enterprises to SMEs. The forest sector today contributes more than 5.7 million jobs to employment in registered enterprises in tropical producer regions. More than 95% of these enterprises are micro enterprises, with 5–10 employees. Such enterprises employ more than 60% of the wood-industry workforce in the tropics, compared with around 20% in China and industrialized countries (Figure 34). In fact, the backbone of the wood industry in industrialized regions are SMEs, which have up to 300 employees;[11] such enterprises employ the lion's share (50–60%) of the workforce. In tropical countries, the SME share of the workforce is barely 20%.

In many tropical countries, wood-industry development is stagnating despite increasing demand (Figure 35). For example, the number of wood-processing

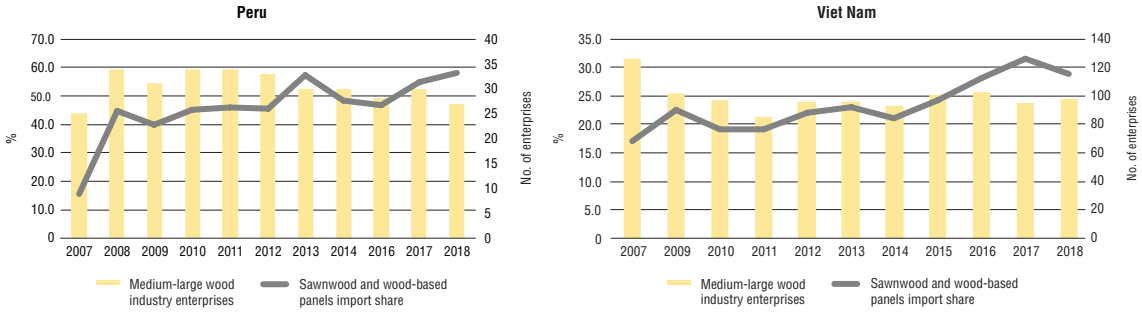
11 In Brazil, Canada and the United States of America, SMEs have up to 500 employees, by definition.

Figure 34: Enterprises, and employment in forest industries, by region, 2015



Sources: Compiled from national accounts statistics, industry surveys and FAO (2020).

Figure 35: Import share of sawnwood and wood-based panels in domestic consumption in Peru and Viet Nam, and development of medium-sized/large wood-industry enterprises, 2007–2018



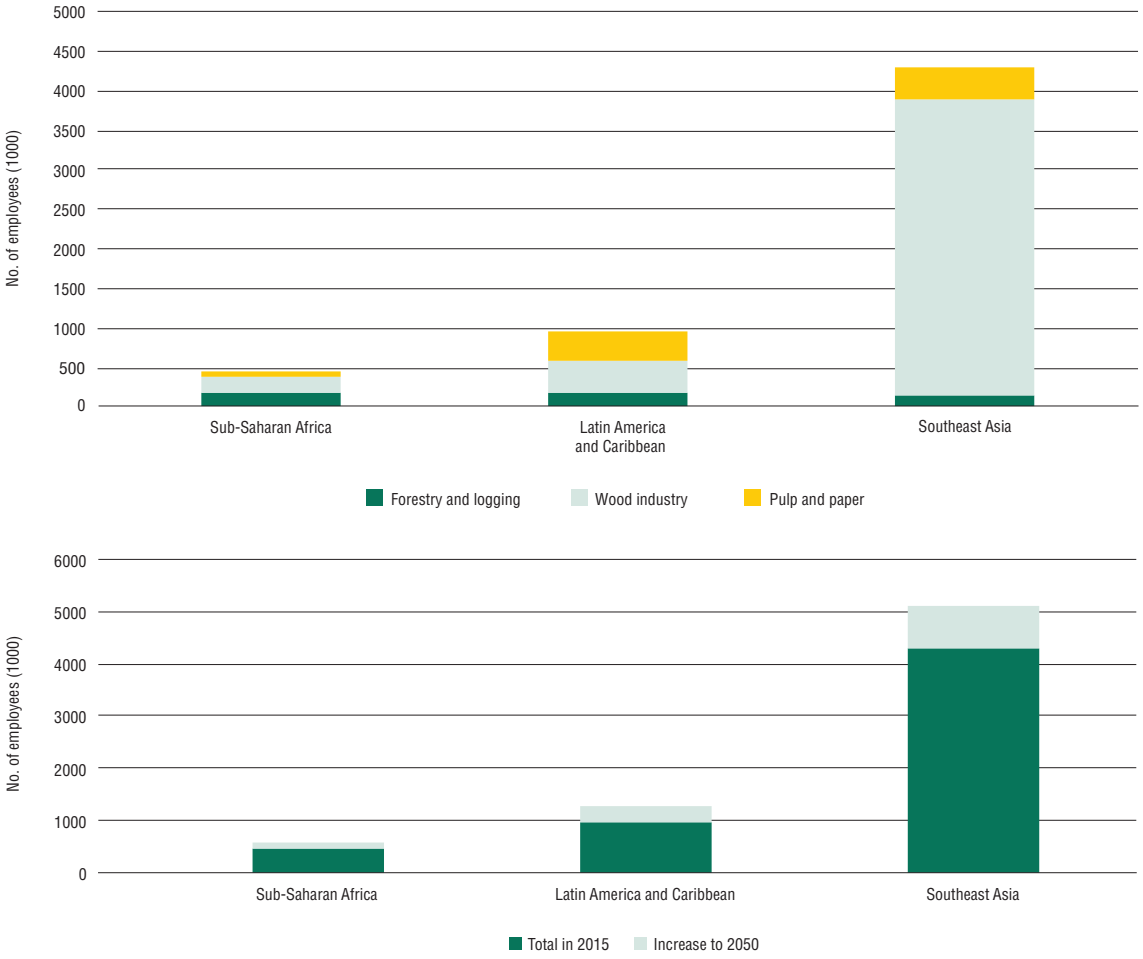
Sources: Compiled from national accounts statistics, industry surveys and FAO (2020).

enterprises is declining in Peru and Viet Nam, and growing domestic demand is being met by imports. Increasingly, tropical countries are importing standardized wood products to supply domestic construction and manufacturing industries, thus missing opportunities for substantial value-adding and employment. A larger share of modern SMEs in tropical producer regions is needed if domestic demand is to be met locally.

The projected increase in IRW production and processing-industry capacity in the tropics will create approximately 1.3 million additional jobs by 2050, for a total of about 7 million[12] direct jobs (Figure 36). Jobs in the forest sector will look different in 2050 compared with today, however, because the forest industries will increasingly require a well-trained labour force. Future employment requirements in forest industries will, for example, encompass job profiles for mechanical harvesting, electricians and mechanics to operate modern machinery, digital designers and information

12 Note that this number reflects registered/formal employment. There is a significant additional informal workforce, especially in households and micro enterprises.

Figure 36: Formal employment in forest industries in tropical producer regions in 2015, by subsector, and increase in employment to 2050



Sources: GFPM; UNIQUE forestry and land-use forest industry benchmarks database (Annex 6).

technology specialists. Thus, realizing the employment potential will require investment in education, particularly vocational training, and on-the-job capacity building.

Tropical timber subsectors need to develop competitive SME segments by providing access to capital and business development support. It is widely acknowledged that SMEs are the drivers of competitive industrial sectors, but they face severe constraints in emerging economies that limit the capacity of micro enterprises to grow into SMEs and restrict the enhanced participation of SMEs in value chains. The key challenges for forest-based SMEs can be summarized as follows:

- To maintain and enhance competitiveness and productivity, micro, small and medium-sized enterprises (MSMEs) require investment and working capital, which generally they cannot access from commercial banks. In this regard they face similar problems to MSMEs in other sectors—the MSME "financing gap" (World Bank/IFC 2017).
- To grow, wood-sector SMEs require reliable sources of legal raw materials. In the highly informal space that exists in many tropical countries, SMEs compete with informal competitors and have difficulty identifying trustworthy providers, which usually supply larger industry players. Transaction costs are high for SMEs, and so is the cost of raw materials.
- Tropical timber-processing SMEs lack access to international markets. Either they are contracted by larger industries, or they directly serve the domestic market. In domestic markets, they face competition from low-priced competitors operating in the informal space. Usually, domestic markets are price- rather than quality-driven.

Figure 37: Expansion of intake capacities and investment requirements for forest industries in tropical producer regions by 2050

Sources: GFPM; UNIQUE forestry and land-use forest industry benchmarks database.

- There is a severe shortage of trained workers in the wood industry. SMEs compete with large companies for qualified staff and lack the capacity to pay competitive salaries. In general, the forest and wood-industry sectors are not perceived as providing an attractive working environment. The situation could worsen as economies grow and the services and manufacturing sectors offer more employment opportunities.
- Overall, the technical equipment and know-how in SMEs is not state-of-the-art. The productivity and quality of wood-sector SMEs are uncompetitive compared with large companies and imported products.

Tropical timber-processing industries will have to mobilize capital for capacity expansion and industry modernization. Given the projected level of production in tropical producer regions in 2050, future IRW processing capacities will need to grow by more than 160 million m³ to meet the regional increase in demand in line with the GFPM forecast. The total intake capacity of tropical wood industries in 2050 will be 476 million m³. To reach this capacity, substantial investments will be needed in new processing lines and existing enterprises will need to modernize their equipment. Most existing machines are configured for large-dimension timber from natural forests but, increasingly, the supply will comprise small-dimension timber from plantations and agroforestry systems. Establishing the necessary

additional capacity in the wood industry will require capital expenditure of about USD 40 billion by 2050,[13] as well as significant investment to modernize outdated facilities.

If tropical producer regions were to avoid log exports and, rather, produce additional value-added products, another USD 18 billion would need to be invested in processing. Domestic production to substitute for wood-product imports would require an investment in capacity of USD 8 billion.

Reaching the production volume projected by the GFPM to 2050 will require an expansion in capacity across all forest subsectors in sub-Saharan Africa. Southeast Asia will require a massive expansion of sawlog- and veneer-log-processing capacity, although minor divestments are projected for the woodpulp subsector. Latin America will need a substantial increase in particleboard and fibreboard capacity, but woodpulp production capacity is projected to decline significantly (Figure 37).

Key actions to support the transition of the tropical timber industry

The tropical timber industry needs transformative public and private investments to overcome its challenges. Public investment would facilitate the raising of private investments at scale and help stimulate sustainable growth. Any effort to increase investment in tropical timber industries will need to be harmonized with action to encourage the widespread adoption of SFM in timber production. The key actions described below would have catalytic power.

Capitalize start-ups and SMEs. Obtaining the required investment in modern industries will only be possible by capitalizing domestic enterprises. A critical mass of technology-driven start-ups and SMEs is needed to build future modern companies that can attract larger equity investments. This requires the formalization of enterprises and the creation of investment accelerators. Financing products are needed that meet the specific needs of the forest sector, such as recoverable or convertible grants or subordinated loans. Building, formalizing and capitalizing enterprises should be accelerated in existing clusters with structures of raw-material supply and multilevel processing.

Develop knowledge and skills in the wood industry. In the future, the labour requirements for modern wood industries will be more sophisticated, and ensuring sufficient well-trained personnel will require solid education and training. Most tropical countries lack sufficient qualified workforces, and the forest sector must compete with other industries for talent at the management and production levels. In addition to wood-processing qualifications, the pool of future workers in wood industries will require skills in information technology for computer-aided design, robotics and e-marketing. The forest sector will need to improve on work conditions, salaries and reputation.

Standardize tropical timber products to make them competitive in a global commodity market. To be competitive, tropical timber products will need to comply with international product standards. Only standardized products will allow mass markets in construction and fibre to expand timber use and compete with non-wood products.

