Planting for the Future

How Demand for Wood Products Could Be Friendly to Tropical Forests

Union of Concerned Scientists

Planting for the Future

How Demand for Wood Products Could Be Friendly to Tropical Forests

Pipa Elias
Doug Boucher

October 2014

Union of Concerned Scientists

This report was produced by the Tropical Forest and Climate Initiative (TFCI) of the Union of Concerned Scientists (UCS).
Doug Boucher is the director of the TFCI of the Union of Concerned Scientists.
Pipa Elias is a consultant to the TFCI.

The Union of Concerned Scientists puts rigorous, independent science to work to solve our planet's most pressing problems. Joining with citizens across the country, we combine technical analysis and effective advocacy to create innovative, practical solutions for a healthy, safe, and sustainable future.

The TFCI, a project of the UCS Climate and Energy Program, analyzes and promotes ways to cut global warming pollution by reducing tropical deforestation. To learn more about this work, visit *www.ucsusa.org/forests.*

This report is available online (in PDF format) at *www.ucsusa.org/futurewooduse.*

Design: David Gerratt/*NonProfitDesign.com*
Cover photo: © iStockphoto/Global-Pics

Printed on recycled paper

[CONTENTS]

[FIGURES, TABLES, AND BOXES]

FIGURES

TABLES

BOXES

[ACKNOWLEDGMENTS]

This report was made possible through the generous support of the Environmental Investigation Agency and UCS members.

The authors express their gratitude to Pedro Brancalion, Fred Cubbage, and John Herbohn for their thoughtful peer review of this report. We also are grateful for the help we received from many people at UCS, including Jordan Faires, Sarah Goldberg, Lael K. Goodman, Kathleen Rest, Seth Shulman, Sharon Smith, Miriam Swaffer, Heather Tuttle, and Bryan Wadsworth.

Data for parts of this study were obtained with the Global Forest Products Model (GFPM); however, the authors take sole responsibility for the results and their interpretation. UCS thanks the model's developers, especially J. Buongiorno, for granting permission to use the GFPM and for their support throughout the study process.

More information about the GFPM is online at *labs.russell.wisc.edu/buongiorno/welcome/gfpm*.

We are very grateful to Steven J. Marcus, who edited the report, and to David Gerratt for its design and layout.

The opinions expressed herein do not necessarily reflect those of the organization that funded the work or of the individuals who reviewed it. The Union of Concerned Scientists bears sole responsibility for the report's content.

The logging of tropical forests for global trade in wood products, such as paper, furniture, and construction materials, causes major forest damage and sometimes even loss. In this report we explore how future demand for wood products may worsen, or improve, the situation.

Our analysis indicates that there are two possible futures: one in which demand for wood products is met in a sustainable way through the careful use of forest plantations; and another in which business as usual for wood and paper production continues to degrade and destroy tropical forests.

The various wood products we use in our everyday lives come from many different types of forests. Each of them, whether they are industrial plantations or logged natural forests, can have adverse environmental impacts and therefore may threaten tropical ecosystems. Unsustainable industrial plantations ultimately can cause deforestation and deplete soil and water resources. Poorly managed logging of natural forests degrades the respective ecosystems and leaves them susceptible to further damage.

Results from our use of the Global Forest Products Model predict demand for different types of wood products through 2060. Regarding products such as construction timber, plywood, and furniture, for example, demand will increase (compared with 2010 consumption) through 2060. And paper products such as newsprint, tissues, cardboard, and writing paper will see even larger growth in demand. These projections indicate that forest management decisions to meet such rising demands could have a profound impact on tropical forests. The analysis suggests that, without protections, tropical forests will become increasingly susceptible to destructive logging and clearing. However, we show that properly managed plantations could meet projected future wood-product needs while also ensuring forest conservation.

[***Poorly managed logging of natural forests degrades the respective ecosystems and leaves them susceptible to further damage.***]

The good news is that there are alternative approaches to unsustainable plantations and destructive logging. Fast-growing wood plantations located on degraded land where there are plenty of nutrients and water, could meet an increasing proportion of the world's demand for wood products, especially paper. Mixed-species plantations in particular could satisfy such demand while also providing additional environmental services.

Thus we recommend that forest management choices be made to minimize logging in natural forests. Instead, plantations following strict best-management practices could increasingly be used to meet future wood-product demand.

Demand on Forests

Tropical deforestation entails a total, and obvious, process: majestic forests are completely cut down and replaced by farms or cattle pasture. But another, less visible form of damage is also plaguing the world's tropical forests. It is forest *degradation*, by which some, but not all, of the trees are removed, usually from logging. Although some trees are left standing, and the totality still looks like a forest, the destruction of just a small proportion of its trees can impair the forest ecosystem.

[*Nearly 3.4 billion cubic meters of wood were harvested globally from forests in 2010.*]

In the five-year period between 2000 and 2005 alone, 20 percent of the tropics were undergoing degradation (Asner et al. 2009). In the logging of natural forests, degradation occurs because for each tree logged, typically another 10 to 20 are left in the forest but have been harmed from being hit by felled logs, damaged by equipment, or dragged down if long vines connect them to logged trees (Putz et al. 2008). Practices exist that reduce such collateral damage, but of the 814 million hectares (ha) of managed tropical forests (an area bigger than all of Australia), these approaches are used, on average, in only 5 percent of the forest (Putz et al. 2008).

In 2010, 13 million ha of tropical forests were cut down (FAO 2011), but despite a large demand for wood products this decimation occurred mostly to cultivate commodities such as palm oil and beef (Boucher et al. 2010). Meanwhile, 3.4 billion cubic meters (m^3) of wood were harvested globally from forests in 2010 for two main purposes—fuelwood and sawnwood—divided about evenly. Our analysis indicates that the half of global wood use for fuel is likely to decrease in the future, and because most fuelwood is used within the

© iStockphoto/ghornephoto

When concrete is poured for building foundations, workers use plywood or particleboard as a form and then discard it once the cement has hardened.

© iStockphoto/Baloncici

Wood is used "behind the scenes" in items such as wooden pallets, which carry cardboard containers full of consumer products.

country where it is logged it is not a globally traded wood commodity. Therefore this report will focus on sawnwood, panels, and pulpwood—the woods we use in our daily lives to build houses, make paper, and package our orders, say, from *Amazon.com* (WWF 2012). Because this total volume, enough to fill 1.3 million Olympic-size swimming pools, is expected to grow in the coming years (WWF 2012), it is important to understand how the increased demand could worsen forest degradation.

This report combines economic modeling and ecological theory to evaluate how future wood demand will grow through 2060, and how that growth could affect tropical forests.

Major Uses of Wood

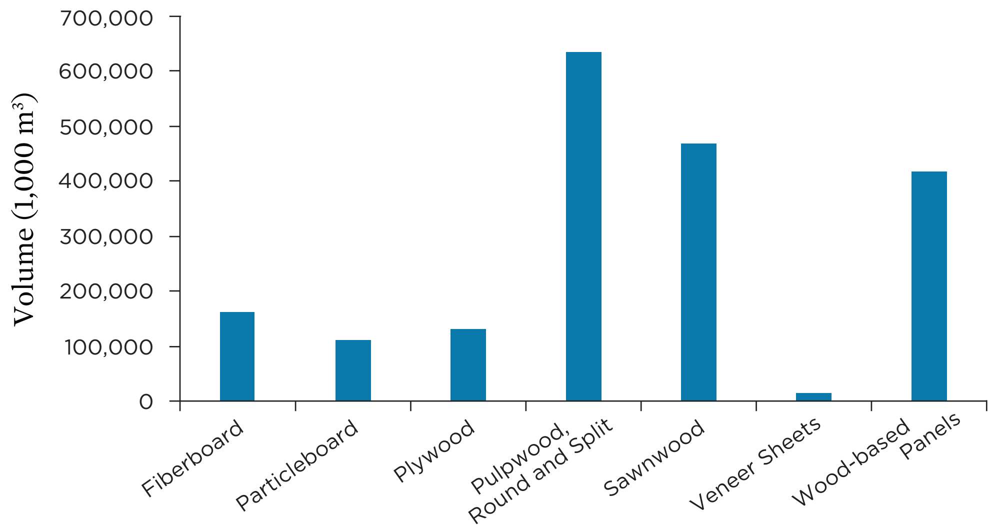
Wood is a ubiquitous part of everyday life (Table 1), manifested in products such as the cabinet from which we take our cereal bowl in the morning, the desk we use at work, and the book we read on the commute to and from the office.

There are also many other uses of wood that are more or less unnoticed in our routines. Most of us do not see the timbers holding up our houses, and we rarely envision the enormous amount of plywood or particleboard used when the concrete for the foundation of our office buildings was poured. We do not always consider the process of turning a tree into the cardboard used to package our retail purchases or the wooden pallets that carry the shipment of those products across the world and onto a forklift in a warehouse.

TABLE 1. The Daily Uses of Various Wood Products

Primary Product	Uses
Sawnwood (including planks, beams, lumber, and rafters)	Furniture Home and industrial construction
Panels (including plywood, veneer sheets, particleboard, and fiberboard)	Home and industrial construction Manufacture of items such as furniture and cabinetry
Pulpwood	Printing and writing paper Paperboard and cardboard Newsprint Tissues, sanitary paper, diapers
Biomass	Energy

FIGURE 1. Global Production of Major Wood Products in 2012



In 2012 the global production of solid-wood and pulpwood products exceeded 1.9 million cubic meters. This is an increase over years past, and production is expected to continue increasing in the future.

Note: These data exclude fuelwood production.

SOURCE: FAO 2014.

Different species of trees are identified with different kinds of wood products. There are two main reasons for this, the first being a technical one—the inherent characteristics of a species that make the wood appropriate for particular uses. Traits such as strength, rot resistance, and fiber length all can affect which species is selected to make a certain wood product. For example, a species that is rot-resistant is more useful for telephone poles because they are going to be exposed to the elements. The characteristic of the wood's fiber length is more important for making paper.

The second reason for selecting different species for diverse wood products is cultural—we expect certain looks of the wood we use. For example, there are cultural associations with a mahogany desk—even if few of us have ever sat at one.

Engineering innovations are constantly breaking down barriers to the technical specifications of different products. Today, improvements in log handling, sawing techniques, and drying technology are changing the mix of species that can be used. Increasingly, species that were historically used to make paper (a lower-value product) are being grown in such a way that they can compete with hardwood species for higher-value products such as furniture and construction (Flynn 2003). On top of this, marketing campaigns—which may, for example, identify for consumers certain species as lower-cost alternatives to high-end wood products for home décor—are shifting market demand patterns (Flynn 2003).

Although the largest use of wood is for pulp and paper, these lower-value products also have lower impacts on prices.

Figure 1 depicts the global production of the major wood products in 2012 that were most commonly traded *internationally* (which means, for the purposes of this report, the exclusion of fuelwood). In solid wood products, the volumes were highest for sawnwood and various types of panels. Because wood is critical to erecting buildings—for the frames of homes and for concrete forms—construction has historically been the main economic factor driving global wood consumption and prices (FAO 2012). Note that although the largest global use of wood is for pulp and paper, these lower-value products also have lower impacts on prices.

