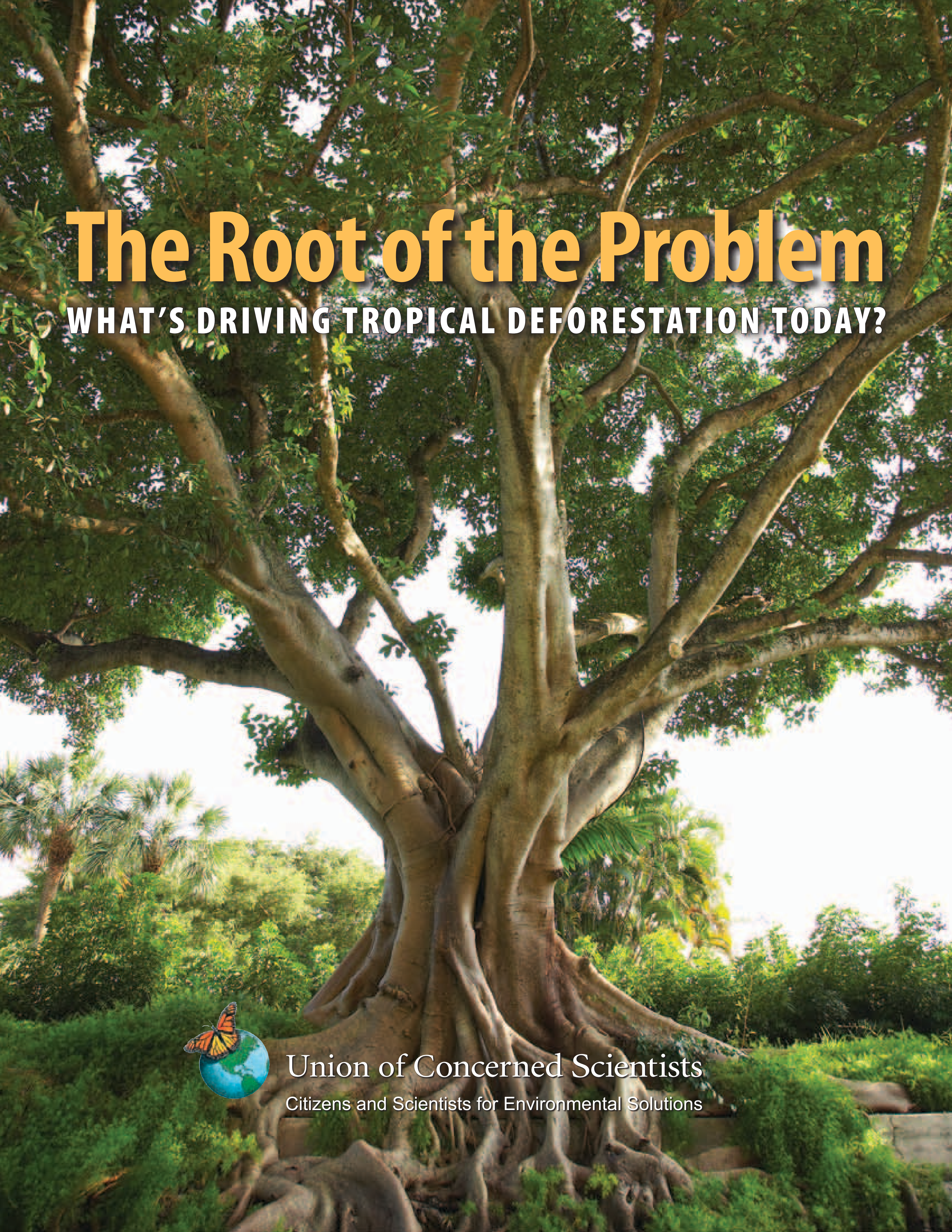
The Root of the Problem

WHAT'S DRIVING TROPICAL DEFORESTATION TODAY?



Union of Concerned Scientists

Citizens and Scientists for Environmental Solutions

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WHAT'S DRIVING TROPICAL DEFORESTATION TODAY?

Doug Boucher, Pipa Elias, Katherine Lininger,
Calen May-Tobin, Sarah Roquemore, and Earl Saxon

Tropical Forest and Climate Initiative
Union of Concerned Scientists

Union of Concerned Scientists
Citizens and Scientists for Environmental Solutions