Encourage traceability-of-origin and sustainability certification to gain access to new markets for wood products in substituting for non-renewable materials. Increasing the positive contributions of tropical timber products to sustainable growth in tropical countries will require reliable sustainability certification and environmental product declarations to facilitate their preferential use according to public procurement guidelines and private market preferences.

13 This assumption is based on an industry average capital expenditure investment of USD 250 per m^3 of intake in modern primary-processing industries.

Plywood production, Côte d'Ivoire. Photo: © R. Carrillo/ITTO

4 TROPICAL TIMBER IN A SUSTAINABLE ECONOMY

Key points

- Global resource use could more than double by 2050, exceeding global sustainable supply sooner rather than later and triggering negative impacts on biodiversity, climate, ecosystems and human wellbeing.
- Economic growth in emerging countries will increase net global material use from 89 Gt in 2017 to 167 Gt in 2060, an increase of 88%. In the future material mix, fossil fuels and non-renewable construction materials will represent the largest shares.
- Strategies for coping with future material demand should prioritize resource-use efficiency and encourage societies to strive to achieve carbon-neutral production based on renewable and sustainably produced materials such as wood.
- The adoption of strategies to reduce non-renewables and increase sustainable resources from tropical forests in the materials mix in emerging economies will reduce negative externalities.
- Tropical timber could take a leading role because the increasing demand for goods in the construction sector and other sectors like plastics and textiles can partly be met by wood-based products.
- Five complementary generic strategies could help increase the use of tropical timber: 1) increase resource efficiency; 2) reallocate resources; 3) reduce export volumes and increase domestic value-added by developing processing industries; 4) improve forest management; and 5) encourage timber-focused investments in natural capital.

Tropical timber can play a major role in slowing down biodiversity loss, ecosystem degradation, social inequality and other negative externalities related to the extraction of natural resources in tropical producer regions. Although there are natural and economic limits to the resource base, there is potential to make increased use of sustainably produced tropical timber products to enhance value-added and the sustainable timber footprint in the tropics.

At the time of this study, countries were dealing with the impacts of the COVID-19 pandemic at all levels of their national economies. The shock to economies and enterprises is dynamic and in some cases specific to regions and industries. The measures taken by governments are varied; the impacts of societal constraints, and the short-term success of monetary backup strategies, may be more or less assessable, but the long-term effects remain uncertain.

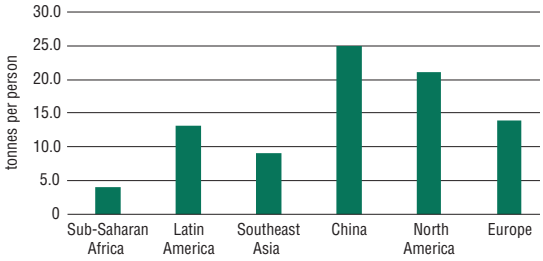
The pandemic has increased awareness of the need to build sustainable economies and societies. Many governments, non-governmental organizations and corporate stakeholders are committed to doing so. “Building back better” means building resilient societies after the pandemic by safeguarding nature and biodiversity, creating green jobs and fostering the transition to a carbon-neutral society (UNEP 2020).

Material consumption in tropical producer regions

Growing populations and higher living standards will significantly increase demand for goods and services, housing and energy in coming decades. Global resource use could more than double by 2050 (OECD 2018; UNEP 2016), exceeding global sustainable supply sooner rather than later (UNEP 2016) and triggering negative impacts on biodiversity, ecosystems and human wellbeing. If emerging economies continue to pursue current development paths, carbon emissions will continue to increase and pressure on valuable ecosystems will rise. The economic costs of climate change will be accompanied by increasing human-health problems. OECD (2018) projected that the toxic effects on humans and ecosystems related to the extraction and processing of metals will at least double by 2060.

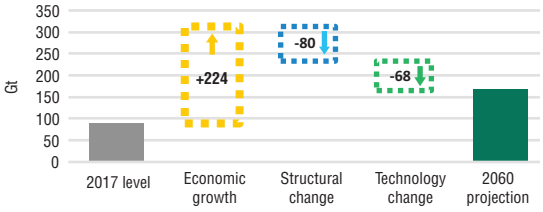
High-income countries have material-consumption footprints of about 27 tonnes per capita, which is about 13 times that of low-income countries (UNEP 2020). The lion’s share of this footprint comprises non-renewable materials; Figure 38 presents a comparison of per-capita resource consumption in selected world regions.

Figure 38: Per-capita material consumption, selected world regions, 2017



Source: UN (2020b).

Figure 39: Global material use in 2017 and 2060, and impact of structural and technology change



Source: OECD (2018).

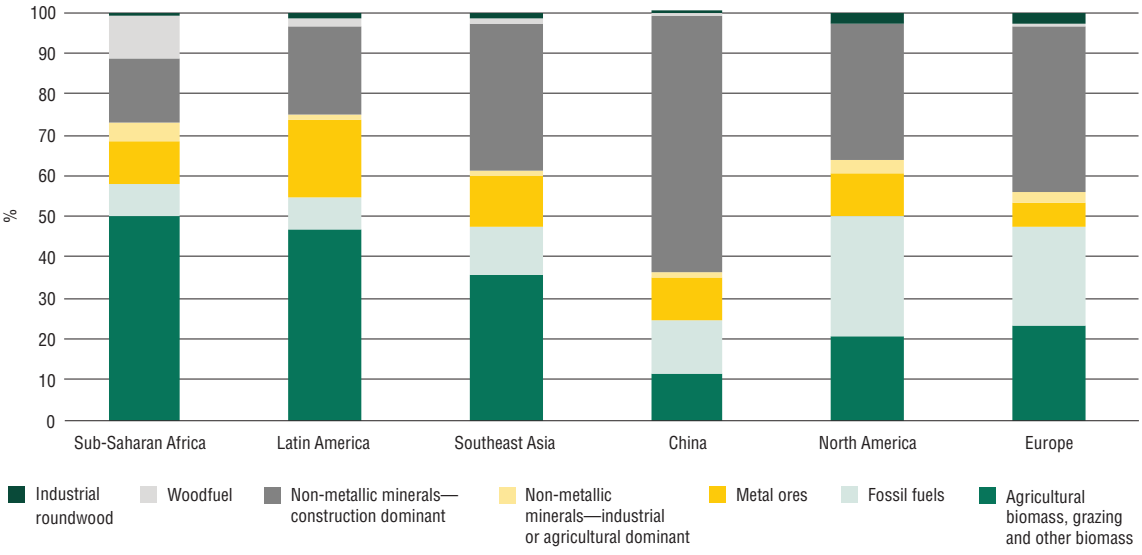
Tropical producer regions exhibit low-to-medium consumption compared with China, Europe and North America. On the other hand, future economic growth will be higher in emerging countries than in other regions.

Living standards gradually assimilate across economies, and the resource use of emerging economies in tropical producer regions will increase fast—as projected for India and Indonesia and most countries in sub-Saharan Africa and Asia with rapidly growing material use (OECD 2018).

Material intensity will decline due to technical and structural developments, an important step towards decoupling production growth from resource extraction. OECD (2018) projected that, by 2060, structural and technology changes will enable a decrease of 148 gigatonnes (Gt) (80 Gt + 68 Gt) in annual material use. The growing economies and their demand will outweigh the savings made from those efficiency gains, however (Figure 39): economic growth will increase net global material use from 89 Gt in 2017 to 167 Gt in 2060, an increase of 88%. It is important, therefore, to focus on the types of materials used and to evaluate their externalities, especially their environmental and social impacts.

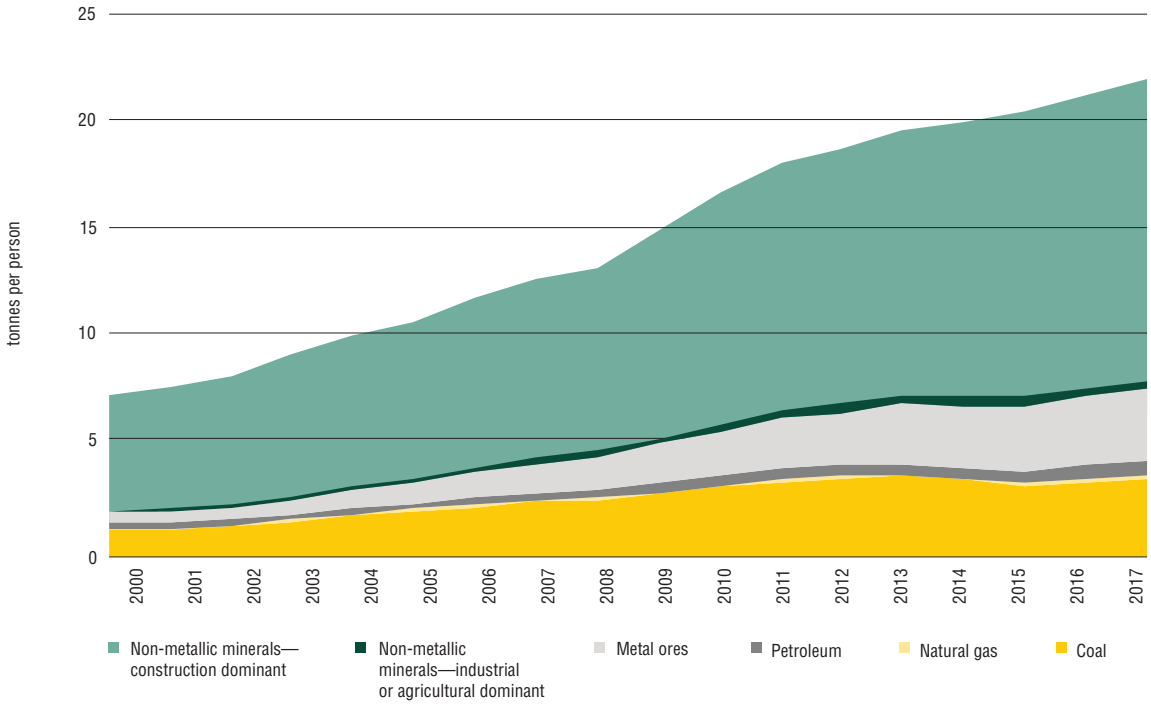
The global extraction of metals and non-metallic minerals has increased significantly, from almost 12 billion tonnes per year in the 1970s to close to 55 billion tonnes per year in 2017. The externalities related to the mining and refining of these materials account for 20% of climate-change impacts and also for 20% of particulate-matter health impacts (UNEP 2016).

Figure 40: Material consumption mix, selected world regions, 2017



Source: UN (2020b); industrial roundwood and woodfuel shares based on current wood consumption.

Figure 41: China's non-renewable material use per capita, 2000–2017



Source: UN (2020b).

According to OECD projections, concrete production alone will account for 12% of total greenhouse-gas emissions in 2060 and metal production for another 12% (OECD projections for 2060). According to the International Energy Agency and the Cement Sustainability Initiative, cement production (a key input in concrete) could increase by as much as 23% by 2050, but cement-related emissions will have to fall by at least 16% by 2030 to meet the target set in the Paris Agreement on climate change of limiting global warming to below 2 °C (Lehne and Preston 2018). Tropical regions currently use a considerably higher proportion of agricultural biomass and woodfuel in their material mixes (Figure 40), but demand for concrete and metals in those regions will grow rapidly as populations and economies grow.

Sixty-eight percent of the global population—7 billion people—will live in urban areas by 2050, up from 54% in 2015 (UN 2020a). This implies that an additional 2.7 billion people will live in cities, almost half (1.3 billion) of whom will be in tropical producer regions. It is clear, therefore, that urbanization will be a main driver of increased material use due to high demand for housing and building materials.