Increases in demand for each of these products in the future will affect how forests around the world are used. First, however, it is important for decision makers to understand the major types of forest management, how they impact tropical forests, and which types of products each of them is used to make.

[CHAPTER 2]

Different Forests Make Different Products

In forestry, certain wood types, species, and forest management approaches (Box 1, p. 6) are used in growing the wood for products traded globally. To assess how future demands for different products could affect the world's tropical forests, it is especially important to know which approach is used in each case (Table 2).

Each of these forest management approaches can, if well implemented, be part of a sustainable supply of wood products—i.e., grown in a way that protects the social and environmental services provided by the forest (beyond the supply of wood). However, without appropriate safeguards, some of these management approaches could *threaten* existing natural forests. The discussions that comprise the remainder of this section offer insights into which approaches may cause forest degradation, or even deforestation, if not correctly implemented.

TABLE 2. Forest Management Types Associated with Various Wood Products

Primary Product	Forest Management Approach	Source Countries
Sawlogs and Sawnwood	Intermediate- and long-rotation plantations	Canada, Chile, Finland, India, Sweden, U.S.A.
	Natural forests	Brazil, Canada, Indonesia, Malaysia, Russia, U.S.A.
Panels	Fast wood plantations	Brazil
	Intermediate-rotation plantations	Canada, Chile, New Zealand, U.S.A.
Veneer and Plywood	Fast wood plantations	Brazil, China
	Intermediate-rotation plantations	Canada, U.S.A.
	Natural forests	Brazil, Canada, Indonesia, Malaysia, U.S.A.
Pulpwood	Fast wood plantations	Brazil, Chile, China, India, Indonesia, South Africa
	Intermediate-rotation plantations	Canada, Japan, Sweden, U.S.A.
	Natural forests	Canada, China, Finland, India, Indonesia, Russia
Biomass	Fast wood plantations	Brazil, China, India
	Intermediate-rotation plantations	Canada, U.S.A.
	Natural forests	Dem. Rep. of Congo, Ethiopia, Nigeria, Tanzania

SOURCE: FAO 2014.

BOX 1.

Forest Management Approaches

Natural Forests

Natural forests are not replanted after they are logged. Instead, individual trees are harvested and then forest managers depend on the regeneration that occurs as the remaining trees in the forest produce seeds or as stumps resprout. Generally, natural forests are logged for higher-value hardwood species used in products such as sawnwood or veneer (in the Americas), but these forests are sometimes cut for pulpwood (in parts of Eastern Europe and Asia). It is important to distinguish between pristine natural forests that have not been previously logged (known as primary forests) and natural forests that have been sustainably producing wood for many years (known as managed secondary forests). Trees' growth rates in natural forests vary globally, but they generally range from 1 to 5 m^3 per ha per year—though in some cases they are as high as 10 m^3 per ha per year.

> ***Natural forests are generally logged for higher-value hardwoods used in products such as sawnwood or veneer in the Americas.***

Production Plantations

Plantations are areas in which humans have replanted trees after the area has been cleared. Production plantations are established with the intention of harvesting another rotation (as opposed to conservation plantations, which are not intended for further wood production). For the purposes of this report, if a natural forest has been cleared and replaced with a production plantation, we consider the area deforested.

Industrial Production Plantations

Inserting the term "industrial" simply means the plantation's wood is used for industrial purposes, regardless of the kind of management involved. It is more useful, when evaluating the impacts on forests in the tropics, to differentiate between three types of industrial plantations, among which the management approach, species grown, and end product vary:

FAST WOOD MONOCULTURE PLANTATIONS

The trees in these plantations grow at a rapid rate—15 to 60 m^3 per ha per year—and have a rotation length of less than 20 years. Almost all of these species are exotic trees transplanted from their native range and have been improved through tree breeding programs. The wood from these plantations is used mostly for pulp and paper, wood fiber panels, and industrial fuel (including charcoal), but in some cases it can also be used for sawnwood.

INTERMEDIATE-ROTATION PLANTATIONS

These plantations have growth rates of 10 to 20 m^3 per ha per year and rotations of 20 to 35 years, and the wood is normally used for sawnwood.

LONG-ROTATION PLANTATIONS

These plantations have growth rates of 5 to 10 m^3 per ha per year and rotation lengths of more than 35 years, and the wood is normally used for sawnwood.

Nonindustrial Production Plantations

These plantations produce wood for nonindustrial uses (fuel or other domestic applications), and because they tend not to be traded on the international market, they will not be discussed in this report.

Conservation Plantations

These are plantations grown for environmental outcomes such as slope stabilization, regreening, and reduction of soil erosion. They are not meant for wood production, and thus will not be discussed in this report.

Tree Crop Plantations

Some plantations are planted for tree crops, including cocoa, coconut, coffee, palm oil, and rubber. In these cases the trees are used not for their wood. Although these plantations can have large environmental impacts, they will not be discussed in this report, which focuses on wood products.

Fast Wood Monocultures

Expanding urban populations in developing countries are expected to drive an increase in demand for the kinds of wood grown in fast wood plantations. Globally, consumption of paper, charcoal, and wood-based panels—products that are often supplied from these plantations—is increasing faster than other wood products (Cossalter and Pye-Smith 2003). Therefore many fast wood plantations are being established with the expectation of continued growth in demand for the types of products they produce (ABRAF 2012). Currently, these plantations are expanding by about 0.8 million to 1.2 million ha, or about twice the size of Delaware, each year, a rate that is expected to continue over the next few decades (Cossalter and Pye-Smith 2003).

Globally, eucalyptus species are by far the most often used in these plantations, especially in Brazil, India, and South Africa (Cossalter and Pye-Smith 2003). Brazil is the largest grower of fast wood eucalyptus, of which 71 percent is allocated to pulp and paper, 18 percent to charcoal for steel production, and 7 percent to wood-based panels (ABRAF 2012).

The most common fast wood species used in Asia is acacia (typically, *Acacia mangium*), which is grown in China, India, Indonesia, Malaysia, Thailand, and Vietnam. There have been some attempts to use acacia in the high-value wood market, but those plantations—especially in Indonesia—are subject to diseases that make it difficult to grow the trees for long enough to turn them into saw logs (Potter, Rimbawanto, and Beadle 2006). Some fast wood plantations have also been established with pine in tropical and subtropical Venezuela (mostly *Pinus caribaea var. hondurensis*) and in Swaziland (mostly *P. patula* and *P. elliottii*) (Cossalter and Pye-Smith 2003). Fast wood pine species are also grown in Argentina, southern Brazil, Chile, Colombia, South Africa, and Uruguay (Cubbage et al. 2010).

A research team examines an acacia plantation in Vietnam. In other parts of Southeast Asia as well, tropical forests are being cut down and replaced with acacia plantations.

© Flickr/DHobern

Eucalyptus, a fast-growing species, growing in a monoculture plantation in Australia.

The warm and wet tropics, where trees can grow virtually year-round, are an important region for fast wood monocultures. Further, it is often cheaper to operate in these regions' countries, though the level of investment risk associated with operating there is high (Cossalter and Pye-Smith 2003). There also are a few fast wood plantations in the warmer, frost-free temperate regions, including eucalyptus in Argentina, Australia, Chile, China, Portugal, South Africa, Spain, and Uruguay; and poplar in China.

LAND USE IMPACTS

In Brazil, fast wood monoculture plantations of eucalyptus (Myrtacea *Eucalyptus*) are usually grown on former pastures (Brancalion 2014; Piotto 2013). This approach tends to be the most economical for establishing these plantations, as the land is already cleared of competing vegetation (Cossalter and Pye-Smith 2003).

The cases of fast wood plantations causing deforestation directly (i.e., the deliberate clearing of an area of natural forest to plant fast wood plantations in its place) appear to be limited mostly to Southeast Asia, and to Indonesia in particular (Uryu et al. 2010; Cossalter and Pye-Smith 2003). Even in Indonesia, forest plantations were historically considered a less important driver of deforestation than plantations for oil palm and other crops (Cossalter and Pye-Smith 2003), but there is reason for continued concern and recent evidence that this is changing.

> ***In Brazil, eucalyptus plantations are usually grown on former pastures. This approach tends to be the most economical for establishing these plantations, as the land is alrady cleared of competing vegetation.***

Clearing forests and replacing them with fast wood plantations for pulp and paper accounted for more deforestation between 2000 and 2010 in Indonesia than did oil palm plantations and coal mining.

Actually, clearing forests and replacing them with fast wood plantations for pulp and paper accounted for more deforestation between 2000 and 2010 in Indonesia than did oil palm plantations and coal mining (Abood et al. 2014). Establishment of plantations in areas cleared of natural forests in the early 2000s was significant enough that it caused the industry backlash against the requirement of the Forest Stewardship Council—one of the world's leading organizations certifying sustainability of wood—that plantations not be established on any land cleared after 1994 (Indonesia Pulp and Paper Association 2004).[1]

Further, the Indonesian government's 2006 plan to significantly increase the country's area of plantations could continue to threaten natural forests (Barr 2007). In a 2010 study evaluating forest loss in Sumatra, Indonesia's largest island, the authors noted that, even more than palm oil, "industrial timber plantations are the top threat to Sumatra's natural forests" (Uryu et al. 2010). The climate change implications are particularly dire because many acacia plantations in Sumatra are, or will be, planted on soils with high carbon content (peat)—which will continue to emit global warming emissions for decades. Once the soils have decomposed (which is what causes the emissions) the plantations would need to be abandoned because the area will be flooded by groundwater. For example, after clearing a natural forest growing on 4.4 meter-deep peatlands, an acacia plantation would only achieve about five rotations—although some peatlands have deeper soils and therefore would likely take longer to flood (Uryu et al. 2010). Of the permits for fast wood plantation establishment in Indonesia between 2000 and 2010, about 26 percent have been located on areas with peat soils (Abood et al. 2014).

Beyond the impacts on forests, the other environmental impacts of fast wood plantations are difficult to generalize because they are so site-specific. Moreover, many of these plantations are still in the early stages of learning how to practice sustainable management (Hardiyanto, Anshori, and Sulistyono 2004). Previous land use can affect the kinds of forests that are best grown in an area. For example, on land with intensive previous land use such as long-term pasture, non-native monoculture plantations, which usually can use seedlings selected for their growth properties, grow better than native species or secondary forests (Bonner, Schmidt, and Shoo 2013; Arias et al. 2011). Using fast-growing species can actually help improve the site enough to reestablish native forest (Cossalter and Pye-Smith 2003). However, this approach may not be necessary where land use was less intensive and a seed bank is available (i.e., the area is close to existing forests); in such locales, secondary forests can often regrow on their own.

Fast wood plantations require more water and nutrients than natural forests growing at slower rates. For example, if fast wood plantations grow 10 times faster than natural ones, they could require 10 times more inputs—even though many are more efficient. This rapid growth could deplete local soils and require the use of fertilizers, herbicides, and pesticides to maintain productivity, thereby resulting in adverse environmental impacts.