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

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List of Acronyms

ABIOVE	Brazilian Association of Vegetable Oil Industries
ANEC	National Association of Cereal Exporters
CBWP	community-based wood production
CPO	crude palm oil
FAO	Food and Agriculture Organization of the United Nations
FSC	Forest Stewardship Council
GDP	gross domestic product
ha	hectare (about 2.5 acres)
HCV	high conservation value
HFLD	high forest, low deforestation
IFC	International Finance Corporation, a member of the World Bank Group
IMAZON	Amazon Institute of People and the Environment
INPE	Brazilian National Space Research Institute
IPAM	Amazon Environmental Research Institute
Mt CO_2eq	global warming potential equivalent to one metric ton of carbon dioxide, per year
m^3	cubic meters
mt	metric tons (1 mt = 2,205 lb)
Mmt	million metric tons
MODIS	moderate-resolution imaging spectroradiometer (on two satellites)
NGOs	non-governmental organizations
OECD	Organization for Economic Cooperation and Development
PES	payment for environmental services
REDD+	reducing emissions from deforestation and forest degradation, plus related pro-forest activities
RSPO	Roundtable on Sustainable Palm Oil

Acknowledgments

As a science-based organization, the Union of Concerned Scientists (UCS) puts a strong emphasis on the peer review process. Particularly in the Internet age, peer review is what distinguishes credible information from mere assertion. This conviction manifests itself in two ways in this report.

First, we have benefited from the willingness of many colleagues outside UCS (as well as several within it) to read chapters of this report and provide their assessments. We are deeply grateful for the contribution these peer reviewers, whose names are listed below, made to the quality of the final product.

Second, the report itself is based principally on peer-reviewed literature, supplemented by various publicly available sources of data. Scientific studies on the drivers of deforestation have become more frequent in recent years, stimulated by new sources of satellite data and international concern about how deforestation affects climate. There is a growing realization—as clearly demonstrated in the decision of the December 2010 Cancun climate change negotiations to undertake a two-year examination of the drivers—that to end deforestation we have to understand what causes it. Thus, we now have a rich collection of peer-reviewed studies to draw upon, and have made this our main source of information.

We have put special emphasis on papers published since 2000, and particularly on those published in the last five years. Not only has the literature been changing during this period, but so has the subject matter itself. For example, if we had published this report just five years ago, it would not have included these critical new developments:

- The global decline in emissions from deforestation (Friedlingstein, P., R.A. Houghton, G. Marland, J. Hackler, T.A. Boden, T.J. Conway, J.G. Canadell, M.R. Raupach, P. Ciais, and C. Le Quéré. 2010. Update on CO_2 emissions. *Nature Geoscience* 3:811–812.)
- The success of the 2006 soybean moratorium in Brazil (Rudorff, B.F.T., M. Adami, D.A. Aguilar, M.A. Moreira, M.P. Mello, L. Fabiani, D.F. Amaral, and B.M. Pires. 2011. The soy moratorium in the Amazon biome monitored by remote sensing images. *Remote Sensing* 3:185–202.)
- The initiation of a similar moratorium in the beef cattle industry in 2009, and Brazil's success in reducing its deforestation rate (Boucher, D.H. 2011. Brazil's success in reducing deforestation. UCS Tropical Forest and Climate Briefing #8. Cambridge, MA: Union of Concerned Scientists. Online at *www.ucsusa.org/assets/documents/global_warming/Brazil-s-Success-in-Reducing-Deforestation.pdf*.)
- Consensus on the predominant role of urban and export demand in driving deforestation in a globalized economy (DeFries, R., T.K. Rudel, M. Uriarte, and M. Hansen. 2010. Deforestation driven by urban population growth and agricultural trade in the twenty-first century. *Nature Geoscience* 3:178–181. And: Rudel, T.K., R. DeFries, G.P. Asner, and W.F. Laurance. 2009. Changing drivers of deforestation and new opportunities for conservation. *Conservation Biology* 23:1396–1405.)

We are deeply grateful both to those who wrote the many papers on which this report is based, and to those who helped improve it as reviewers (see below).

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Executive Summary

DEFORESTATION AND FOREST DEGradation have been occurring for thousands of years. Both deforestation, which completely removes the forest canopy, and degradation, which maintains the canopy but causes losses of carbon, are important sources of global warming pollution, as well as threats to biodiversity and to the livelihoods of forest peoples. Thus it is important to understand the causes of these changes—the "drivers" of deforestation.

In this report we focus on the economic agents that play a critical role in deforestation: soybeans, beef cattle, palm oil, timber and pulp, wood for fuel, and small farmers. We also examine the role of population and diet, which are key underlying factors in the demand for the tropical commodities causing deforestation. We conclude by describing successes in dealing with these drivers, and asking how the world can achieve development without deforestation.

Global population growth, which has already slowed considerably in recent decades, is projected to level off in the later twenty-first century and perhaps decline. The most important demographic phenomenon of our time is not population growth, but urbanization. Rural populations have actually started to decline in important tropical forest countries such as Brazil and Indonesia, and the sources of demand that lead to deforestation are now predominantly urban and export markets. Globally, diets have been shifting toward more consumption of meat and other livestock products, which require additional land to produce the same amount of food (particularly beef). However, this trend has started to level off in developed countries and will eventually do so in developing countries as well. Thus both population and diet trends underlying the increasing demand for food are expected to diminish after several decades, lessening the pressure on tropical forests.