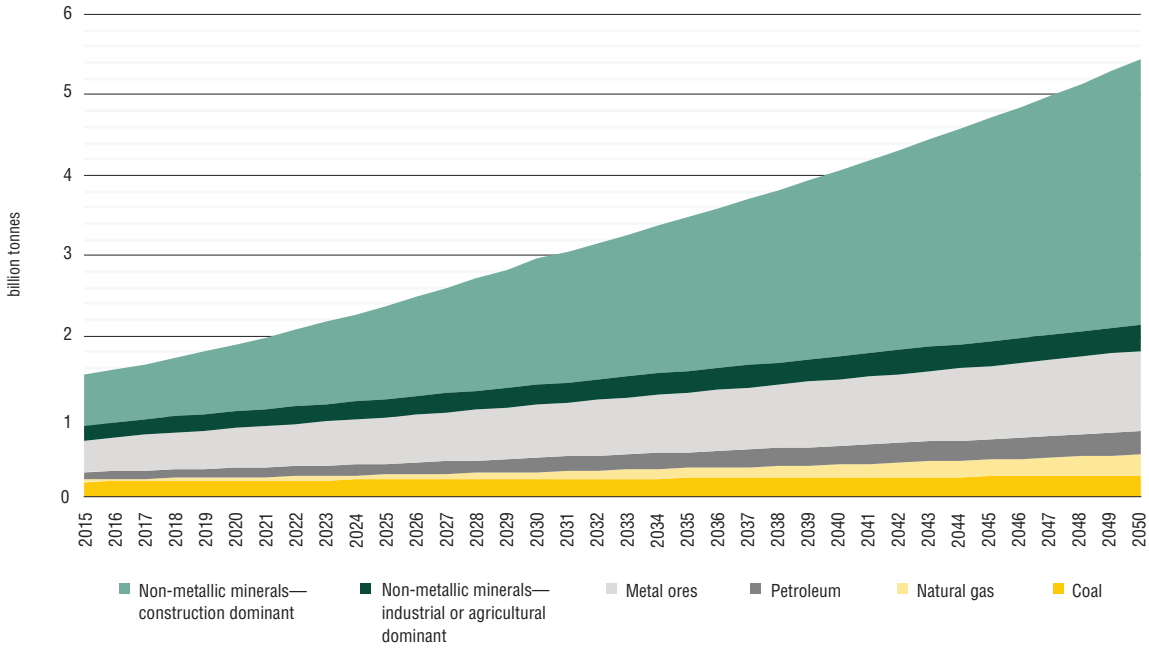
Without tangible action, both politically and in industrial development, material use will increase in non-renewable segments, and bio-based products will lose significant share (see Figure 41). Planetary boundaries will be exceeded and pollution externalities will increase. Many tropical producer countries will be affected disproportionately.

Strategies for coping with future demand for goods and housing should prioritize resource-use efficiency and encourage societies to strive to achieve carbon-neutral production based on renewable and sustainably produced materials such as wood.

OECD (2018) projected that the highest growth in material intensity will be in emerging and developing economies, including many tropical producer countries.

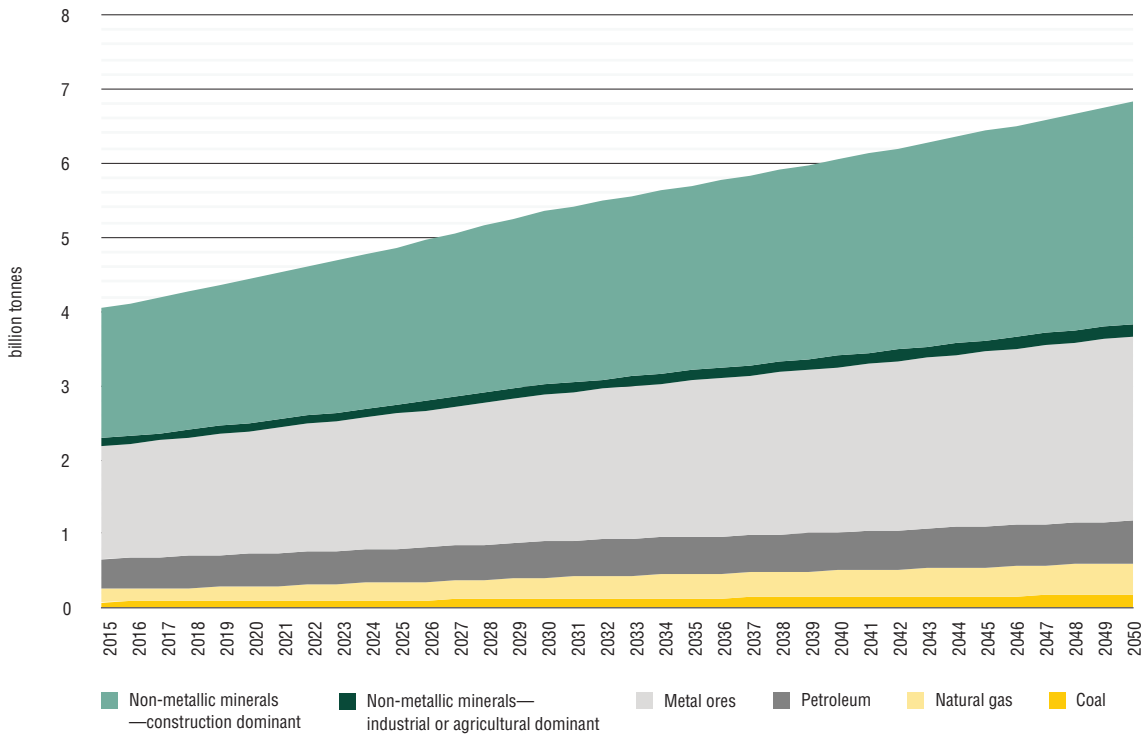
Figure 41 depicts how material use develops in fast-growing economies, using China as an example. Material consumption there increased rapidly, based predominantly on the extraction of unsustainable non-metallic minerals, metal ores and coal; the consumption of renewable resources (not shown) remained relatively constant.

Figure 42: Non-renewable material consumption in sub-Saharan Africa, 2015–2050



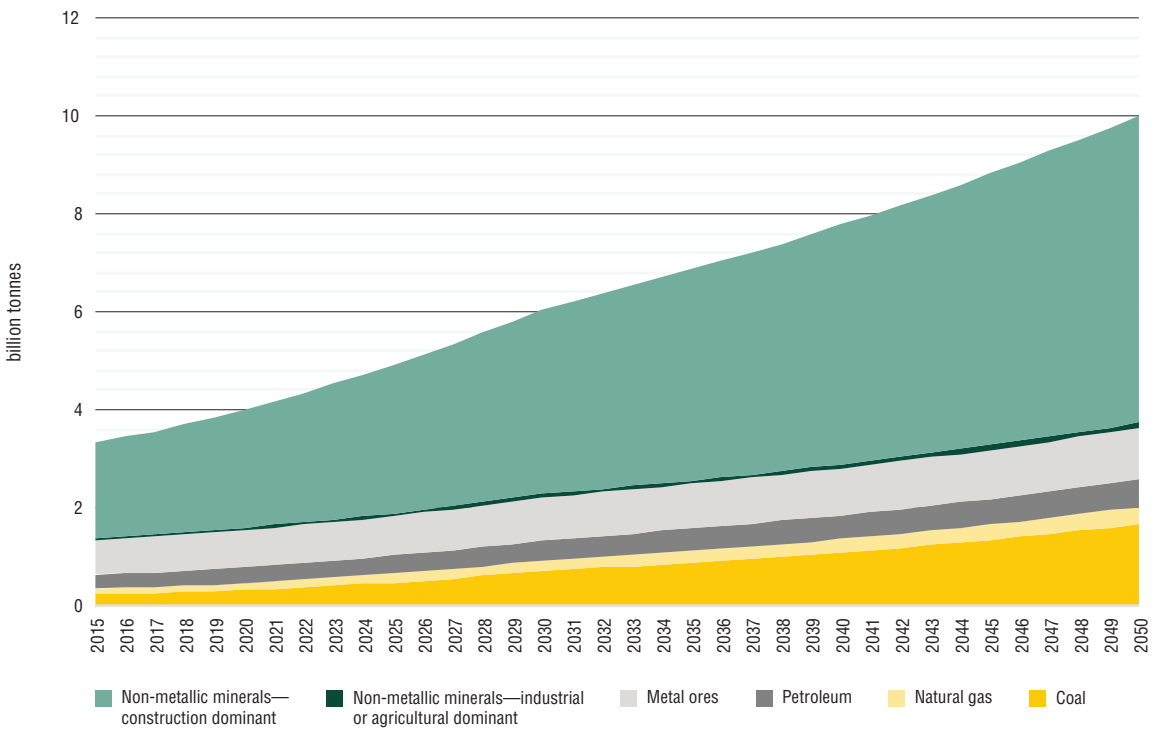
Sources: Projections based on UN (2020a) and UN (2020b).

Figure 43: Non-renewable material consumption in Latin America and the Caribbean, 2015–2050



Sources: Projections based on UN (2020a) and UN (2020b).

Figure 44: Non-renewable material consumption in Southeast Asia, 2015–2050



Sources: Projections based on UN (2020a) and UN (2020b).

An extrapolation of historical trends based on compound annual growth rates for the tropical producer regions suggests a similar possible development path. Figure 42, Figure 43 and Figure 44 show that, if these projections come to reality, they will make achievement of the Paris Agreement on climate change and the Sustainable Development Goals unlikely. Material demand is growing, and this is unavoidable, but the adoption of strategies to reduce non-renewables and increase sustainable resources from tropical forests in the materials mix in emerging economies will downsize negative externalities.

The biggest driver of non-renewable material and energy use, the construction sector, is underdeveloped with regard to wood use. Data on the market share of wood construction is incomplete and there are big regional differences. It can be assumed, however, that the market share of wood in the construction sector is below 10% globally (Leskinen et al. 2018) and that this share will decline in the future due to the overall rapid growth in the use of other materials.

Tropical timber for construction, textiles and plastics

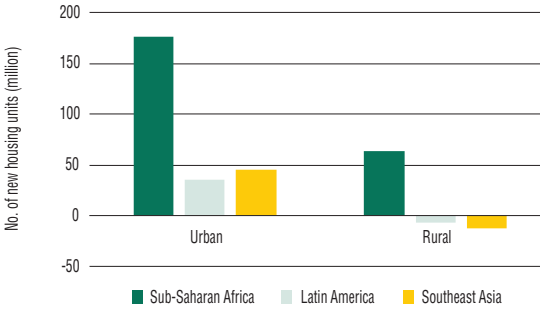
Decoupling material use from economic growth is an ultimate goal, but it is not foreseeable on a global scale. Material substitution may be second-best, but it is a ready-to-use solution. Tropical timber could take a leading role because the increasing demand for goods in the construction sector and other sectors like plastics and textiles can partially be met by wood-based products. Substitution with sustainably produced wood should cause reductions in greenhouse-gas emissions[14] and bring about benefits for human health and wellbeing, especially in rural areas.

Material substitution in the construction sector

Total demand for new residential housing in tropical producer regions will be around 321 million units to 2050, mostly in urban areas (Figure 45). The demand for housing in these regions has not been sufficiently addressed in recent decades due to

14 See Annex 8 for greenhouse-gas substitution factors of wood products.

Figure 45: Housing demand in tropical producer regions, 2015–2050



Note: Average of five persons per unit.
Source: Authors' own calculations based on UN (2020a) and UN (undated).

misguided administrative planning and a lack of capital in households. Nevertheless, future economic pathways indicate that residential construction will become more formal and standards will increase. With most population growth likely to occur in urban areas, new construction will be realized in a mix of houses and apartments in multistorey buildings.