No sweeping generalization can be made about whether fast wood plantations should be avoided wholesale. Instead, management decisions should be guided by their ability to achieve positive objectives and avoid pollution. Maintaining sustainable fast wood plantations is most likely to be achieved in locations with plentiful rainfall and nutrient-rich soils, but such plantations should be avoided where they would have negative ecological impacts.

Intermediate-Rotation Hardwood Plantations

Intermediate-rotation monocultures are most commonly used at present for furniture and construction products; however, for products that can derive from fast wood plantations, the role of intermediate-rotation plantations is likely to diminish, as the latter produces as little as half the wood of the former and take two to three times longer to reach maturity (Cossalter and Pye-Smith 2003). The largest area of intermediate-rotation monocultures consists not of hardwoods but rather

1 *The Forest Stewardship Council continues to use this standard in all of its certified forests.*

Teak, an intermediate-rotation hardwood from the tropics, being grown in a plantation in Belize.

of pine species—in the United States, New Zealand, Chile, Australia, Spain, South Africa, Argentina, and Uruguay (Cossalter and Pye-Smith 2003). Because these plantations tend to be sited in cooler and drier climates than the tropics, their establishment is not a cause of tropical deforestation.

Hardwoods are much less ubiquitous in intermediate-rotation plantations than the softwoods (usually grown as spruce [Pinaceae *Picea*], fir [Pinaceae *Abies*], pine [Pinaceae *Pinus*], and poplar [Salicacaea *Populus*] plantations in Canada, China, Finland, Russia, and Sweden). The most common hardwood species grown is teak (Lamiaceae *Tectona*), most of which comes from selectively logged forests in Ecuador, Ghana, India, and Myanmar. Teak is the major emerging high-value hardwood on the global market, where it is sold for ship building and furnishing, high-end furniture, decorative building elements, veneer, flooring, and utility poles (i.e., for transmission lines). The area of planted teak forests has increased over the past few years, covering about 4.3 million ha in Asia, Africa, and tropical America. Teak plantations are estimated to produce a fairly good yield—of 1.5 to 2 million m^3 annually (Kollert and Cherubini 2012).

Almost all of the world's processing of teak occurs in India, where it can be reexported or used to meet strong domestic demand. However, demand for teak in the U.S. market is often met by exports from Africa and Latin America (Kollert and Cherubini 2012). A major limitation outside India is that only a few countries' sawing industries have adjusted its technology to move from processing the large tropical logs harvested from natural forests to the smaller hardwoods grown in plantations, though the furniture industries in Thailand and Malaysia are exceptions (ITTO 2002).

LAND USE IMPACTS

As a species valued for decades, teak has been managed in plantations longer than most other tropical species. Therefore the implications and challenges of growing teak in a plantation are relatively well understood. To optimize financial returns, most teak plantations are on a 20-year rotation (Kollert and Cherubini 2012), but a study in Costa Rica found that teak rotation of 25 years was more likely to produce desired wood characteristics with still-good economic returns (Bermejo, Canella, and San Miguel 2004). In Africa, Asia, and the Caribbean, most teak plantations are government-owned, while in Central and South America they are largely under private ownership (Kollert and Cherubini

2012). Teak plantations can serve as habitat for some critical wildlife (such as elephants), so their corridors can be maintained during planting (Bonnington, Weaver, and Fanning 2007).

One of the difficulties in purchasing teak is that some of it still comes from natural forests. Most teak logged from natural forests likely derives from India, Indonesia, Myanmar, or other Southeast Asian countries. However, India, Laos, Thailand, and, very recently, Myanmar, now have log-export bans in place (Erickson-Davis 2014; Kollert and Cherubini 2012), so any nonplantation teak from these countries would be illegal (Box 2).

Long-Rotation Hardwood Plantations

Long-rotation hardwood plantations are used for selected high-value species, mostly with the idea of avoiding the need to log natural forests. Today there are very few places where plantations are established for long-rotation hardwoods. This is mostly due to the poor economic returns associated with expensive planting operations and the long time period during which this capital is tied up before the slow-growing trees reach harvestable size (Venn 2005).

LAND USE IMPACTS

In the tropics there are increasing efforts to grow big-leaf mahogany (*Swietenia macrophylla*) and rosewood (*Dalbergia*) in long-rotation plantations. Due to the severe economic limitations of this approach, the expansion of these plantations will not be a threat to forests. On the other hand, their success could be helpful in protecting pristine natural forests.

The loss of habitat due to conversion of forests to agriculture fields and pastureland, combined with the commercial logging of big-leaf mahogany in natural forests, have caused this majestic tree to lose 66 percent of its historic range (Grogan et al. 2010). In an effort to continue meeting the global demand for its precious wood, big-leaf mahogany has been established in about 100,000 ha of plantations around the world (Wadsworth and González 2008). These plantations range from pure stands of big-leaf mahogany to "enrichment plantings," in which the species is planted into a regrowing natural forest (Mayhew et al. 2003). Any planting of big-leaf mahogany is limited by the fact that it takes a long time for the tree to mature. A study in Puerto Rico showed that even after 69 years, the heartwood (the most valuable part of the tree) was still increasing (Wadsworth and González 2008), making it difficult to decide when to cut it so as to garner the best economic outcome. Meanwhile, a threat to the crop looms: the Meliaceae shoot borer, a moth that attacks the

BOX 2.

Illegal Logging

Illegal logging includes a host of illicit activities associated with the production of a wood product. Such actions include removing trees from protected areas, removing trees without a permit, logging more trees than permitted, cutting protected species, stealing wood from forests owned by others, failing to pay taxes for wood products, and "laundering" illegal wood material. Illegal logging negatively affects ecosystems, communities, and economies, and it has been a persistent problem around the world (Elias 2012). One of the primary purposes of forest-product certification was to reduce illegal logging. However, certification tended to be adopted by those already producing wood products legally, and it largely failed to address illegal logging (FAO 2012). So this issue has continued to plague forests.

Governance of managed forests can be critical to addressing illegal logging (Elias 2012). Brazil, for example, has been successful at governance and enforcement within this economic sector; over two decades, the country has shifted logging from being mostly illegal to mostly legal. The main idea behind its measures is that increasing the cost of illegal activities—through stricter regulations, higher fines, and stronger enforcement—makes legal, managed forests more economically attractive (Macqueen et al. 2003). In the Congo Basin, governed and managed logging provides more financial and social benefits to local communities—by bringing them into the cash economy—than illegal logging (Endamana et al. 2010). Choices to crack down on illegal logging reduce its environmental impacts as well.

[***Illegal logging has a negative impact on ecosystems, communities, and economies, and it has been a persistent problem around the world.***]

twigs and seeds of big-leaf mahogany, makes plantations vulnerable to destruction when the pest spreads (Mayhew et al. 2003).

Rosewood is the general term for a number of species that have red-colored wood, which is highly desirable for furniture and decorative pieces. Some of the species in this category are endangered in natural forests, leading to a desire to grow them in plantations. In Thailand, one plantation successfully restored a degraded site (Aerts et al. 2010). However, the long rotation cycle of rosewood means that it will take a long time for newly established plantations to meet demand (Wenbin and Xiufang 2013).

Logged Natural Forests in the Tropics

Natural forests can be logged for almost any product; most often, however, the highest-value species are logged for use in furniture, cabinetry, and some of the decorative touches of construction. In the tropics, 403 million ha of natural forests are designated for production (Blaser et al. 2011). Companies receive permits to harvest in these forests, but in many cases their activities are legal only if they permanently retain forest cover through selective logging (Gaveau et al. 2013).

Countries in which selective logging of natural forests is a large part of the timber sector include Congo, Ghana, Guyana, and Myanmar. Papua New Guinea and the Solomon Islands also are critical sources; they sell directly to China, which has a huge demand for tropical hardwoods (Wenbin and Xiufang 2013). In some of these places, selective logging is not done sustainably.

LAND USE IMPACTS

In theory, the idea of selective logging seems absolutely attractive, given that natural forests are not replaced by plantations but rather are allowed to recover after selected trees have been removed. Trees can be selected based on their size (i.e., leaving the small trees so that they can continue to mature), on their species (i.e., taking out only a few of the highest-value species), or on other characteristics. Research shows, however, that when selective logging is poorly implemented, it can have negative ecological impacts. In fact, such logging is considered the primary cause of forest degradation across the tropics (Hosonuma et al. 2012).

The haphazard "selective" logging of just one tree can damage another 10 to 20 surrounding trees (Putz et al. 2008). Further, the residual damage can make the complete clearing of the selectively logged forest physically easier. In the Brazilian Amazon, 16 percent of selectively logged forests are completely cleared within a year (Asner et al. 2006).

In addition to the long-term damage associated with unmanaged selective logging, the evidence that selective logging in the tropics can function over multiple rotations is inconsistent (Gourlet-Fleury et al. 2013). This is likely due to the enormous variability of tropical forests in terms of how they grow, their land use history, and their soil fertility. While the few existing studies on this topic show that in some but not all cases, the forest carbon lost during well-managed harvesting can recover in as few as 20 and up to 100 years, the availability of timber (i.e., sizable trees of the desired species) is difficult and complicated to manage, especially for those species that require a lot of light to grow (Gourlet-Fleury et al. 2013; Peña-Claros et al. 2008; Sist and Ferreira 2007). Moreover, the kinds of management practices needed to sustainably harvest over multiple rotations may sometimes be too expensive (Peña-Claros et al. 2008).

Because selective logging occurs across a variety of forest types and also varies in intensity, it can be difficult to draw conclusions about its impact on ecosystem diversity. However, a recent review of the global literature on tropical forests found that animals' responses to logging depends on which kind of animal species are being studied. For invertebrates, amphibians, and mammals, increasing selective-logging intensity reduces biodiversity, while birds tend to thrive in more heavily logged areas (Burivalova, Sekercioglu, and Koh 2014).

[The haphazard "selective" logging of just one tree can damage another 10 to 20 surrounding trees. Further, the residual damage can make the complete clearing of the selectively logged forest physically easier. In the Brazilian Amazon, 16 percent of selectively logged forests are completely cleared within a year.]


© Flickr/CIFOR

Although teak wood can be grown in plantations, much of it is still logged from natural forests in India, Indonesia (shown here), Myanmar, and other locations in Southeast Asia.

There are some places in which the logging of natural forests is more destructive than other management options, because the forests there are completely cleared for their tropical hardwoods. This is most often the case in Southeast Asia, as in Indonesia or Malaysia, where the forests have proportionately more valuable species than in other parts of the world. However, even without a lot of valuable species, the forests are often cleared regardless of the financial outcomes. For example, in 2005 some 70 percent of Indonesia's pulpwood, a relatively low-value product, came from mixed tropical hardwoods growing in natural forests (Barr 2007).