Resource demand in the construction sector, and the related emissions, are—and will remain—exceptional compared with other sectors. The sector released almost 40% of energy- and process-related emissions in 2018. To achieve the Sustainable Development Goals, decarbonizing the building and construction sector is essential;[15] according to UNEP (2019), this would be among the most cost-effective climate actions for achieving the commitments embodied in the Paris Agreement.

Ximenes et al. (2012) calculated greenhouse-gas emissions for different (standard) building configurations in Australia and concluded that greenhouse-gas emissions from extraction, manufacturing, transport, use in construction, maintenance and disposal could easily be halved by replacing construction elements like subfloors made of concrete and wall elements (brick) with mass timber products. Mass timber construction is a construction process based on wood materials as the main structural element; it is a fast-growing market segment in temperate regions, replacing common building materials like concrete and steel, mostly in low- to mid-rise buildings but with the potential for more. Cross-laminated timber (CLT), an engineered wood product, is a success story in mass timber construction. It is an excellent substitute for walls and floors and, at the same time, it provides an opportunity to produce higher-value-added products from low-quality timber. CLT production is still mainly located in Europe, however; it is growing strongly in North America, and Japan is paving the way for CLT production. There is a need for further research on CLT production with tropical species; Liao et al. (2017) tested the feasibility of manufacturing CLT using fast-grown small-diameter *Eucalyptus*, with promising results.

15 See Annex 7 for substitution factors of timber in construction.

Substitution of textile fibre

It is projected that, by 2050, the global textiles industry will account for 26% of the global carbon budget (including emissions from fibre production, clothing manufacture and disposal). Moreover, polyester-based textiles will add 22 million tonnes of microfibre to the pollution of the oceans.

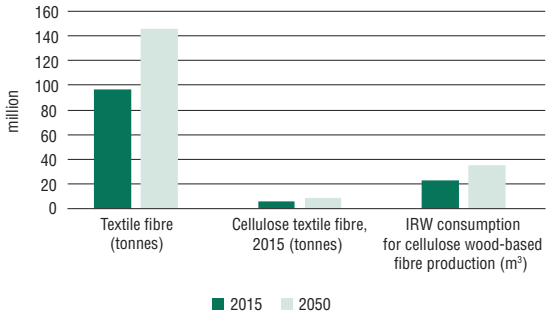
According to BSR (2009), energy use for the raw-material feedstock and production of polyester fibre is about 90 megajoules per kilogram of fibre, much higher than the global average of 12 megajoules per kilogram for viscose pulp.[16] When wood-based textile fibre is produced at an integrated pulp-and-paper site, textile fibres can be manufactured with very low and possibly even zero carbon emissions.[17]

The raw material for viscose and other wood-based fibres can be produced with low-water-using processes, making the water footprint significantly less than that for cotton and polyester. Cellulose textile fibre could also be an alternative for cotton in regions where climate-change-induced temperature increases and water shortages restrict the growing capability of cotton.

Total consumption of textile fibre is projected to increase to 146 million tonnes by 2050 (Figure 46), with polyester fibres holding 77% of the market (Hughes 2018). Today, the share of cellulose fibre in textile fibre production is 6%, which is low compared with cotton (25%) and polyester and other synthetics (69%) (Textile Exchange 2019). There are major cellulosic fibre production facilities in China, India and Southeast Asia. In Southeast Asia, where the GPFM is projecting a severe regional woodpulp gap by 2050, it would be worthwhile assessing the feasibility of combined the processing capacities of woodpulp and textile fibre.

16 If viscose production is used as a benchmark, the lowest-emission producer emits under 0.5 million tonnes of carbon-dioxide equivalent per tonne of viscose grade pulp.
17 https://paper360.tappi.org/2019/07/22/wood-pulp-the-new-cotton-for-the-garment-industry

Figure 46: Production of textile fibre, cellulose fibre and corresponding industrial roundwood demand, 2015 and 2050



Source: Authors' own calculations based on WEF (2016) and Textile Exchange (2019).

The main hindrance to cellulosic fibre commanding a higher market share is its high production costs. The end-price of viscose in the market is significantly higher than that of polyester. The main challenges for enhanced production, therefore, will be to decrease production costs and to organize efficient supply chains.

Substitution of plastics

More than 90% of plastics produced today are derived from virgin fossil-fuel feedstock, with a significant carbon impact that will become even more significant as consumption increases. Plastics production accounts for about 6% of global oil consumption (WEF 2016).

Plastics production is projected to grow from 311 million tonnes in 2015 to 1.1 billion tonnes in 2050. If so, the plastics sector will account for 20% of total oil consumption and 15% of the global annual carbon budget by 2050. Moreover, plastic packaging is almost exclusively single-use; it generates significant negative externalities, with the United Nations Environment Programme conservatively valuing these at USD 40 billion in 2015 (WEF 2016).

Substitutes for plastics made from wood (bioplastics) are technologically available and some are already in mass production, but production costs are higher than for conventional plastics (Selvamurugan and Sivakumar 2019). The products are biodegradable and reusable; as for conventional plastics, the single use of bioplastics should be avoided to increase its positive environmental impacts. The global pulp-and-paper industry is investing in research and prototype production lines to increase product versatility and cost-efficiency. It is reasonable to assume that, by 2050, competitive cellulose-based plastic substitutes will be available on the market.

In addition to innovative bioplastics, conventional wood and paper products can substitute for plastics in several applications, such as single-use packaging, laminates in flooring, and plastic furniture. The substantial substitution of plastics with wood products could contribute significantly to achieving emission reduction targets—if wood products outperform plastics in their durability. Using 1 tonne of wood products to substitute for plastics mitigates approximately 3.6 tonnes of carbon-dioxide equivalent emissions (Rüter et al. 2016; see Annex 8 for a list of emission substitution factors for selected non-wood products).

Key actions to promote tropical timber in a sustainable economy

Globally changing consumption patterns and increasing resource efficiency will release wood resources for allocation elsewhere. Investments in nature-based solutions, such as tropical rainforest conservation and landscape restoration, and subsidies or tax reductions for green products, will encourage increases in natural capital and economic efficiency. Due to their complexity and interrelatedness, the extent of the potential increase in natural capital is not projected here; nevertheless, it could be substantial.

Tropical timber will only be able to contribute to sustainable economies if:

- its production is delinked from deforestation and forest degradation;
- it can be produced at competitive price levels;
- the technical specifications are competitive and accepted in consumer markets;
- sufficient capital can be mobilized to invest in raw-material production and processing; and
- there is a favourable policy environment.

Putting aside the heterogeneous conditions among tropical producer countries and regions, the following five complementary generic strategies (depicted in Figure 47) could help increase the use of tropical timber:

1) *Increase resource efficiency*—for example by reducing waste through technical improvements in production processes and the digitization of value chains, using side-streams and byproducts, and applying cascade use where reasonable.

2) *Reallocate resources*—the global consumption of wood-based products changes over time; where demand declines for a certain product (e.g. the

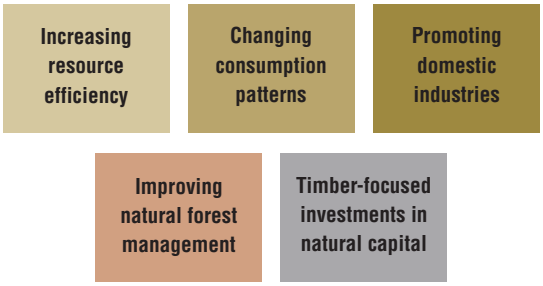
projected 30% decline in woodpulp production in Latin America to 2050), the free resource can be allocated to another use path. Moreover, future developments and the adoption of new technologies will lead to more efficient energy systems and the reduced use of woodfuel.

3) *Reduce export volumes and increase domestic value-added by developing processing industries*—according to GFPM projections, all tropical producer regions will be net exporters of IRW by 2050. The surplus production will primarily originate in plantation estates in a few countries (e.g. Brazil, Malaysia, South Africa, Uruguay and Viet Nam) (see Annex 9 for detailed projected net export volumes; other tropical countries, such as the Philippines and Uganda, are projected to have significant IRW deficits). In GFPM projections, 60–70 million m³ (6%) of timber production in tropical producer regions will be exported in 2050, mainly as IRW, but processed products will mainly be imported. Overcoming the projected lack of industry development and investment in tropical regions requires increasing in-country value-added on timber products and additional volumes of wood in regional value chains (related to side-streams and cascades). Viet Nam, for example, produces 12 million m³ of woodchips per year in its large expanse of plantations. These woodchips are exported, and the country's booming furniture industry is supplied largely by imported roundwood and primary-processed wood products.

4) *Improve forest management*—for example by expanding certification, improving management planning and undertaking active asset management. Production systems will need to be modified to enable higher harvesting rates, improve forest health and produce higher-value assortments. Global woodfuel production is concentrated in tropical regions, but the production of IRW and processed products is underrepresented. The GFPM projects that 57% (719 million m³) of tropical wood resources will still be used for woodfuel in 2050.

5) *Encourage timber-focused investments in natural capital*—a growing number of stimulus packages include investments in (for example) forest landscape restoration and nature-based solutions. As an umbrella concept, nature-based solutions act to protect, sustainably manage and restore ecosystems in order to provide diverse services for human wellbeing. Producing tropical timber under this umbrella seems reasonable but will need to ensure inclusive approaches that combine complex environmental, societal and economic considerations. There is a further need to explore and test business models for nature-based solutions in the tropical timber sector.

Figure 47: Five generic strategies to enhance the use of tropical wood resources



5 ITTO'S ROLE IN THE TRANSITION AND MODERNIZATION OF THE TROPICAL FOREST SECTOR

In light of the opportunities and challenges identified in this study, ITTO could take a leading role in guiding the development of the tropical forest sector in the decades to come. The Organization's work programme deals with specific aspects of the development of the tropical forest sector. Table 3 provides an indicative list of potential future activities (some of which ITTO is already engaged in).