On the other hand, there also are cases in which logging from natural forests is less destructive than from other approaches. Although there is no tree planting after harvest, natural regeneration can be aided by forestry methods other than planting. In particular, reduced-impact logging (RIL)—one of the most common ways to ameliorate some of the land use impacts of selective logging—includes: modifying the number of trees left in the forest; leaving trees of certain sizes to grow into a mature forest; harvesting during seasons that will not damage the soil; establishing no-cut zones in steep terrain or close to water; and avoiding damage to the trees surrounding those that are harvested. Because RIL can reduce residual forest damage by as much as 50 percent (Putz et al. 2008), it has been found to offset many of the adverse effects of the unmanaged logging of tropical forests in Africa (Medjibe et al. 2011), Asia (Sist et al. 2002), and Latin America (Pereira et al. 2002). One small study in Brazil found that communities working in partnership with RIL companies on their land had more annual income and did not lose access to the nontimber forest products they depend on for food and supplemental income (Menton et al. 2009).

Another option for reducing the impact of natural-forest logging is to rely on natural secondary forests—those that have already been disturbed by previous human activity and that regrew without any management interventions—as a source of wood (Lamb, Erskine, and Parrotta 2005). There is now a large area of secondary forests in the tropics (Asner et al. 2009), and because many of these forests do not provide the level of biodiversity as primary forests (Gibson et al. 2011), they could be seen as a source of wood for the short term—while waiting for plantations to grow—or for those few species that do not grow in plantations.

[CHAPTER 3]

The Future of the Global Forestry Sector

Modeling Demand for Wood Products

Over the next few decades, worldwide demand for wood products is expected to rise. Factors such as expanding global wealth, a greater need for improved housing, and more convenient shipping around the world will enhance the market for these products. Meanwhile, on the flip side, the spread of recycling, and the growing use of electronics in lieu of paper could, in theory, reduce the economic pressure for converting trees into products—though the net environmental pressure will still be significant. Because different types of forest management are used to meet the demand for different wood-based products, the future of forests will be highly dependent on which products are consumed the most.

We projected future demand for wood through 2060 using the Global Forest Products Model (GFPM) (Buongiorno et al. 2003), which provides a country-by-country estimate of what the trade in wood products will look like. The database for this model's production, import, and export numbers came from the Food and Agriculture Organization's (FAO's) Statistical Database (available online at *http://faostat.fao.org*). The FAO was also the data source for forest area and forest stock (Buongiorno et al. 2012).

The GFPM simulates world wood markets for 180 countries and calculates consumption, production, and trade of 14 commodity groups. The model is dynamic, in that each year's inputs are dependent on the outputs from the previous year, with the dynamic variables including demand, supply, forest parameters, manufacturing costs, transportation costs, tariff rates, and trade inertia.

Because the model is based on international data, it features product categories (and the primary products they embrace) that are universally used in global forestry, as indicated in Table 3.

RESULTS

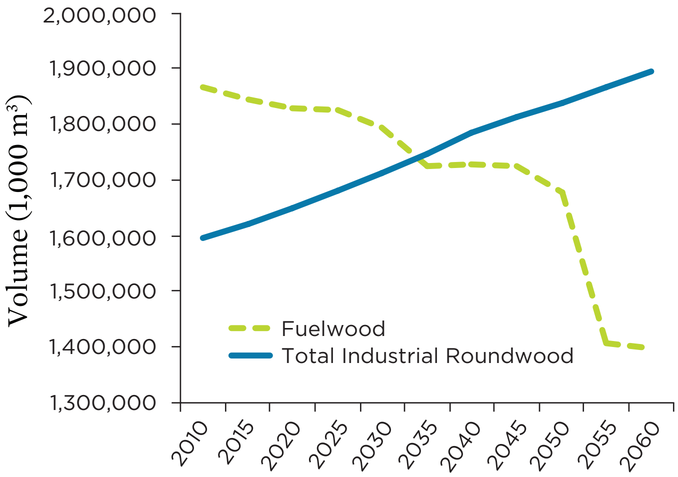
The total consumption of all wood products is expected to be greater in 2060 than in 2010 (Figures 2–5, pp. 15–16); however, relative consumption of different products will change, and the absolute consumption of some products will actually decrease.

The most notable increases in projected wood product consumption by 2060 will be in pulp and paper (Figures 4 and 5, p. 16). Indeed, the model predicts that all types of paper consumption will increase by more than 100 percent from 2010. This category includes, among other products, recycled paper (which will increase by 192 percent), printing and writing paper (which will increase by 180 percent), and paperboard (which will increase by 125 percent).

TABLE 3. Wood Products Associated with International Wood-Trade Categories

Modeled	Primary Product
Solid Wood Products	Sawnwood (including planks, beams, lumber, and rafters) Panels (including veneer sheets, plywood, particleboard, and fiberboard)
Pulp and Paper	Office paper, books, paperboard, newsprint, tissue paper
Fuelwood	Biomass

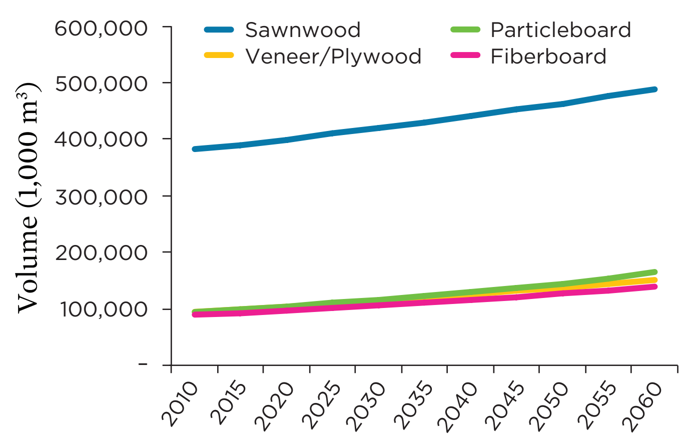
FIGURE 2. Wood Consumption through 2060



Modeling of global industrial roundwood and fuelwood consumption from 2010 to 2060 indicates that demand for industrial products will increase in the future, while fuelwood use will decrease.

Note: Results based on the Global Forest Products Model.

FIGURE 3. Solid Wood Product Consumption through 2060



Modeling of changes in the four major categories of solid wood product consumption indicates an increase in demand from 2010 to 2060.

Note: Results based on the Global Forest Products Model.

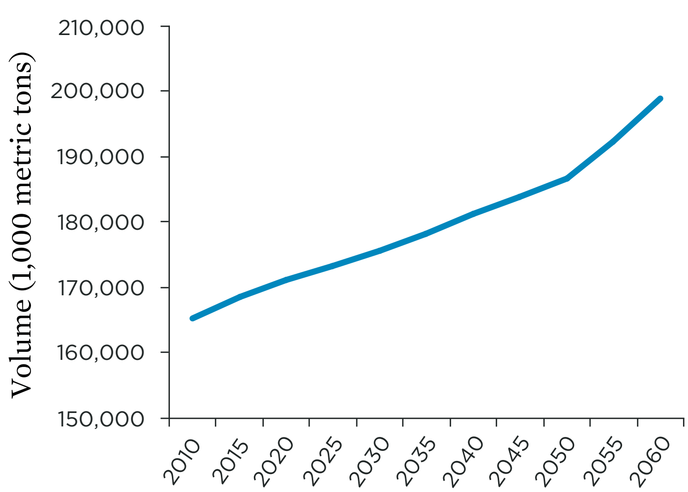
Consumption of solid wood products is expected to grow at a lower rate (Figures 2 and 3). For example, sawnwood will increase by 28 percent, wood-based panels by 64 percent, and veneer and plywood by 61 percent.

By contrast, fuelwood consumption is expected to decrease by 23 percent (Figure 2). This is because developing countries are following a path similar to that of most industrialized nations—shifting away from wood as an industrial energy source or home heating and cooking material, and toward oil, coal, and renewable energy as their economies grow.[2]

A Picture of Future Forests

The GFPM results—predictions of the growth or decrease in consumption of different wood products—provide a sense of the future demands on various kinds of forests. The largest increases will be in demand for pulp and paper products such as tissue paper, diapers, paperboard, newsprint, and printing and writing paper. The other major product category with large relative expected growth is sawnwood, and panels in particular—veneer/plywood, particleboard, and fiberboard,

FIGURE 4. Woodpulp Consumption through 2060

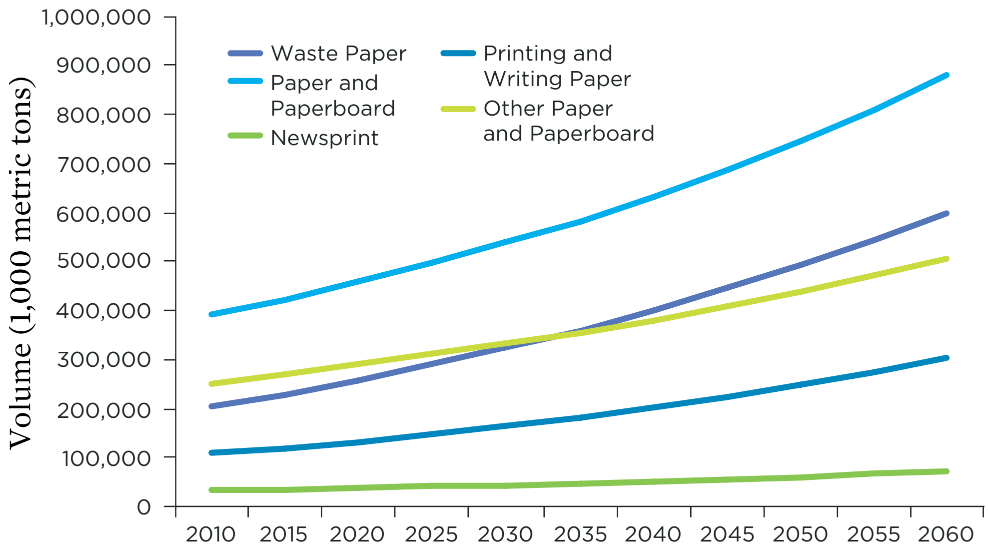


Global woodpulp consumption is expected to increase dramatically in the decades ahead due to consumer demand. If not managed sustainably, this growth could further drive deforestation and affect tropical ecosystems.

Note: Results based on the Global Forest Products Model.

2 *There is much debate as to the role of biomass as a source of energy that could potentially have a smaller global warming impact than fossil fuels; however, for this report we did not consider policies aimed at increasing the use of biomass for fuel in modeling future wood consumption.*

FIGURE 5. Woodpulp-based Products Consumption through 2060



While all woodpulp-based products are expected to increase in the decades ahead, the most notable changes will be in paper and paperboard as well as wastepaper.

Note: Results based on the Global Forest Products Model.

for example. These predicted increases in demand for paper products and construction-related materials indicate that plantations, especially fast wood plantations, are likely to play a larger role in the future wood market.

THE ROLE OF PLANTATIONS

In 2005, plantations covered about 260 million ha, distributed unevenly across the globe (Carle and Holmgren 2008), as shown in Figure 6.

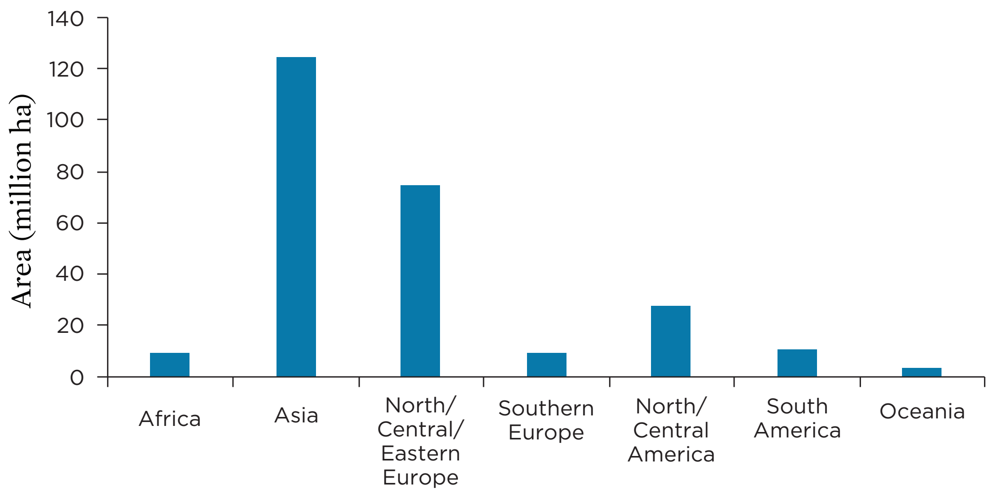
The most commonly grown species for fast wood plantations—eucalyptus—can produce 33 to 83 m^3 per ha per year in Brazil (Stape et al. 2010). Assuming a conservative average of 30 m^3 per ha per year, this means that 3,333 ha are needed to produce an additional 100,000 m^3 annually. Because these trees are usually harvested every 10 years or so, 33,330 ha would be required for each additional 100,000 m^3 demanded through 2060.

Therefore it would take an additional 59 million ha to meet the 178 million m^3 increase in demand for wood-based panels, 19 million ha to meet the 57 million m^3 increase in demand for veneer/plywood, 23 million ha to meet the 70 million m^3 increase in demand for particleboard, 17 million ha to meet the 50 million m^3 increase in demand for fiberboard, and 7 million ha to meet the 34 million metric ton increase in demand for wood pulp,[3] for a total of 125 million ha (Figure 7, p. 18). Based on these calculations, it would be possible for plantation area to meet the new demand, though with some

> ***These predicted increases in demand for paper products and construction-related materials indicate that plantations, especially fast wood plantations, are likely to play a larger role in the future wood market.***

3 *Assuming that 1 m^3 of plantation-grown eucalyptus weighs 0.65 tonnes.*

FIGURE 6. Distribution of Global Plantation Area in 2005



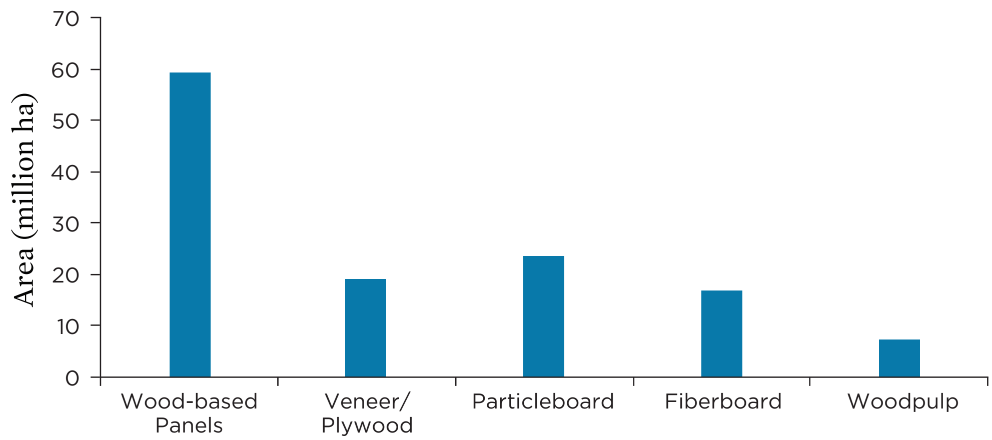
Most plantation area has been concentrated in Asia and Europe, but the increasing role of fast wood plantations may lead to more of these kinds of forests in the tropics of South America and Africa as well.

SOURCE: CARLE AND HOLMGREN 2008.

© Flickr/Rainforest Action Network

Without deliberate planning to avoid unsustainable clearing for pulpwood, as occurred here in Indonesia, future demand could threaten tropical forests.

FIGURE 7. Fast Wood Plantation Area Needed to Meet 2060 Demand



Fast wood plantations could expand significantly in the years ahead, helping to meet increased global demand for wood products without disturbing natural forests.

Note: Results based on the Global Forest Products Model.

effort. Carle and Holmgren (2008) predicted that by 2030, plantation area could expand by 84.5 million ha to a total of 345 million ha. One of the ways to ensure that this occurs in an environmentally sustainable way is to involve local communities as forest managers (Box 3).

THREATS TO SUSTAINABLE WOOD PRODUCTION

Although the world's total plantation area is increasing, and most of the expected growth in demand for wood products will be for those most easily produced from plantations (e.g., woodpulp), primary natural forests are still being cleared today for wood products. However, improvements in technology, and policies to avoid the replacement of natural forests with plantations, could help move the sector away from such unnecessary deforestation.

Improvements in manufacturing techniques are increasing the likelihood that plantation-grown wood can meet the technical characteristics needed for the products usually obtained from natural forests (Bowyer, Shmulsky, and Haygreen 2007). Further, plantation area is expected to continue expanding over the next few decades. Most of this expansion will occur in the tropics—largely Asia and Latin America—where the high growth rates of trees can contribute to the greater role of plantations there in meeting global wood supply (FSC 2012; Siry, Cubbage, and Abt 2000). In the tropics, about 4 million ha of plantations are now being established annually (Siry, Cubbage, and Abt 2000). At a very conservative average growth rate of 10 m^3 per ha per year, an additional 40 million m^3 per year could be available at the end of a 10-year rotation.

But putting in new plantations depends on many factors: government policies, technological capabilities, markets, land availability, and environmental issues (Siry, Cubbage, and Abt 2000). For slower-growing plantations, weaker economic returns are a major limit to establishment (Brown 2000). It also is difficult to shift demand for wood from high-value luxury species, which are not grown in plantations. Finally—

[***Improvements in manufacturing techniques are increasing the likelihood that plantation-grown wood can meet the technical characteristics needed for the products usually obtained from natural forests.***]

Logs being shipped from Central Kalimantan in Indonesia. Improvements in technologies and policies to avoid deforestation could move the timber sector toward sustainable production.

as has been suggested for the wildlife trade—completely banning these products could possibly expand the black market or illegal logging for those products (Pavlin, Schloegel, and Daszak 2009). Nevertheless, slower-growing plantations and mixed-species plantations could increasingly be used to meet demand. And while these options are being researched and implemented, managed secondary forests could fill the gap. Global estimates suggest that more than 2 billion ha of degraded land are available for restoration and reforestation, which could reduce pressure to log natural forests and help supply global demand for wood (see *www.wri.org/tools/atlas/map.php?maptheme=restoration* for a geographic breakdown).

BOX 3.

Community Forest Management

Some of the most successful forest-conservation programs have been based on decentralizing control and depending on communities to make management decisions (Boucher et al. 2014). Thus it is worth evaluating the role that community management could play in the sustainable production of wood worldwide.

Community forestry enterprises have existed in Mexico for decades, providing a precedent for the participation of other countries' communities in the commercial timber sector. While there is no single model for how such enterprises work, generally they have three basic features: 1) government-granted responsibility for forest management; 2) the goal of ecologically sustainable forestry; and 3) centrality of social and economic benefits as an outcome (Charnley and Poe 2007). Such approaches provide local economic development while still meeting sustainability criteria, including forest conservation (Antinori and Bray 2005). In addition to the long-standing tradition in Mexico, community forestry is also practiced in Bolivia, India, Nepal, and the Philippines (Elias and Lininger 2010).

Another (and rapidly growing) approach to community involvement entails partnerships between forest companies and small-scale producers—known as outgrower agreements—under which local growers own and operate plantations and then sell the wood to their partner mills (Cossalter and Pye-Smith 2003). Case studies show that this process can be beneficial to both parties—the mills reduce their risk, work within policies that limit the size of landholdings, and diversify their wood sources; the tree farmers benefit from the research done by large companies, obtain the best seedlings to plant, have a guaranteed market, and spread their risk (if they are growing trees in addition to agricultural commodities) (Desmond and Race 2000). Overall, outgrower schemes usually lead to less conflict and provide enhanced local employment (Cossalter and Pye-Smith 2003).

Alternatives That Could Create a Sustainable Future for Forests

Know Your Wood

The modern consumer should be able to make informed wood product purhasing decisions based on where wood is coming from and on the associated forestry approaches and practices. Toward that end, technology to track wood products can help provide verifiable systems to trace wood from the forest, through transit, to the mill and factory, during export, and at the retail outlet (ITTO 2012). Without such systems, it is difficult to feel confident in the sustainability and legality of a timber product. For example, a recent report by the Environmental Investigation Agency exposed the inability of the Myanmar government to account for almost half of the logging occurring in the country (EIA 2014).

© Flickr/Rainforest Action Network

Deforestation in Indonesia to meet global demand for pulpwood. Plantations that follow strict "best practices" could help meet future wood-product demand. But they must not be built in areas that have been cleared of natural forests for this purpose.

Multiple approaches and technologies are available to track timber from the source to the consumer (Table 4). Further, mixes of various technologies can be applied. For example, a lower-cost primary system (such as bar coding) coupled with random checks by less forgery-prone approaches (e.g., DNA fingerprinting) could help reduce corruption (RAFT 2012). But no tracking option will be comprehensive if it is stand-alone—that is, if it is not part of a larger forest inventory, accounting, auditing, sales, and tax system (ITTO 2012). Therefore companies need to consider how any national or corporate infrastructures can be supportive of their tracking systems.

DNA fingerprinting can identify a specific *individual* tree—i.e., it can track a product sample all the way back to a tree stump and tell the user if is made from a species protected by law. In one pilot project, a company used this technology to differentiate between Merbau wood hailing from Indonesia, Malaysia, Papua New Guinea, or Singapore (Double Helix 2011). However, for the technology to function on a global scale, greater knowledge of forest genetics—that is, development of gene databases from the most common wood sources around the world—is needed.