Table 3: Future fields of activity in the transition and modernization of the tropical forest sector

Focus area	Field of future activities
1 SFM: managing and conserving tropical forests	Develop innovative business models and multiple revenue streams for natural forest management, including "concessions 2.0"
	Develop concepts to provide the raw materials of the future: high-quality raw materials for modern industries from productive plantations that are resilient to climate change
2 Economics, statistics and markets: improving the transparency of—and expanding international markets for—tropical timber	Support international initiatives that promote timber trade, legality and transparency through data analytics and impact monitoring
	Analyse current and future market requirements and understand the transitions required for tropical timber supply and value chains
3 Sustainable forest industries: developing efficient and value-adding tropical forest-based industries	Promote innovation and digitalization in tropical timber sectors, from forest information systems and timber production to wood-product processing and consumer requirements
	Develop incentive and capitalization schemes for small and medium-sized enterprises
4 Climate-change mitigation and adaptation: addressing climate change	Promote the substitution of non-renewable materials with sustainable timber to mitigate greenhouse-gas emissions and other negative externalities associated with the use of non-renewable materials
	Cooperate with initiatives that address deforestation and degradation and promote reforestation for commercial purposes
5 Capacity building: raising the capacity of forest stakeholders to manage and benefit from their resources	Promote diversity in tropical timber production to enable broad participation, ownership and benefit-sharing in SFM, including in small to large enterprises and between, private and public actors, genders and generations
	Facilitate knowledge transfer and provide training and education to meet future silvicultural and industry labour requirements

Annex 1: List of countries and regions

Region	Country
Sub-Saharan Africa	Angola
	Benin
	Botswana
	Burkina Faso
	Burundi
	Cabo Verde
	Cameroon
	Central African Republic
	Chad
	Comoros
	Congo
	Côte d'Ivoire
	Democratic Republic of the Congo
	Djibouti
	Equatorial Guinea
	Eritrea
	Eswatini
	Ethiopia
	Gabon
	Gambia
	Ghana
	Guinea
	Guinea-Bissau
	Kenya
	Lesotho
	Liberia
	Madagascar
	Malawi
	Mali
	Mauritania
	Mauritius
	Mayotte
	Mozambique
	Namibia
	Niger
	Nigeria
	Rwanda
	Saint Helena, Ascension and Tristan da Cunha
	Sao Tome and Principe
	Senegal
	Seychelles
	Sierra Leone
	Somalia
	South Africa
	South Sudan
	Togo
	Uganda
	United Republic of Tanzania
	Zambia
	Zimbabwe
Northern America	Canada
	Greenland
	Saint Pierre and Miquelon
	United States of America
Latin America and Caribbean	Antigua and Barbuda
	Argentina
	Aruba
	Bahamas
	Barbados
	Belize
	Bolivia (Plurinational State of)
	Brazil
	British Virgin Islands
	Cayman Islands
	Chile
	Colombia
	Costa Rica
	Cuba
	Curazao
	Dominica
	Dominican Republic
	Ecuador
	El Salvador
	Falkland Islands (Malvinas)
	French Guiana
	Grenada
	Guadeloupe
	Guatemala
	Guyana
	Haiti
	Honduras
	Jamaica
	Martinique
	Mexico
	Montserrat
	Nicaragua
	Panama
	Paraguay

	Peru
	Saint Kitts and Nevis
	Saint Lucia
	Saint Vincent and the Grenadines
	Saint-Martin (French Part)
	Suriname
	Trinidad and Tobago
	Turks and Caicos Islands
	Uruguay
	Venezuela (Bolivarian Republic of)
South Asia	Afghanistan
	Bangladesh
	Bhutan
	India
	Iran (Islamic Republic of)
	Maldives
	Nepal
	Pakistan
	Sri Lanka
Southeast Asia	Brunei Darussalam
	Cambodia
	Indonesia
	Lao People's Democratic Republic
	Malaysia
	Myanmar
	Philippines
	Singapore
	Thailand
	Timor-Leste
	Viet Nam
China	China
	China, Hong Kong SAR
	China, Macao SAR
	China, mainland
	China, Taiwan Province of
Rest of Asia	Democratic People's Republic of Korea
	Japan
	Kazakhstan
	Kyrgyzstan
	Mongolia
	Republic of Korea
	Tajikistan
	Turkmenistan
	Uzbekistan

Northern Africa/ Western Asia	Algeria
	Armenia
	Azerbaijan
	Bahrain
	Cyprus
	Egypt
	Georgia
	Iraq
	Israel
	Jordan
	Kuwait
	Lebanon
	Libya
	Morocco
	Oman
	Palestine
	Qatar
	Saudi Arabia
	Sudan
	Sudan (former)
	Syrian Arab Republic
	Tunisia
	Turkey
	United Arab Emirates
	Yemen
Europe	Albania
	Andorra
	Austria
	Belarus
	Belgium
	Bosnia and Herzegovina
	Bulgaria
	Croatia
	Czechia
	Denmark
	Estonia
	Faroe Islands
	Finland
	France
	Germany
	Gibraltar
	Greece
	Hungary
	Iceland
	Ireland
	Italy

	Latvia
	Liechtenstein
	Lithuania
	Luxembourg
	Malta
	Montenegro
	Netherlands
	North Macedonia
	Norway
	Poland
	Portugal
	Republic of Moldova
	Romania
	Russian Federation
	Serbia
	Slovakia
	Slovenia
	Spain
	Sweden
	Switzerland
	Ukraine
	United Kingdom

Oceania	American Samoa
	Australia
	Christmas Island
	Cocos (Keeling) Islands
	Cook Islands
	Fiji
	French Polynesia
	Kiribati
	Marshall Islands
	Micronesia (Federated States of)
	Nauru
	New Caledonia
	New Zealand
	Niue
	Norfolk Island
	Northern Mariana Islands
	Palau
	Papua New Guinea
	Pitcairn Islands
	Samoa
	Solomon Islands
	Tokelau
	Tonga
	Tuvalu
	Vanuatu
	Wake Island
	Wallis and Futuna Islands

Annex 2: Wood product conversion factors to RWE

Product	Coefficient
Fibreboard	1.7
Industrial roundwood	1
Particleboard	1.51
Plywood	2
Sawnwood	2
Veneer sheets	2
Woodfuel	1
Woodpulp	4

Source: FAO (2020).

Annex 3: GFPM tables

Region	Production (m^3, RWE)			
	IRW		Woodfuel	
	2015	2050	2015	2050
Sub-Saharan Africa	65 442 700	78 049 330	589 613 500	351 641 817
Latin America and Caribbean	226 641 900	282 664 100	262 105 900	240 440 300
Southeast Asia	136 945 700	173 205 698	154 202 200	126 730 200
Subtotal (tropical regions)	**429 030 300**	**533 919 128**	**1 005 921 600**	**718 812 317**
China	268 066 600	327 863 100	174 309 100	163 582 100
Europe	568 543 500	918 743 200	146 345 500	153 780 000
North America	511 471 000	786 943 500	47 322 800	49 573 600
India	46 842 600	97 331 200	303 968 200	236 986 700
Rest of South Asia	9 582 500	11 212 155	79 182 500	50 147 962
Rest of world	111 118 600	152 821 600	78 708 400	67 286 218
Total (world)	**1 944 655 100**	**2 828 833 883**	**1 835 758 100**	**1 440 168 897**
	Sawnwood		Veneer and plywood	
	2015	2050	2015	2050
Sub-Saharan Africa	19 497 800	22 552 834	3 348 400	9 823 027
Latin America and Caribbean	69 776 800	83 009 440	13 713 200	34 884 800
Southeast Asia	43 060 400	88 841 000	27 499 000	58 827 600
Subtotal (tropical regions)	**132 335 000**	**194 403 274**	**44 560 600**	**103 535 427**
China	136 481 200	61 567 410	221 336 000	575 518 400
Europe	299 021 000	590 053 465	21 685 400	62 551 295
North America	239 789 800	256 116 200	25 309 400	42 909 200
India	13 967 000	17 284 000	5 948 200	28 527 600
Rest of South Asia	5 924 800	8 018 896	1 020 400	1 474 200
Rest of world	58 735 800	65 867 298	11 349 600	29 792 575
Total (world)	**886 254 600**	**1 193 310 543**	**331 209 600**	**844 308 697**
	Particleboard and fibreboard		Woodpulp	
	2015	2050	2015	2050
Sub-Saharan Africa	1 911 094	4 695 253	6 386 000	13 291 589
Latin America and Caribbean	21 116 722	46 856 470	97 503 200	66 011 397
Southeast Asia	13 057 855	17 059 146	33 516 800	29 998 400
Subtotal (tropical regions)	**36 085 671**	**68 610 870**	**137 406 000**	**109 301 386**
China	143 895 888	412 428 243	37 517 200	8 870 372
Europe	110 427 422	266 488 416	182 034 800	155 585 268
North America	53 140 226	67 714 007	263 743 200	386 109 200
India	512 774	2 182 070	27 064 050	52 838 370
Rest of South Asia	2 924 569	4 109 425	2 041 150	1 435 230
Rest of world	26 708 001	61 415 620	50 504 000	50 030 300
Total (world)	**373 694 551**	**882 948 651**	**700 310 400**	**764 170 127**

Region	Consumption (m^3 roundwood equivalent)			
	IRW		Woodfuel	
	2015	2050	2015	2050
Sub-Saharan Africa	58 376 800	62 657 758	589 752 500	369 787 824
Latin America and Caribbean	215 450 700	240 601 900	262 077 000	240 438 300
Southeast Asia	112 508 800	159 315 200	154 178 300	126 706 000
Subtotal (tropical regions)	**386 336 300**	**462 574 858**	**1 006 007 800**	**736 932 124**
China	335 161 900	593 318 100	174 318 500	163 582 600
Europe	557 120 800	911 318 943	143 818 100	150 356 700
North America	491 252 900	574 762 400	47 123 000	50 287 000
India	54 038 300	125 795 000	303 971 200	236 986 900
Rest of South Asia	9 667 700	11 557 120	79 185 500	50 157 062
Rest of world	109 653 900	149 952 341	78 776 200	68 194 463
Total (world)	**1 943 231 800**	**2 829 278 762**	**1 833 200 300**	**1 456 496 848**
	Sawnwood		Veneer and plywood	
	2015	2050	2015	2050
Sub-Saharan Africa	17 084 400	22 548 743	3 422 000	12 119 645
Latin America and Caribbean	63 847 800	82 925 800	10 606 000	22 525 400
Southeast Asia	35 139 200	56 814 400	16 869 400	50 833 000
Subtotal (tropical regions)	**116 071 400**	**162 288 943**	**30 897 400**	**85 478 045**
China	194 282 200	285 082 600	203 815 400	594 817 800
Europe	213 047 400	250 272 000	22 377 400	35 807 000
North America	214 469 000	247 360 200	31 509 800	42 861 000
India	15 143 000	24 758 800	6 654 200	28 966 800
Rest of South Asia	8 469 600	11 660 200	1 131 400	3 694 845
Rest of world	116 495 400	149 320 200	28 347 800	47 490 200
Total (world)	**877 978 000**	**1 130 742 943**	**324 733 400**	**839 115 690**
	Particleboard and fibreboard		Woodpulp	
	2015	2050	2015	2050
Sub-Saharan Africa	2 559 349	7 745 918	6 536 400	9 600 000
Latin America and Caribbean	21 397 539	44 907 704	37 990 800	58 259 600
Southeast Asia	6 770 006	24 215 732	27 341 600	47 592 000
Subtotal (tropical regions)	**30 726 894**	**76 869 354**	**71 868 800**	**115 451 600**
China	140 379 119	468 289 016	107 630 400	137 418 000
Europe	99 862 012	161 732 011	196 052 400	158 400 401
North America	54 610 785	71 898 947	217 603 600	200 924 000
India	1 199 184	5 892 336	30 553 770	58 356 480
Rest of South Asia	5 004 297	14 715 366	4 259 430	6 339 120
Rest of world	37 686 714	78 912 934	69 543 200	72 164 000
Total (world)	**369 469 005**	**878 309 964**	**697 511 600**	**749 053 601**