Another common approach to tracking timber is isotope fingerprinting. Different combinations of element isotopes (especially of hydrogen, oxygen, nitrogen, and sulfur) arise in different regions. Because these isotopes migrate from the local soil and end up throughout the plant, identifying material can be extracted from any part of the plant. If the regional isotope signature of an element is known, the wood product can be linked to that region. This method of course requires data on isotopic signatures from the most common wood sources around the world. Such data are not difficult to

TABLE 4. A Comparison of the Strengths and Challenges Associated with Various Timber-Tracking Technologies

Technology	Strengths	Challenges
Physical Technology		
Paper Tracking with Simple Labeling	Paint, chisel, or nailed tags are inexpensive and easy to apply; can withstand transport; usable in remote areas without electronic infrastructure.	Labor intensive; prone to human error; difficult to enforce and easy to forge; some tags are subject to durability concerns or to becoming detached.
Wood Anatomy	A good first line of defense for identifying species once wood products have been seized, with no complex technology required.	Inefficient; requires substantial expertise to inspect and accurately identify each piece of wood.
Bar Coding or Radio Frequency Identification (RFID)	Bar coding is a relatively low-cost technology that tracks individual logs; bar coding and RFID can be easily incorporated into an electronic system and are difficult to forge.	Bar codes and RFIDs can become detached; requires trained staff to operate readers; technologies can be difficult to use after wood processing, especially when wood from multiple sources has been combined; RFIDs can be expensive.
Remote Sensing	Can be used to support a bar coding system with species information, though it is unclear if the system can be reliably used in tropical forests.	Requires substantial expertise and large investment in remote-sensing technology, regular mapping, and ground-truthing (on-site verification).
Chemical Technology		
DNA Fingerprinting	Very resistant to forgery; not subject to errors or other concerns with tagging; provides reliable identification of species; provides reliable identification and chain of custody of individual log to stump.	Expensive; requires large investment in establishing a database of DNA samples from known species for comparison with unknown specimens; requires high quality of DNA, which can be hard to obtain.
Isotope Fingerprinting	Very resistant to forgery; not subject to errors or other concerns with tagging; provides reliable identification of geographic origin on a regional scale.	Requires substantial expertise and large investments in lab equipment and in initial sampling to build database.

ADAPTED FROM RAFT 2012. ADDITIONAL SOURCE: ITTO 2012.

© Flickr/Biodiversity International

Paint is a commonly used option for identifying logs and tracking timber; however, it is easily evaded. Timber-tracking approaches should integrate multiple (and complementary) technologies to ensure that consumers know where their wood is coming from.

acquire; isotope fingerprinting is commonly used today in the agriculture sector for tracing food down to the field level (ITTO 2012; GIZ 2011).

Timber tracking can be expensive, especially through methods, such as isotope or DNA fingerprinting, that require lab tests. As a result, few forest managers or factory owners could absorb these systems into their operating costs and they would thus be dependent on public funding or on being part of a research project (ITTO 2012). Policy makers should take such costs, and the limitations to each approach, into consideration before promoting one technology over another. It may turn out that a mix of approaches is usually most appropriate.

There is evidence that multispecies plantations can induce better soil quality, achieve quicker growth, and have higher timber yields.

Planting Now to Affect the Future: Using Multispecies Plantations

In addition to the traditional forest management types explored thus far, another kind of industrial plantation should be considered as a source of wood products. There is evidence that *multispecies* plantations can induce better soil quality, achieve quicker growth, and have higher timber yields (Bonner, Schmidt, and Shoo 2013; Erskine, Lamb, and Bristow 2006). For example, Erskine, Lamb, and Bristow (2006) found that average diameter growth of a mixed-species plantation increased directly as the number of species in the plantation increased (up to the experiment's maximum mix of eight species). These results show the ecological theory that limited resources are more efficiently allocated among a number of species than when just one species competes with itself.

Multispecies plantations are more expensive to plant and manage, but the higher costs could be fully offset with timber yields only 10 percent higher than in monocultures—an increase that appears relatively easy to achieve (Nichols, Bristow, and Vanclay 2006). Factors that can influence where multispecies plantations are established and what is planted in them include production costs, wood prices, the regulatory

> ***Multispecies plantations are more expensive to plant and manage, but the higher costs could be fully offset with timber yields only 10 percent higher than in monocultures—an increase that appears relatively easy to achieve.***

environment, and risk (Cubbage et al. 2010). These factors interact to influence the return on plantation investment and the decisions on whether to establish new plantations in the first place. On a more fundamental level, policies that affect production costs, wood prices, and regulatory regimes can shift the balance toward incentivizing sustainable practices over high-environmental-impact forest-management methods.

LIMITATIONS

Although research has indicated that they can produce better results, mixed-species plantations now account for a tiny portion of plantations globally (less than 0.5 percent) (Nichols, Bristow, and Vanclay 2006). There is a wide range of opinions as to why this is so. Some think it is the absence of large-scale demonstration projects; others believe it is a dearth of seed sources and seedlings; some point out that there are too few studies showing mixed-species plantations to be financially reliable; and some, particularly among research scientists, simply dismiss research into multispecies plantations as redundant—they maintain that the general study of natural ecosystems should suffice (Piotto 2013; Nichols, Bristow, and Vanclay 2006).

Overcoming the financial momentum behind logging natural forests and planting monoculture plantations is one of the most commonly cited challenges to increasing the use of using mixed-species plantations. Thus strong incentives are needed to encourage the latter's growth. Currently there are few such incentives, and the small markets (for certified sustainable products from multispecies plantations) that do exist are concentrated in developed countries, not in the ever-growing emerging economies (Brancalion 2014).

Although proponents of mixed-species plantations express confidence in the management approaches to these systems, the modest diffusion and application of this knowledge is still a barrier (Nichols, Bristow, and Vanclay 2006); and there is little evidence that these plantations will produce desired timber characteristics across a range of ecosystems (Brancalion 2014). For example, one of the main practices behind high-yield monoculture plantations is the identification of the ideal species, number of trees in a given area, and resource inputs (e.g., fertilizer, water) for reducing the competition among trees in the stand. Evidence from an experiment mixing acacia trees into a eucalyptus monoculture found varying yield results at different locations (Epron et al. 2013), showing that similar identifications for mixed-species plantations need to be made and better understood for sites where such information is already known for monocultures.

CREATING INCENTIVES TO ENCOURAGE MULTISPECIES PLANTINGS

Although few incentives to establish and manage multispecies plantations now exist, this can be changed. Researchers who work in this field have suggested two approaches: paying for these plantations with more than just the harvested wood; and "riding the wave" of reducing deforestation to move toward sustainable forestry practices.

In the first approach, aimed at making multispecies plantations more economically competitive (Brancalion et al. 2012), species could be selected to provide not only timber over a long timeframe but also a steady flow of nontimber products, including those supporting ecosystem services that could be financed through Payment for Ecosystem Services programs. However, there is almost no evidence that the markets alone would help shift preferences away from natural forests as a source of wood. Appropriate legislation and regulations are needed. For example, government intervention in the form of financial support has often been available to spur plantation development (Cossalter and Pye-Smith 2003); this support should be shifted to promote multispecies plantations in particular.

Regarding the second suggested approach: many countries and companies today are taking deforestation seriously, and they are spending significant financial and political capital to reduce destructive activities. This phenomenon could provide the momentum to invest money in and direct research toward plantations so that they are ready to meet market demand in decades to come. Further, the rise in consumer demands for sustainability could pressure timber companies to improve their practices and move toward multispecies plantations.

© Flickr/BCGovPhotos

The growing wealth of developing countries such as China raises their per capita demand for wood products.

Stimulating Key Markets

DOMESTIC MARKETS IN DEVELOPING COUNTRIES

The growing economies in many developing countries can affect their forest industries, and vice versa, in several ways. First, forestry can help increase the wealth in these countries. For example, in 2010, forestry accounted for 17.7 percent of Liberia's gross domestic product, 6.7 percent of Papua New Guinea's, 2.8 percent of Brazil's, 2.5 percent of Korea's, 2.5 percent of Indonesia's, and 1.9 percent of Nicaragua's, compared with a global average of 1 percent (FAO 2011). In Brazil, this sector accounts for about half a million jobs (Macqueen et al. 2003) and in Indonesia it is estimated to employ 1.5 percent of all residents. Much of this wealth is concentrated in just two companies—Sinar Mas Forestry and Asia Pulp and Paper, which together account for almost 1 percent of Indonesia's gross domestic product (ITS Global 2011).

Conversely, rising wealth in developing countries increases per capita demand for many wood products (Cossalter and Pye-Smith 2003). At the turn of the century in Brazil, 86 percent of the wood harvested from the Amazon was consumed within the country's domestic market (Smeraldi and Veríssimo 1999), where the demand for hardwoods is strong because they provide the most desirable material for construction (Brancalion 2014). These countries' strengthening domestic markets put pressure on their native forests, however, because hardwood plantations' timber prices tend to be higher than those of the artificially cheap illegal wood coming out of those forests (Piotto 2013).

[*India and China, the two largest emerging economies, together account for 80 percent of global imports of tropical hardwoods. Much of this wood is subsequently exported as finished products to developed countries.*]

India and China, the two largest emerging economies, together account for 80 percent of global imports of tropical hardwoods (Wenbin and Xiufang 2013). Much of this wood is subsequently exported as finished products to developed countries—in 2005, 80 percent of the industrial roundwood imported into China later left the country in final-product form (Canby 2006). This pattern is changing, however, as wood imported into China is more and more being used domestically or for other developing-country markets (Wenbin and Xiufang 2013; Canby 2006). A similar trend applies to the pulpwood market as well. In 2005, only 11 percent of pulpwood imported into China was reexported (Canby 2006).

Our GFPM results indicate that a few countries, such as Egypt, Haiti, The Gambia, the Netherlands, and Serbia, will increase their demand for industrial roundwood by more than 100 percent by 2060. However, the growth in demand among the 10 largest countries is expected to be smaller. Demand is predicted to rise by only 28.9 percent in Indonesia, 22.4 percent in India, 18.3 percent in China, 8.8 percent in Brazil, 3.8 percent in Russia, and 0.8 percent in Japan. Some of the largest countries will see a decrease in demand—14.5 percent in Nigeria and 13.9 percent in the United States.

MARKETS FOR SUSTAINABLE TIMBER

Consumers commonly rely on certification when looking for sustainably produced wood. However, forest certifications are not equitably distributed. As of 2012, some 92 percent of the world's certified forests were in the Northern Hemisphere, while only 2 percent of tropical forests were certified—with Latin America having a slightly greater relative area certified than Africa and Asia (FAO 2012). Further, the demand for certified timber is also concentrated in developed countries (Piotto 2013). The high demand in the European Union and Canada does, however, provides markets for those certified wood products coming from the Southern Hemisphere.

Beyond certification, consumer pressure on large companies has also led to some independent verification agreements. For example, Asia Pulp and Paper (APP) has recently partnered with the Rainforest Alliance—a verification program known for ensuring the sustainable growth of products ranging from coffee and bananas to timber (Butler 2014). APP had been denounced for years by environmental groups such as Greenpeace for its practice of destroying natural forests through complete clearing for timber products—sometimes leaving them in a degraded state and sometimes replacing them with fast wood plantations.

But under the company's new agreement with the Rainforest Alliance, APP's commitments to protecting high-conservation-value forests and areas with high carbon stocks, to limiting global warming emissions from carbon-rich peat soils, and to obtaining free, prior, and informed consent from local communities before developing new plantations will all be independently audited. This pledge to meet sustainability criteria, and the opportunity for third-party verification, indicates major progress within the timber sector over the past few years, in large part due to pressure from consumers and environmental organizations (Butler 2014). Such public indications that forest destruction will not be tolerated have also compelled other large companies in Indonesia to follow suit (Nazeer 2014).

> ***[Consumer pressure on large companies has led to some independent verification agreements.]***

VALUING CARBON-SEQUESTRATION SERVICES

Economies that put a value on carbon—for example, through a global warming emissions cap or a carbon tax, could make some forests worth more for their carbon sequestration and storage than for their wood products (Chiabai et al. 2011). However, our GFPM analysis suggests that significant carbon prices would be needed. In addition, the nascent carbon market has so far provided little in the way of payment for forest conservation (Boucher and Elias 2013). Modeling how consumption, prices, and forest stock would change if carbon-price policies—aiming to limit harvest to 75 percent of growth rates—were set, we found the differences to be very small. Total industrial roundwood consumption would decrease by 3 percent, global wood prices would go up by 2.5 percent, and global forest stock would increase by only 0.51 percent.

In our modeling studies, the small impacts of policies with low carbon prices are primarily due to many countries' existing policies constraining harvest rates—intended to ensure that they do not exceed growth rates. Therefore other incentives to produce wood sustainably—such as strict logging limitations on natural forests combined with reduced-impact logging—are likely to have bigger effects on forests than a (relatively modest) carbon price.

Making an Impact

The research efforts on logging natural forests and forest plantations—both our own studies and those of many others—

Fast wood plantations and technological improvements can provide wood to meet growing demands for construction.

point to the importance of avoiding tropical deforestation and forest degradation, assuring legal harvests, obtaining forest certification, and achieving sustainable management.

These insights, coupled with the large predicted increases in wood demand due to growth in populations and higher levels of affluence, indicate that the global wood sector could be shifted toward sustainable management systems by:

- Planting multispecies plantations to meet wood demand
- Minimizing the use of natural forests to log for industrial roundwood and pulpwood
- Improving consumer understanding of sustainable production practices
- Leveraging technological improvements to enable plantations to meet more demand
- Ensuring that plantation forestry follows strict best-management practices to minimize toxic chemical use, prevent pollution, and avoid adverse effects on water supplies (especially in dry regions)
- Using multiple timber-tracking technologies to reduce illegal logging and help consumers know the sources of wood products they consider buying

Meanwhile, significant political, cultural, and technological innovations will be needed to create a future in which natural forests are protected from logging and sustainable-management techniques are commonly applied throughout the world.

[REFERENCES]

Abood, S.A., J.S.H. Lee, Z. Burivalova, J. Garcia-Ulloa, and L.P. Koh. 2014. Relative contributions of the logging, fiber, oil palm, and mining industries to forest loss in Indonesia. *Conservation Letters*. Published online April 21.

Aerts, R., H. Volkaert, N. Roongruangsree, U. Roongruangsree, R. Swennen, and B. Muys. 2010. Site requirements of the endangered rosewood Dalbergia *oliveri* in a tropical deciduous forest in northern Thailand. *Forest Ecology and Management* 259:117–123.

Antinori, C., and D.B. Bray. 2005. Community forest enterprises as entrepreneurial Firms: Economic and institutional perspectives from Mexico. *World Development* 33(9):1529–1543.

Arias, D., J. Calvo-Alvarado, D. Richter, and A. Dohrenbusch. 2011. Productivity, aboveground biomass, nutrient uptake, and carbon content in fast-growing tree plantations of native and introduced species in the southern region of Costa Rica. *Biomass and Bioenergy* 35(5):1779–1788.

Asner, G.P., T.K. Rudel, T.M. Aide, R. Defries, R. Emerson, and U. Evaluaci. 2009. A contemporary assessment of change in humid tropical forests. *Conservation Biology* 23(6):1386–1395.

Asner, G.P., E.N. Broadbent, P.J.C. Oliveira, M. Keller, D.E. Knapp, and J.N.M. Silva. 2006. Condition and fate of logged forests in the Brazilian Amazon. *Proceedings of the National Academy of Sciences USA* 103(34):12947–12950.

Associação Brasileira de Produtores de Florestas Plantadas (ABRAF). 2012. *Anuário estatístico da ABRAF 2012—Ano base 2011*. Brasilia: ABRAF.

Barr, C. 2007. Intensively managed forest plantations in Indonesia: Overview of recent trends and current plans. Presentation to meeting of the Forest Dialogue, March 7–8. Pekanbaru, Indonesia: Center for International Forestry Research.

Bermejo, I., I. Canella, and A. San Miguel. 2004. Growth and yield models for teak plantations in Costa Rica. *Forest Ecology and Management* 189:97–100.

Blaser, J., A. Sarre, D. Poore, and S. Johnson. 2011. *Status of tropical forest management 2011*. International Tropical Timber Organization (ITTO) Technical Series 38. Yokohama, Japan: ITTO.

Bonner, M., S. Schmidt, and L.P. Shoo. 2013. A meta-analytical global comparison of aboveground biomass accumulation between tropical secondary forests and monoculture plantations. *Forest Ecology and Management* 291:73–86.

Bonnington, C., D. Weaver, and E. Fanning. 2007. The use of teak (*Tectona grandis*) plantations by large mammals in the Kilombero Valley, southern Tanzania. *African Journal of Ecology* 47(2):138–145.

Boucher D., P. Elias, J. Faires, and S. Smith. 2014. *Deforestation success stories: Tropical nations where forest protection and reforestation policies have worked*. Cambridge, MA: Union of Concerned Scientists.

Boucher, D., and P. Elias. 2013. From REDD to deforestation-free supply chains: The persistent problem of leakage and scale. *Carbon Management* 4(5):473–475.

Boucher D., P. Elias, K. Lininger, C. May-Tobin, S. Roquemore, and E. Saxon. 2010. *Root of the Problem: What's driving tropical deforestation today?* Cambridge, MA: Union of Concerned Scientists.

Bowyer, J.L., R. Shmulsky, and J.G. Haygreen. 2007. *Forest products and wood science: An introduction*, fifth edition. Ames, IA: Blackwell Publishing.

Brancalion, P.H.S. 2014. Personal communication, January 22. Pedro Henrique Santin Brancalion is professor of native species forestry in the Department of Forest Sciences at the University of São Paulo.

Brancalion, P.H.S., R.A.G. Viani, B.B.N. Strassburg, and R.R. Rodrigues. 2012. Finding the money for tropical forest restoration. *Unasylva* 239(63):41–50.

Brown, C. 2000. *Global forest products outlook study: The global outlook for future wood supply from forest plantations*. Rome, Italy: Food and Agriculture Organization of the United Nations.

Buongiorno, J., S. Zhu, R. Raunikar, and J.P. Prestemon. 2012. *Outlook to 2060 for world forests and forest industries*. Asheville, NC: U.S. Department of Agriculture (USDA).

Buongiorno, J., S. Zhu, D. Zhang, J. Turner, and D. Tomberlin. 2003. *The global forest products model*. Waltham, MA: Academic Press.

Burivalova, Z., C.H. Sekercioglu, and L.P. Koh. 2014. Thresholds of logging intensity to maintain tropical forest biodiversity. *Current Biology* 24(16):1893–1898.

Butler, R. 2014. Rainforest Alliance to independently audit APP's zero-deforestation commitment. *Mongabay.com*, January 29. Online at *http://news.mongabay.com/2014/0130-rainforest-alliance-app.html*, accessed on August 21, 2014.

Canby, K. 2006. China and the global market for forest products: Transforming trade to benefit forests and livelihoods. Washington, DC: Forest Trends. Online at *www.forest-trends.org/documents/files/doc_1033.pdf*, accessed on August 21, 2014.

Carle, J., and P. Holmgren. 2008. Wood from a global outlook 2005–2030. *Forest Products Journal* 58(12):6–18.

Charnley, S., and M.R. Poe. 2007. Community forestry in theory and practice: Where are we now? *Annual Review of Anthropology* 36:301–336.

Chiabai, A., C.M. Travisi, A. Markandya, H. Ding, and P.A.L.D. Nunes. 2011. Economic assessment of forest ecosystem services losses: Cost of policy inaction. *Environmental and Resource Economics* 50(3):405–445.

Cossalter, C., and C. Pye-Smith. 2003. *Fast-wood forestry: Myths and realities*. Bogor, Indonesia: Center for International Forestry Research.

Cubbage, F., S. Koesbandana, P. Mac Donagh, R. Rubilar, G. Balmelli, V.M. Olmos, R. De La Torre, M. Murara, V.A. Hoeflich, and H. Kotze. 2010. Global timber investments, wood costs, regulation, and risk. *Biomass and Bioenergy* 34(12):1667–1678.

Desmond, H., and D. Race. 2000. Global survey and analytical framework for forestry outgrower arrangements. Canberra, Australia: Australian National University.

Deutsche Gesselschaft für Internationale Zusammenarbeit (GIZ). 2011. *Innovative timber tracking using genetic and isotopic fingerprints*. Eschborn, Germany. Online at *www.giz.de/fachexpertise/downloads/giz2011-en-fingerprints.pdf*, accessed on August 21, 2014.

Double Helix. 2011. *Applied genetics for forest conservation and sustainable trade: The state of DNA technology for trees and wood products*. Singapore.

Environmental Investigation Agency (EIA). 2014. *Data corruption: Exposing the true scale of logging in Myanmar*. London, UK.

Elias, P.E. 2012. *Logging and the law: How the U.S. Lacey Act helps reduce illegal logging in the tropics*. Boston, MA: Union of Concerned Scientists.

Elias, P.E., and K. Lininger. 2010. *The plus side: Promoting sustainable carbon sequestration in tropical forests*. Boston, MA: Union of Concerned Scientists.

Endamana, D., A.K. Boedhihartono, B. Bokoto, L. Defo, A. Eyebe, Z. Nzooh, M. Ruiz-Perez, and J.A. Sayer. 2010. A framework for assessing conservation and development in a Congo Basin forest landscape. *Tropical Conservation Science* 3(3):262–281.

Epron, D., Y. Nouvellon, L. Mareschal, R.M.E. Moreira, L.-S. Koutika, B. Geneste, J.S. Delgado-Rojas, J.-P. Laclau, G. Sola, J.L.D.M. Gonçalves, and J.-P. Bouillet. 2013. Partitioning of net primary production in eucalyptus and acacia stands and in mixed-species plantations: Two case studies in contrasting tropical environments. *Forest Ecology Management* 301:102–111.

Erickson-Davis, M. 2014. "Better late than never": Myanmar bans timber exports to save remaining forests. *Mongabay.com,* April 24. Online at *http://news.mongabay.com/2014/0424-morgan-myanmar-ban.html*, accessed on August 21, 2014.

Erskine, P.D., D. Lamb, and M. Bristow. 2006. Tree species diversity and ecosystem function: Can tropical multispecies plantations generate greater productivity? *Forest Ecology Management* 233(2–3):205–210.

Flynn, R. 2003. *Eucalyptus: Having an impact on the global solidwood industry.* Washington, DC: World Resources Institute.

Food and Agriculture Organization of the United Nations (FAO). 2014. FAO forestry trade flows. Online at *http://faostat.fao.org,* accessed on April 11, 2014.

Food and Agriculture Organization of the United Nations (FAO). 2012. *Forest products annual market review 2010–2011*. Rome, Italy.