Region	Net export volume			
	IRW		Woodfuel	
	2015	2050	2015	2050
Sub-Saharan Africa	7 065 900	15 391 573	-139 000	-18 146 006
Latin America and Caribbean	11 191 200	42 062 200	28 900	2 000
Southeast Asia	24 436 900	13 890 498	23 900	24 200
Subtotal (tropical regions)	**42 694 000**	**71 344 270**	**- 86 200**	**-18 119 806**
China	-67 095 300	-265 455 000	-9 400	-500
Europe	11 422 700	7 424 257	2 527 400	3 423 300
North America	20 218 100	212 181 100	199 800	-713 400
India	-7 195 700	-28 463 800	-3 000	-200
South Asia	-85 200	-344 965	-3 000	-9 100
Rest of world	1 464 700	2 869 259	-67 800	-908 245
Total (world)	**1 423 300**	**-444 879**	**2 557 800**	**-16 327 951**
	Sawnwood		Veneer and plywood	
	2015	2050	2015	2050
Sub-Saharan Africa	2 413 400	4 091	-73 600	-2 296 618
Latin America and Caribbean	5 929 000	83 640	3 107 200	12 359 400
Southeast Asia	7 921 200	32 026 600	10 629 600	7 994 600
Subtotal (tropical regions)	**16 263 600**	**32 114 331**	**13 663 200**	**18 057 382**
China	- 57 801 000	-223 515 190	17 520 600	-19 299 400
Europe	85 973 600	339 781 465	-692 000	26 744 295
North America	25 320 800	8 756 000	-6 200 400	48 200
India	-1 176 000	-7 474 800	-706 000	-439 200
Rest of South Asia	-2 544 800	-3 641 304	-111 000	-2 220 645
Rest of world	-57 759 600	-83 452 902	-16 998 200	-17 697 625
Total (world)	**8 276 600**	**62 567 600**	**6 476 200**	**5 193 007**
	Particleboard and fibreboard		Woodpulp	
	2015	2050	2015	2050
Sub-Saharan Africa	-648 255	-3 050 665	-150 400	3 691 589
Latin America and Caribbean	-280 817	1 948 766	59 512 400	7 751 797
Southeast Asia	6 287 849	-7 156 586	6 175 200	-17 593 600
Subtotal (tropical regions)	**5 358 777**	**-8 258 484**	**65 537 200**	**-6 150 214**
China	3 516 769	-55 860 773	-70 113 200	- 128 547 628
Europe	10 565 410	104 756 405	-14 017 600	-2 815 133
North America	-1 470 559	-4 184 940	46 139 600	185 185 200
India	-686 410	-3 710 266	-3 489 720	-5 518 110
Rest of South Asia	-2 079 728	-10 605 941	-2 218 280	-4 903 890
Rest of world	-10 978 713	-17 497 314	-19 039 200	-22 133 700
Total (world)	**4 225 546**	**4 638 687**	**2 798 800**	**15 116 526**

Annex 4: Comparison of production volumes versus FAO-reported data

Timber volumes reported by FAO versus case-study data on illegal production		
Country	**IRW production m³ reported by FAO for 2013/14**	**Under/overestimation of illegal/informal volumes**
Indonesia[a]	74 041 000	+12%
Malaysia[a]	16 748 000	–31%
Democratic Republic of the Congo[a]	4 611 013	–8%
Papua New Guinea[a]	4 017 000	0%
Cameroon[a]	2 700 000	–11%
Congo[a]	2 233 123	+10%
Ghana[a]	2 337 000	+14%
Lao People's Democratic Republic[a]	2 132 000	+6%
Weighted average, IRW		**–4%**
Country	**Sawnwood production in m³ reported by FAO for 2010/11**	**Under/overestimation of illegal/informal volumes**
Cameroon[b]	1 003 000	–50%
Gabon[b]	500 000	0%
Congo[b]	228 000	–54%
Democratic Republic of the Congo[b]	150 000	–67%
Central African Republic[b]	58 357	–243%
Ghana[b]	515 000	–46%
Indonesia[b]	4 160 000	–1%
Guyana[b]	76 000	–97%
Peru[b]	711 000	–111%
Suriname[b]	113 000	–33%
Weighted average, sawnwood		**–27%**

Sources: FAO (2020); [a] Hoare (2015); [b] Kishor and Lescuyer (2012).

Annex 5: Comparison of roundwood projections for Africa

The significant reduction in woodfuel consumption in sub-Saharan Africa projected by the GFPM contradicts other forecast studies (e.g. Grieg-Gran et al. 2015) that expect significantly higher woodfuel consumption in sub-Saharan Africa. Usually, other studies extrapolate historic consumption figures or actual per-capita consumption into the future. In contrast, the GFPM configuration factors in woodfuel substitution rates considering reduction pathways in developing countries that follow woodfuel consumption in industrialized economies.

A cross-check of historical forecast studies shows that the GFPM has been quite accurate in forecasting woodfuel consumption in Africa.

The following table compares historical IRW and wood fuel projections for Africa for 2020 by:

- The GFPM projected in 2006. The GFPM was based on a set of assumptions, as explained in Chapter 1, and was parametrized with historical data up to 2005.
- The FAO Forest Sector Outlook Study Africa from 2003 (FOSA). The FOSA forecast was based on historical trend extrapolations and per-capita consumption ratios.

The 2020 projections for industrial roundwood production in Africa were quite similar for both GFPM and FOSA. Actual FAO data for 2019 show that the GFPM underestimated IRW production by 6%, while the FOSA projection overestimated production by 13%.

Woodfuel projections for woodfuel production in Africa were wider apart for both approaches. Compared against actual production figures for 2019, the GFPM projection was much more accurate, underestimating production by 2%, compared with the FOSA approach, which overestimated woodfuel production by 21%.

Comparison of historical long-term forecasts for IRW and woodfuel in Africa

Consumption in 1000 m³	Projection 2020		Actual FAO data 2019[c]		Deviation GFPM 2006 vs. FAO actual 2019	
	IRW	Woodfuel	IRW	Woodfuel	IRW	Woodfuel
GFPM 2006[a]	83 495	688 743	78 910	700 072	–4 585	–11 329
FOSA 2003[b]	89 000	850 000			10 090	149 928

Sources : [a] Turner et al. (2010) ; [b] FAO (2003); [c] FAO (2020).

Annex 6: Employment factors

2015 employment factors from UNIQUE forest-sector employment database					
per 1000 m³ (RWE) production volume	Forestry and logging	Wood industry (sawnwood, veneer, plywood)	Wood industry (particleboard and fibreboard)	Woodpulp (and paper)	Other uses (pellets, bioplastics, textile fibre)
Sub-Saharan Africa	3	10	5	2.5	0
Latin America and Caribbean	1	5	5	2	0
Southeast Asia	1	20	5	3.5	0
Employment factors assuming increased efficiency and productivity 2050					
per 1000 m³ (RWE) production volume	Forestry and logging	Wood industry (sawnwood, veneer, plywood)	Wood industry (particleboard and fibreboard)	Woodpulp	Other uses (pellets, bioplastics, textile fibre)
Sub-Saharan Africa	2	10	5	2	2
Latin America and Caribbean	1	5	5	2	2
Southeast Asia	1	10	5	2	2

Source: Factors derived from National Accounts and industry surveys.

Annex 7: Timber construction factors

Residential housing type	Timber construction type	Volume of IRW per 1000 m^2 floor area in structural elements	Average floor area (m^2 per unit)	Total IRW consumption per unit (m^3)
Multistorey urban residential apartment block	CLT and mass timber construction	296 m^3 [(a)]	75	22
Low-cost house (single-storey)	Timber frame construction	243 m^3 [(b)]	75	18

Sources: [a] Forestry Innovation Investment (2017); [b] Reynoso (2017).

Annex 8: Emission substitution factors for wood products

Harvested wood product (HWP)	Carbon stored in HWPs (tonnes carbon per m^3 HWP)	Substitution factor for HWP (tonnes carbon per tonne HWP)	Comment	
Sawnwood	0.06[a]	1.26[b]	Substituting conventional construction material mix (concrete, steel, bricks)	Substitution factor likely to increase if cement industry is able to reduce carbon footprint up to 2050
Wood fibre pulp	Not accounted	3.62[b]	Substituting polyester textile fibre	Substitution factor likely to increase if industries decrease up to 2050
		2[b]	Substitution mix polyester and other plastics	
Wood pellets	Not accounted	1[d]	Substituting mineral coal	

Sources: [a] VCS module VMD 0026 estimation of carbon stocks in the long-lived wood products pool, vs 1, 2012; [b] Rüter et al. (2016); [c] Own estimate based on Rüter et al. (2016); [d] Conservative value based on Brack (2017).

Annex 9: Net trade data, GFPM

IRW net trade 2050	
Latin America and Caribbean	
Country	**Net trade (m³)**
Argentina	45 800
Bahamas	–27 500
Barbados	–1 400
Belize	–27 800
Bolivia (Plurinational State of)	–1 100
Brazil	22 676 100
Chile	16 815 500
Colombia	235 100
Costa Rica	746 000
Cuba	–2 300
Dominica	–1 300
Dominican Republic	–12 500
Ecuador	36 200
El Salvador	119 900
French Guiana	9 500
Guatemala	1 100
Guyana	204 300
Haiti	–24 700
Honduras	–9 700
Jamaica	–82 100
Martinique	–1 000
Mexico	–1 400
Netherlands Antilles	0
Nicaragua	–200
Panama	137 900
Paraguay	1 700
Peru	–52 600
Saint Lucia	–300
Saint Vincent/Grenadines	–1 800
Suriname	272 000
Trinidad and Tobago	–159 800
Uruguay	1 143 700
Venezuela Bolivarian Republic of	24 900
Southeast Asia	
Country	**Net trade (m³)**
Brunei Darussalam	–2 600
Cambodia	5 700
Indonesia	300 900
Lao People's Democratic Republic	2 616 600
Malaysia	7 487 200
Myanmar	216 900
Philippines	–480 000
Singapore	–4 102
Thailand	466 600
Timor-Leste	–1 200
Viet Nam	3 284 500
Sub-Saharan Africa	
Country	**Net trade (m³)**
Angola	1 300
Benin	30 000
Botswana	–2 500
Burkina Faso	126 898
Burundi	22 100
Cameroon	109 700
Central African Republic	253 700
Chad	–400
Congo	1 514 200
Côte d'Ivoire	22 000
Democratic Republic of the Congo	25 000
Djibouti	–300
Equatorial Guinea	656 100
Ethiopia	–86 100
Gabon	298 500
Gambia	296 100
Ghana	35 600
Guinea	–22 500
Guinea-Bissau	30 000
Kenya	–113 200
Lesotho	–1 300
Liberia	55 800
Madagascar	900
Malawi	–600
Mali	–9 600
Mauritania	–87 400
Mauritius	–28 300
Mozambique	170 900
Niger	–6 811
Nigeria	36 613
Réunion	5 700
Rwanda	7 500
Sao Tome and Principe	0
Senegal	–81 700
Sierra Leone	21 800
Somalia	–2 700
South Africa	14 544 200
Swaziland	–2 600
Togo	–3 781
Uganda	–2 046 846

United Republic of Tanzania	–364 100
Zambia	–11 200
Zimbabwe	–1 100
Sawnwood net trade 2050	
Latin America and Caribbean	
Country	**Net trade (m³)**
Argentina	195 600
Bahamas	–1 400
Barbados	–16 800
Belize	–5 400
Bolivia (Plurinational State of)	21 600
Brazil	5 568 400
Chile	2 079 200
Colombia	–258 400
Costa Rica	3 200
Cuba	–3 600
Dominica	–13 600
Dominican Republic	–552 200
Ecuador	47 600
El Salvador	–126 200
French Guiana	15 200
Guatemala	–448 649
Guyana	13 600
Haiti	–101 600
Honduras	–10 800
Jamaica	–183 800
Martinique	–70 200
Mexico	–6 871 400
Netherlands Antilles	0
Nicaragua	2 800
Panama	–94 911
Paraguay	4 200
Peru	639 400
Saint Lucia	–36 400
Saint Vincent/Grenadines	–4 200
Suriname	21 600
Trinidad and Tobago	–205 600
Uruguay	477 000
Venezuela (Bolivarian Republic of)	–600
Southeast Asia	
Country	**Net trade (m³)**
Brunei Darussalam	0
Cambodia	18 600
Indonesia	–732 400
Lao People's Democratic Republic	944 600
Malaysia	18 608 600
Myanmar	336 200
Philippines	2 131 000
Singapore	–646 600
Thailand	11 940 400
Timor-Leste	0
Viet Nam	–573 800
Sub-Saharan Africa	
Country	**Net trade (m³)**
Angola	400
Benin	88 200
Botswana	–166 400
Burkina Faso	–25 000
Burundi	0
Cameroon	1 874 800
Central African Republic	18 600
Chad	–16 200
Congo	56 200
Côte d'Ivoire	291 600
Democratic Republic of the Congo	408 000
Djibouti	–27 600
Equatorial Guinea	400
Ethiopia	–251 056
Gabon	191 600
Gambia	0
Ghana	72 200
Guinea	2 800
Guinea-Bissau	0
Kenya	–163 800
Lesotho	–32 600
Liberia	400
Madagascar	18 200
Malawi	15 000
Mali	–49 200
Mauritania	–9 200
Mauritius	–231 000
Mozambique	929 200
Niger	–77 800
Nigeria	–2 210 033
Réunion	–220 765
Rwanda	–800
Sao Tome and Principe	2 600
Senegal	–124 600
Sierra Leone	8 200
Somalia	–42 200
South Africa	–228 400
Swaziland	4 400