Food and Agriculture Organization of the United Nations (FAO). 2011. *State of the world's forests 2011*. Rome, Italy.

Forest Stewardship Council (FSC). 2012. Strategic review on the future of forest plantations. Helsinki, Finland.

Gaveau, D., M. Kshatriya, D. Sheil, S. Sloan, E. Molidena, A. Wijaya, S. Wich, M. Ancrenaz, M. Hansen, M. Broich, M. Guariguata, P. Pacheco, P. Potapov, S. Turubanova, and E. Meijaard. 2013. Reconciling forest conservation and logging in Indonesian Borneo. *PLoS ONE* 8(8): e69887.

Gibson, L., T.M. Lee, L.P. Koh, B.W. Brook. T.A. Gardner, J. Barlow, C.A. Peres, C.J.A. Bradshaw, W.F. Laurance, T.E. Lovejoy, and N.S. Sodhi. 2011. Primary forests are irreplaceable for sustaining tropical biodiversity. *Nature* 478(7369):378–381.

Gourlet-Fleury, S., F. Mortier, A. Fayolle, F. Baya, D. Ouédraogo, and N. Picard. 2013. Tropical forest recovery from logging: A 24-year silvicultural experiment from Central Africa. *Philosophical Transactions of the Royal Society B: Biological Sciences* 368(1625):20120302.

Grogan, J., A.G. Blundell, R.M. Landis, A. Youatt, R.E. Gullison, M. Martinez, R. Kómetter, M. Lentini, and R.E. Rice. 2010. Over-harvesting driven by consumer demand leads to population decline: Big-leaf mahogany in South America. *Conservation Letters* 3:12–20.

Hardiyanto, E.B., S. Anshori, and D. Sulistyono. 2004. Early results of site management in *Acacia mangium* plantations at PT Musi Hutan Persada, South Sumatra, Indonesia. In *Site management and productivity in tropical forests: Proceedings from workshops in Congo July 2001 and China February 2003,* edited by E.K.S. Nambiar, J. Ranger, A. Tiarks, and T. Toma. Bogor, Indonesia: Center for International Forestry Research.

Hosonuma, N., M. Herold, V. De Sy, R.S. De Fries, M. Brockhaus, L. Verchot, A. Angelsen, and E. Romijn. 2012. An assessment of deforestation and forest degradation drivers in developing countries. *Environmental Research Letters* 7(4):044009.

International Trade Strategies Pty Ltd (ITS Global). 2011. *The economic contribution of Indonesia's forest-based industries*. Melbourne, Australia.

International Tropical Timber Organization (ITTO). 2012. *Tracking sustainability: Review of electronic and semi-electronic timber tracking technologies*. Yokohama, Japan.

International Tropical Timber Organization (ITTO). 2002. *Tropical timber products: Development of further processing in ITTO producer countries*. Yokohama, Japan.

Indonesia Pulp and Paper Association. 2004. *Indonesian pulp and paper industry's perspective on FSC's policy on certification of plantations*. Jakarta, Indonesia.

Kollert, W., and L. Cherubini. 2012. *Teak resources and market assessment 2010*. FAO Planted Forests and Trees Working Paper FP/47/E. Rome, Italy: Food and Agriculture Organization of the United Nations.

Lamb, D., P.D. Erskine, and J.A. Parrotta. 2005. Restoration of degraded tropical forest landscapes. *Science* 310(5754):1628–1632.

Macqueen, D., M. Greig-Gran, E. Lima, J. MacGregor, F. Merry, N. Scotland, R. Smeraldi, and C. Young. 2003. *Growing exports: The Brazilian tropical timber industry and international markets.* London, UK: International Institute for Environment and Development.

Mayhew, J.E., M. Andrew, J.H. Sandom, S. Thayaparan, and A.C. Newton. 2003. Silvicultural systems for big-leaf mahogany plantations. In *Big-leaf mahogany: Genetics, ecology, and management*, edited by A.E. Lugo, J.C. Figueroa Colón, and M. Alayón. New York: Springer, 261–277.

Medjibe, V.P., F.E. Putz, M.P. Starkey, A.A. Ndouna, and H.R. Memiaghe. 2011. Impacts of selective logging on aboveground forest biomass in the Monts de Cristal in Gabon. *Forest Ecology and Management* 262(9):1799–1806.

Menton, M.C.S., F.D. Merry, A. Lawrence, and N. Brown. 2009. Company-community logging contracts in Amazonian settlements: Impacts on livelihoods and NTFP harvests. *Ecology and Society* 14(1):39–58.

Nazeer, Z. 2014. Indonesia's 2nd largest pulp company goes green. *Jakarta Post*, January 29. Online at *www.thejakartapost.com/news/2014/01/29/indonesias-2nd-largest-pulp-company-goes-green.html*, accessed on August 21, 2014.

Nichols, J.D., M. Bristow, and J.K. Vanclay. 2006. Mixed-species plantations: Prospects and challenges. *Forest Ecology and Management* 233(2):383–390.

Pavlin, B.I., L.M. Schloegel, and P. Daszak. 2009. Risk of importing zoonotic diseases through wildlife trade, United States. *Emerging Infectious Diseases* 15(11):1721–1726.

Peña-Claros, M., T.S. Fredericksen, A. Alarcón, G.M. Blate, U. Choque, C. Leaño, J.C. Licona, B. Mostacedo, W. Pariona, Z. Villegas, and F.E. Putz. 2008. Beyond reduced-impact logging: Silvicultural treatments to increase growth rates of tropical trees. *Forest Ecology and Management* 256(7):1458–1467.

Pereira, R., J. Zweede, G.P. Asner, and M. Keller. 2002. Forest canopy damage and recovery in reduced-impact and conventional selective logging in eastern Para, Brazil. *Forest Ecology and Management* 178:77–89.

Piotto, D. 2013. Personal communication, Oct 14. Daniel Piotto studies forest ecology at the Federal University of Southern Bahia, Brazil.

Potter, K., A. Rimbawanto, and C. Beadle. 2006. *Heart rot and root rot in tropical acacia plantations*. Proceedings of a workshop held in Yogyakarta, Indonesia, February 7–9. Canberra, Australia: Australian Centre for International Agricultural Research.

Putz, F.E., P.A Zuidema, M.A. Pinard, R.G.A. Boot, J.A. Sayer, D. Sheil, P. Sist, and J.K. Vanclay. 2008. Improved tropical forest management for carbon retention. *PLoS Biology* 6(7):e166.

Responsible Asia Forestry and Trade (RAFT). 2012. *High time for timber tracking to go high tech?* Bangkok, Thailand: The Nature Conservancy. Online at *www.traffic.org/non-traffic/RAFT-newsletter-November-2012.pdf*, accessed on August 21, 2014.

Siry, J.P., F.W. Cubbage, and R.C. Abt. 2000. *The role of plantations in world forestry.* Raleigh, NC: North Carolina State University. Online at *http://sofew.cfr.msstate.edu/papers/25siry.pdf*, accessed on August 21, 2014.

Sist, P., and F.N. Ferreira. 2007. Sustainability of reduced-impact logging in the eastern Amazon. *Forest Ecology and Management* 243(2–3):199–209.

Sist, P., D. Sheil, K. Kartawinata, and H. Priyadi. 2002. Reduced-impact logging in Indonesian Borneo: Some results confirming the need for new silvicultural prescriptions. *Forest Ecology and Management* 179:415–427.

Smeraldi, R., and A. Veríssimo. 1999. *Acertando o alvo: Consumo de madeira no mercado interno brasileiro e promoção de certificação florestal*. São Paulo, Brazil: IMAZON.

Stape, J.L., D. Binkley, M.G. Ryan, S. Fonseca, R.A. Loos, E.N. Takahashi, C.R. Silva, S.R. Silva, R.E. Hakamada, J.M.D.A. Ferreira, A.M.N. Lima, J.L. Gava, F.P. Leite, H.B. Andrade, J.M. Alves, G.G.C. Silva, and M.R. Azevedo. 2010. The Brazil Eucalyptus Potential Productivity Project: Influence of water, nutrients, and stand uniformity on wood production. *Forest Ecology and Management* 259(9):1684–1694.

Uryu, Y., E. Purastuti, Y. Laumonier, Sunarto, Setiabudi, A. Budiman, K. Yulianto, A. Sudibyo, O. Hadian, D.A. Kosasih, and M. Stuwe. 2010. *Sumatra's forests, their wildlife, and the climate windows in time: 1985, 1990, 2000, and 2009*. Jakarta, Indonesia: WWF-Indonesia.

Venn, T.J. 2005. Financial and economic performance of long-rotation hardwood plantation investments in Queensland, Australia. *Forest Policy and Economics* 7:437–454.

Wadsworth, F.H., and E. González. 2008. Sustained mahogany (*Swietenia macrophylla*) plantation heartwood increment. *Forest Ecology and Management* 255:320–323.

Wenbin, H., and S. Xiufang. 2013. *Tropical hardwood flows in China: Case studies of rosewood and okoumé*. Washington, DC: Forest Trends.

World Wildlife Fund (WWF). 2012. *Living forests report: Forests and wood products*. Washington, DC.

Planting for the Future

How Demand for Wood Products Could Be Friendly to Tropical Forests

[There are two possible futures: one in which demand for wood products is met in a sustainable way; and another in which business-as-usual production continues to degrade and destroy tropical forests.]

We use wood in our daily lives in numerous ways. While some of this material now comes from sustainable sources, logging is still a threat to a great many forests across the globe. This report applies the Global Forest Products Model to estimate the increase in demand for wood products such as lumber, veneer, and plywood through 2060. The most notable growth, however, will be demand for paper products like newsprint, tissues, cardboard and writing paper. Without protections, future consumption of these products could leave tropical forests susceptible to destructive logging and clearing. However, by cultivating wood through sustainable forest-management techniques, including properly managed plantations, this rise in demand should not adversely affect the world's forests. Consumers can help to ensure this outcome by insisting that virtually all of their wood is sustainably grown.

Union of Concerned Scientists

FIND THIS DOCUMENT ONLINE: www.ucsusa.org/futurewooduse

The Union of Concerned Scientists puts rigorous, independent science to work to solve our planet's most pressing problems. Joining with citizens across the country, we combine technical analysis and effective advocacy to create innovative, practical solutions for a healthy, safe, and sustainable future.

NATIONAL HEADQUARTERS
Two Brattle Square
Cambridge, MA 02138-3780
Phone: (617) 547-5552
Fax: (617) 864-9405

WASHINGTON, DC, OFFICE
1825 K St. NW, Suite 800
Washington, DC 20006-1232
Phone: (202) 223-6133
Fax: (202) 223-6162

WEST COAST OFFICE
500 12th St., Suite 340
Oakland, CA 94607-4087
Phone: (510) 843-1872
Fax: (510) 843-3785

MIDWEST OFFICE
One N. LaSalle St., Suite 1904
Chicago, IL 60602-4064
Phone: (312) 578-1750
Fax: (312) 578-1751

WEB: www.ucsusa.org

PRINTED ON RECYCLED PAPER USING VEGETABLE-BASED INKS