Togo	–367
Uganda	–93 288
United Republic of Tanzania	–8 800
Zambia	5 600
Zimbabwe	–5 200
Veneer and plywood net trade 2050	
Latin America and Caribbean	
Country	**Net trade (m³)**
Argentina	–128 400
Bahamas	–34 000
Barbados	–24 200
Belize	–38 000
Bolivia (Plurinational State of)	–6 200
Brazil	12 105 800
Chile	52 400
Colombia	–48 200
Costa Rica	–4 400
Cuba	–1 800
Dominica	–4 200
Dominican Republic	–121 400
Ecuador	23 200
El Salvador	–38 600
French Guiana	–11 000
Guatemala	–125 000
Guyana	31 400
Haiti	–37 200
Honduras	–69 800
Jamaica	–123 000
Martinique	–17 800
Mexico	–120 400
Netherlands Antilles	0
Nicaragua	–56 600
Panama	–6 000
Paraguay	6 000
Peru	4 800
Saint Lucia	–24 600
Saint Vincent/Grenadines	–7 800
Suriname	–600
Trinidad and Tobago	–17 200
Uruguay	1 213 000
Venezuela (Bolivarian Republic of)	–10 800
Southeast Asia	
Country	**Net trade (m³)**
Brunei Darussalam	–6 000
Cambodia	–470 600
Indonesia	426 600
Lao People's Democratic Republic	11 600
Malaysia	11 357 400
Myanmar	17 600
Philippines	–3 146 800
Singapore	–1 743 800
Thailand	–79 000
Timor-Leste	–22 600
Viet Nam	1 650 200
Sub-Saharan Africa	
Country	**Net trade (m³)**
Angola	–235 600
Benin	–2 000
Botswana	–8 800
Burkina Faso	–89 000
Burundi	–11 400
Cameroon	151 600
Central African Republic	0
Chad	–10 400
Congo	6 000
Côte d'Ivoire	92 000
Democratic Republic of the Congo	–26 400
Djibouti	–60 400
Equatorial Guinea	–27 800
Ethiopia	–378 000
Gabon	672 000
Gambia	–18 400
Ghana	36 800
Guinea	–8 400
Guinea-Bissau	0
Kenya	–80 000
Lesotho	–7 600
Liberia	–35 000
Madagascar	–400
Malawi	9 800
Mali	–35 200
Mauritania	–2 200
Mauritius	–70 000
Mozambique	–11 000
Niger	–146 000
Nigeria	–1 521 468
Réunion	–83 800
Rwanda	–35 600
Sao Tome and Principe	0
Senegal	–87 800
Sierra Leone	–22 400
Somalia	–44 800

South Africa	–33 400
Swaziland	–600
Togo	–40 600
Uganda	–42 550
United Republic of Tanzania	–82 200
Zambia	–800
Zimbabwe	–4 800
Particleboard and fibreboard net trade 2050	
Latin America and Caribbean	
Country	**Net trade (m³)**
Argentina	319 857
Bahamas	0
Barbados	–2 890
Belize	–11 067
Bolivia (Plurinational State of)	–248 503
Brazil	8 148 291
Chile	450 923
Colombia	–1 536 307
Costa Rica	–71 151
Cuba	–170
Dominica	0
Dominican Republic	–45 860
Ecuador	–764 850
El Salvador	–53 203
French Guiana	0
Guatemala	–136 244
Guyana	–5 270
Haiti	–24 480
Honduras	–124 548
Jamaica	–29 918
Martinique	–1 963
Mexico	–2 529 333
Netherlands Antilles	0
Nicaragua	–31 632
Panama	–77 829
Paraguay	–86 271
Peru	–1 101 113
Saint Lucia	0
Saint Vincent/Grenadines	0
Suriname	–24 440
Trinidad and Tobago	–41 990
Uruguay	–23 143
Venezuela (Bolivarian Republic of)	1 870

Southeast Asia	
Country	**Net trade (m³)**
Brunei Darussalam	–5 950
Cambodia	–61 040
Indonesia	–3 140 117
Lao People's Democratic Republic	–29 123
Malaysia	340 698
Myanmar	–199 931
Philippines	–1 065 879
Singapore	–41 609
Thailand	1 457 956
Timor-Leste	0
Viet Nam	–4 411 591
Sub-Saharan Africa	
Country	**Net trade (m³)**
Angola	–67 182
Benin	–11 050
Botswana	–17 255
Burkina Faso	0
Burundi	–13 940
Cameroon	0
Central African Republic	0
Chad	0
Congo	–7 480
Côte d'Ivoire	0
Democratic Republic of the Congo	0
Djibouti	–98 430
Equatorial Guinea	0
Ethiopia	–699 260
Gabon	0
Gambia	–21 420
Ghana	–30 940
Guinea	–30 770
Guinea-Bissau	0
Kenya	–70 854
Lesotho	–15 553
Liberia	–51 170
Madagascar	–5 625
Malawi	436 734
Mali	–181 560
Mauritania	0
Mauritius	–63 859
Mozambique	–64 055

Niger	0
Nigeria	–1 856 155
Réunion	–8 421
Rwanda	–30 770
Sao Tome and Principe	0
Senegal	–9 010
Sierra Leone	–70 550
Somalia	–147 050
South Africa	888
Swaziland	224 688
Togo	0
Uganda	–87 909
United Republic of Tanzania	–10 140
Zambia	–31 620
Zimbabwe	–10 947
Woodpulp net trade 2050	
Latin America and Caribbean	
Country	**Net trade (m³)**
Argentina	–545 200
Bahamas	0
Barbados	0
Belize	0
Bolivia (Plurinational State of)	–78 400
Brazil	12 670 000
Chile	3 379 200
Colombia	–1 732 000
Costa Rica	–96 400
Cuba	–18 800
Dominica	0
Dominican Republic	–9 200
Ecuador	–92 000
El Salvador	–2 800
French Guiana	0
Guatemala	–4 800
Guyana	0
Haiti	0
Honduras	0
Jamaica	0
Martinique	0
Mexico	–6 135 003
Netherlands Antilles	0
Nicaragua	0
Panama	–1 200
Paraguay	0
Peru	–360 800
Saint Lucia	0
Saint Vincent/Grenadines	0
Suriname	0
Trinidad and Tobago	–194 000
Uruguay	1 957 600
Venezuela (Bolivarian Republic of)	–984 400
Southeast Asia	
Country	**Net trade (m³)**
Brunei Darussalam	0
Cambodia	0
Indonesia	–4 420 400
Lao People's Democratic Republic	–17 200
Malaysia	–1 746 400
Myanmar	–14 800
Philippines	–56 400
Singapore	–6 000
Thailand	–6 958 800
Timor-Leste	0
Viet Nam	–4 373 600
Sub-Saharan Africa	
Country	**Net trade (m³)**
Angola	–73 789
Benin	0
Botswana	0
Burkina Faso	0
Burundi	0
Cameroon	–800
Central African Republic	0
Chad	0
Congo	0
Côte d'Ivoire	–7 200
Democratic Republic of the Congo	–14 000
Djibouti	–73 200
Equatorial Guinea	0
Ethiopia	–206 800
Gabon	0
Gambia	0
Ghana	0
Guinea	0
Guinea-Bissau	0
Kenya	–2 400
Lesotho	0
Liberia	0
Madagascar	0
Malawi	0
Mali	0
Mauritania	0

Mauritius	–800
Mozambique	–69 600
Niger	–22 000
Nigeria	4 280 978
Réunion	0
Rwanda	0
Sao Tome and Principe	0
Senegal	–1 200
Sierra Leone	–400
Somalia	0
South Africa	–116 400
Swaziland	0
Togo	0
Uganda	0
United Republic of Tanzania	0
Zambia	0
Zimbabwe	–800

REFERENCES

Bailis, R., Rujanavech, C., Dwivedii, P., Vilela, A., Chang, H. & Miranda, R. 2013. Innovation in charcoal production: a comparative life-cycle assessment of two kiln technologies in Brazil. *Energy for Sustainable Development* 17: 189–200.

BSR 2009. *Apparel industry life cycle carbon mapping*. Business for Social Responsibility (BRS).

Buongiorno J. 2015. Global modelling to predict timber production and prices: the GFPM approach. *Forestry: An International Journal of Forest Research* 88(3): 291–303. https://doi.org/10.1093/forestry/cpu047

Buongiorno, J., Zhu, S., Zhang, D., Turner, J. & Tomberlin, D. 2003. *The Global Forest Products Model (GFPM): structure, estimation, applications*. Academic Press.

Brack, D. 2017. *Woody biomass for power and heat impacts on the global climate*. Research Paper. The Royal Institute of International Affairs, Chatham House, London, UK.

Daigneault, A., Johnston, C., Korosuo, A., Baker, J., Forsell, N., Prestemon, J. & Abt, R. 2018. Developing detailed shared socioeconomic pathway (SSP) narratives for the global forest sector. Paper presented at the 2018 Forest and Agriculture GHG Modeling Forum. Shepherdstown, USA.

D'Annunzio, R., Sandker, M., Finegold, Y. & Min, Z. 2015. Projecting global forest area towards 2030. *Forest Ecology and Management* 352: 124–133.

Dev, I., Ram, A., Baskar, S. & Chaturvedi, O. 2018. *Agroforestry for climate resilience and rural livelihood: role of agroforestry in current scenario*. Natural Resource Management Division, ICAR, New Delhi, India.

Eufrade Junior, H., Monari Ohto, J., da Silva, L., Lara Palma, H. & Ballarin, A.W. 2015. Potential of rubberwood (*Hevea brasiliensis*) for structural use after the period of latex extraction: a case study in Brazil. *Journal of Wood Science* 61: 384–390.

FAO 2002. *Trees outside forests: towards a better awareness*. FAO Conservation Guide 35. Food and Agriculture Organization of the United Nations (FAO), Rome.

FAO 2003. *Forestry outlook study for Africa. Regional report: opportunities and challenges towards 2020*. FAO Forestry Paper No. 141. Food and Agriculture Organization of the United Nations (FAO), Rome.

FAO 2016. *Global forest resources assessment 2015: how are the world's forests changing?* Food and Agriculture Organization of the United Nations (FAO), Rome.

FAO 2018. *Rethinking forest concessions: improving the allocation of state-owned forests for better economic, social and environmental outcomes*. Forestry Working Paper No. 4. Food and Agriculture Organization of the United Nations (FAO), Rome.

FAO 2019a. *Silvopastoral systems and their contribution to improved resource use and sustainable development goals: evidence from Latin America*. Food and Agriculture Organization of the United Nations (FAO), CIPAV and Agri Benchmark, Cali, Colombia.

FAO 2019b. *Agroforestry and tenure*. Forestry Working Paper No. 8. Food and Agriculture Organization of the United Nations (FAO), Rome.

FAO 2020. FAOSTAT. Forestry production and trade 1961–2018 (query panel) [online]. Food and Agriculture Organization of the United Nations (FAO), Rome [accessed 20 January 2020]. www.fao.org/faostat/en/#data/FO

Forest Trends 2018. *Vietnam: diagnoses and regulatory assessment of small and micro forest enterprises in the Mekong region*. Washington, DC.

Forestry Innovation Investment 2017. Introduction to Brock Commons tallwood house: UBC tall wood building [online] [accessed July 2020]. www.naturallywood.com/resource/introduction-to-brock-commons-tallwood-house-ubc-tall-wood-building

Gilmore, D. 2016. *Forty years of community-based forestry: a review of its extent and effectiveness*. FAO Forestry Paper No. 176. Food and Agriculture Organization of the United Nations (FAO), Rome.

GlobalABC 2020. *Regional roadmap for buildings and construction in Latin America: towards a zero-emission, efficient and resilient buildings and construction sector*. International Energy Agency, Paris.

Grieg-Gran, M., Bass, S., Booker, F. & Day, M. 2015. *The role of forests in a green economy transformation in Africa*. United Nations Environment Programme, Nairobi.

Grulke, M., del Valle, P., Calo, I., Merger, E., Pawlowski, G. & Wittmann, N. 2016. *Sustainable natural forest management in the tropics: best practices and investment opportunities for large scale forestry*. Unique, Freiburg, Germany.

Hetemäki, L. & Hurmekoski, E. 2016. Forest products markets under change: review and research implications. *Current Forestry Reports* 2: 177–188.

Hoare, A. 2015. *Tackling illegal logging and the related trade: what progress and where next?* Chatham House, London.

Hughes, K. 2018. *Cotton report 2017: cotton production & trade trends*. International Cotton Advisory Committee.

Iiyama, M., Neufeldt, H., Dobie, P., Njenga, M., Ndegwa, G. & Jamnadass, R. 2014. The potential of agroforestry in the provision of sustainable woodfuel in sub-Saharan Africa. *Current Opinion in Environmental Sustainability* 6: 138–147.

IMF 2020. IMF data (data query) [online]. International Monetary Fund (IMF) [accessed November 2020]. www.imf.org/en/Data

Indufor 2012. *Strategic review on the future of forest plantations*. Helsinki.

Irawanti, S., Race, D. & Stewart, H. 2017. Understanding the timber value chain in community-based forestry in Indonesia: analysis of sengon in central Java. *Journal of Sustainable Forestry* 36(8): 847–862. Doi: 10.1080/10549811.2017.1381029

IRENA 2014. *Global bioenergy: supply and demand projections*. A working paper for REmap 2030. International Renewable Energy Agency (IRENA).

ITTO 2008. *Promotion of rubberwood processing technology in the Asia-Pacific region*. Proceedings of the ITTO/CFC International Rubberwood Workshop, 8–10 December 2008. Yokohama, Japan.

ITTO 2020. Biennial Review statistics (data query) [online]. Yokohama, Japan [accessed November 2020]. www.itto.int/biennal_review

ITTO/IMM 2019. *Forest sector investments in FLEGT VPA countries: scoping study on investors' perspectives and investment monitoring*. ITTO and the Independent Market Monitor (IMM), Yokohama, Japan.

Karsenty, A. & Vermeulen, C. 2016. Toward concessions 2.0: articulating inclusive and exclusive management in production forests in Central Africa. *International Forestry Review* 18(S1).

Kishor, N. & Lescuyer, G. 2012. Controlling illegal logging in domestic and international markets by harnessing multi-level governance opportunities. *International Journal of the Commons* 6(2): 255–270.

Lehne, J. & Preston, F. 2018. *Making concrete change: innovation in low-carbon cement and concrete*. Chatham House, London.

Leskinen, P., Cardellini, G., González-García, S., Hurmekoski, E., Sathre, R., Seppälä, J., Smyth, C., Stern, T. & Verkerk, P. 2018. *Substitution effects of wood-based products in climate change mitigation*. From Science to Policy 7. European Forest Institute, Helsinki.

Liao, Y., Tu, D., Zhou, J., Zhouc, H., Yuna, H., Gua, J. & Hu, C. 2017. Feasibility of manufacturing cross-laminated timber using fast-grown small diameter eucalyptus lumbers. *Construction and Building Materials* 132: 508–515.

MacDicken, K., Sola, P., Hall, J., Sabogal, C., Tadoum, M. & de Wasseige, C. 2015. Global progress toward sustainable forest management. *Forest Ecology and Management* 352: 47–56.

Nepal, P., Korhonenb, J., Prestemonc, J. & Cubbage, F. 2019. Projecting global planted forest area developments and the associated impacts on global forest product markets. *Journal of Environmental Management* 240: 421–430.

OECD 2010. *OECD reviews of risk management policies: future global shocks, improving risk governance*. Organisation for Economic Co-operation and Development (OECD), Paris.

OECD 2018. *Global material resources outlook to 2060*: *economic drivers and environmental consequences*. Organisation for Economic Co-operation and Development (OECD), Paris.

Payn, T., Carnus, J.M., Peter Freer-Smith, P., Kimberley, M., Kollert, W., Liue, S. Orazio, C., Rodriguez, L., Neves Silvah, L. & Wingfield, M. 2015. Changes in planted forests and future global implications. *Forest Ecology and Management* 352: 57–67.

Penna, I. 2010. *Understanding the FAO's 'wood supply from planted forests' projections*. University of Ballarat Centre for Environmental Management. Monograph Series No. 2010/01. University of Ballarat, Ballarat, Australia.

Rahman, S., Sunderland, T., Roshetko, J., Basuki, I. & Healey, J. 2016. Tree culture of smallholder farmers practicing agroforestry in Gunung Salak Valley, West Java, Indonesia Syed Ajijur. *Small-scale Forestry* 15: 433–442.

Reppin, S., Kuyah, S., de Neergaard, A., Oelofse, M. & Rosenstock, T. 2020. Contribution of agroforestry to climate change mitigation and livelihoods in Western Kenya. *Agroforestry Systems* 94: 203–220.

Reynoso, O., de la Rosa, A., Fuentes Salinas, M., Corona Ambriz, A. 2017. *Wood frame house construction project in Mexico*. Proyecto de construcción de una casa de madera tipo en México. División de Ciencias Forestales Universidad Autónoma Chapingo, Mexico.

Riahi, K., van Vuuren, D.P., Kriegler, E., Edmonds, J., O'Neill, B.C., Fujimori, S., et al. 2017. The shared socioeconomic pathways and their energy, land use, and greenhouse gas emissions implications: an overview. *Global Environmental Change* 42: 153–168.

Rüter, S., Werner, F., Forsell, N., Prins, C., Vial, E. & Levet, A. 2016. *ClimWood2030: climate benefits of material substitution by forest biomass and harvested wood products*. Perspective 2030. Final report. Thünen Report 42.

Selvamurugan, M. & Sivakumar, P. 2019. Bioplastics—an eco-friendly alternative to petrochemical plastics. *Current World Environment* 14(1): 49–59.

Shrivastava, S. & Saxena, A. 2017. *Wood is good: but, is India doing enough to meet its present and future needs?* Centre for Science and Environment, New Delhi.

Somirraba, E., Beer, J., Alegre-Orihuela, J., Andrade, H.J., Cerda, R., DeClerck, F. et al. 2012. Mainstreaming agroforestry in Latin America. *In*: P.K.R. Nair and D. Garrity, eds. *Agroforestry—the future of global land use*, pp. 429–453. Advances in Agroforestry 9. Springer.

Textile Exchange 2019. *Preferred fiber & materials. Market report 2019*. Textile Exchange.

Turner, J. 2010. *Long-term outlook for the tropical timber market*. Final report prepared for ITTO.

UN undated. World urbanization prospects 2018 (data query) [online]. United Nations (UN) Department of Economic and Social Affairs, New York, USA [accessed June 2020]. https://population.un.org/wup/DataQuery

UN 2020a. World population prospects 2019 (data query) [online]. United Nations (UN) Department of Economic and Social Affairs, New York, USA [accessed June 2020]. https://population.un.org/wpp/DataQuery

UN 2020b. SDGs indicators: United Nations (UN) global SDG database (data query) [online]. New York, USA [accessed August 2020]. https://unstats.un.org/sdgs/indicators/database

UN Comtrade 2020. United Nations (UN) Comtrade database (data query) [online]. New York, USA [accessed June 2020]. http://comtrade.un.org/db

UNEP 2016. *Global material flows and resource productivity*. Assessment report for the UNEP International Resource Panel. United Nations Environment Programme (UNEP), Nairobi.

UNEP 2019. *2019 global status report for buildings and construction towards a zero emissions, efficient and resilient buildings and construction sector*. UN Environment Programme (UNEP), Nairobi.

UNEP 2020. *Building resilient societies after the CoViD-19 pandemic*. Key messages from the International Resource Panel. United Nations Environment Programme (UNEP), Nairobi.

WEF 2016. *The new plastics economy: rethinking the future of plastics*. World Economic Forum (WEF), Geneva, Switzerland.

Wingfield, M.J., Brockerhoff, E. Wingfield, B. & Slippers, B. 2015. Planted forest health and the need for a global strategy. *Science* 349(6250): 832–836.

World Bank 2017. *Harnessing the potential of private sector: engagement in productive forests for green growth*. World Bank/PROFOR/Climate Investment Fund, Washington, DC.

World Bank 2020. World Bank indicators for current GDP in US$ (data query) [online] [accessed November 2020]. https://data.worldbank.org/indicator/NY.GDP.MKTP.CD

World Bank/IFC 2017. MSME finance gap assessment of the shortfalls and opportunities in financing micro, small and medium enterprises in emerging markets. World Bank and International Finance Corporation (IFC), Washington, DC.

Ximenes, F. George, B., Cowie, A., Williams, J. & Kelly, G. 2012. Greenhouse gas balance of native forests in New South Wales, Australia. *Forests* 3: 653–683.

Zomer, R., Trabucco, A., Coe, R., Place, F., Van Noordwijk, M. & Xu, J. 2014. *Trees on farms: an update and reanalysis of agroforestry's global extent and socio-ecological characteristics*. Working Paper 179. World Agroforestry Centre, Bogor, Indonesia.

Zseleczky, L. & Yosef, S. 2014. Are shocks really increasing? A selective review of the global frequency, severity, scope, and impact of five types of shocks. IFPRI Vision 2020 Conference Paper No. 5.

ITTO undertakes a wide range of work on incentives to promote sustainable forestry in tropical countries, including the development of models for forecasting trends in tropical timber supply and demand. Such models can assist in planning policies at the national and international levels, and they can be used to forecast likely recovery times from shocks to the sector—such as that caused by the COVID-19 pandemic.

This report describes a model developed to forecast trends in tropical timber supply and trade to 2050. It analyzes potential scenarios and examines previous economic and non-economic shocks to estimate the likely time required for the sector to recover to pre-pandemic levels.

The report also considers longer-term factors. With global resource use set to more than double by 2050, it is essential to strive for carbon-neutral production based on renewable and sustainably produced materials such as wood. Sustainably produced tropical timber could take a leading role in this quest as a substitute for non-environmentally friendly materials; the report sets out five complementary strategies that could help drive sustainable growth in the sector.

This report is part of an ongoing effort by ITTO to provide knowledge and learning experiences on incentivizing investments in natural tropical forests and the sustainable production of the wood and non-wood products arising from them. Among other things, the wealth of information herein highlights the crucial role that sustainably managed tropical forests can play in climate-change mitigation and adaptation by encouraging the greater engagement of governments and private-sector players in this sphere.

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