Tropical forests are not all the same. They vary from rain forests in areas with year-round rainfall to dry forests, which are leafless much of the year, to areas with several-month dry seasons. In general rain forests are found closest to the equator, transitioning to dry forests as one goes farther north or south. The combination of dry seasons and fire has converted large areas of dry forest to savannas, particularly in Africa. While rain forests contain large amounts of carbon, dry forests have smaller amounts and savannas even less.

The drivers of deforestation vary a great deal between continents: cattle and soy are important only in Latin America, while palm oil plantations are found almost exclusively in Indonesia and Malaysia. The timber industry has a particularly important role in deforestation in Southeast Asia, where logging is often followed by conversion to plantations to produce palm oil or pulpwood.

The drivers of deforestation vary a great deal between continents: cattle and soy are important only in Latin America, while palm oil plantations are found almost exclusively in Indonesia and Malaysia. The timber industry has a particularly important role in deforestation in Southeast Asia, where logging is often followed by conversion to plantations to produce palm oil or pulpwood.

Soybean production is heavily concentrated in three countries: the United States, Brazil, and Argentina. Expansion of large-scale commercial soy production into the Amazon in the 1990s was an important cause of deforestation, and Brazil became the largest soybean exporter in the world. However, pressure from civil society led to an industry moratorium on buying soybeans from deforested areas beginning in 2006, and recent data indicate that soy's role as an agent of deforestation has diminished greatly as a result.

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Deforestation is a threat to biodiversity

Reducing growth in the demand for commodities that drive deforestation will be important to future successes, but so will increasing the productivity of currently used lands and directing agricultural expansion into grasslands rather than forests.

Pasture expansion to produce beef cattle is the main agent of deforestation in Brazil, occupying more than three-quarters of the deforested area. Beef production in the Amazon tends to be extensive, with low levels of meat production per unit area. As with soy, civil society pressure in Brazil has led to a moratorium since 2009 on buying beef from ranches that have cleared forests to create pasture. Pasture expansion remains an important driver of deforestation in Colombia and other Latin American countries, although over much smaller areas than in Brazil. The cattle industry is not an important cause of deforestation in Africa or Asia.

The palm oil industry is heavily concentrated in two tropical forest countries, Indonesia and Malaysia, and has been expanding rapidly in recent years. Emissions from deforestation caused by palm oil plantations are particularly important in terms of global warming pollution, as considerable amounts of plantation expansion take place in peat swamps with very large amounts of carbon in the soil. The palm industry is dominated by large integrated companies that are also involved in timber cutting and establishing tree plantations for pulpwood production, so Southeast Asian deforestation depends on complex interactions between logging and palm and pulp plantations.

Although only a small part of global timber production and trade, logging in tropical forests can be an important cause of forest degradation. In Southeast Asia, where many more tree species are commercially valuable, it leads to deforestation as well. In Latin America and Africa most clearing is for land, not timber, but logging is often the first step to complete deforestation of an area. Plantations of native species can supply large amounts of wood to take some of the pressure off of natural forests, but only if established in already cleared areas.

Firewood collection has often been blamed for deforestation, but although the volume of wood involved is large, most of it comes from already dead trees and branches, from non-forest areas, or from small trees and shrubs in the understory. Thus it is generally not causing deforestation or even significant degradation. However, charcoal production, particularly to supply nearby cities, can be a locally important driver of degradation and eventual deforestation, especially in Africa. Firewood use is expected to diminish in the tropics in coming decades, and has already dropped considerably in Latin America. Charcoal production, on the other hand, is likely to grow.

Small-scale farming has become less important to deforestation in recent decades, as rural populations have leveled off or declined and large businesses producing commodities for urban and export markets have expanded into tropical forest regions. Africa is an exception to this generalization. However, deforestation rates and associated emissions there tend to be low compared with Amazonia and Southeast Asia, the other two large tropical forest regions. Traditional shifting cultivation has diminished over time in all three regions, and few tropical farmers are now subsistence producers.

In recent years, there has been a considerable decline in tropical deforestation. The clearest such "success story" is in the largest tropical forest country, Brazil, where moratoria on deforestation-linked soybeans and beef, the establishment of protected areas and indigenous lands, and Norway's support for Brazil's REDD+ (reducing emissions from deforestation and forest degradation, plus related pro-forest activities) program have played important roles. Data from Indonesia also indicate declining deforestation in the 2000s. Some tropical countries have actually reduced deforestation to zero and started reforesting, although in part this reflects the displacement of deforestation to other countries. However, emissions overall have diminished substantially, and are down by a third or more from the levels that prevailed during the latter decades of the twentieth century.

Reducing growth in the demand for commodities that drive deforestation will be important to future successes, but so will increasing the productivity of currently used lands and directing agricultural expansion into grasslands rather than forests. The spread of biofuel production, which would create a demand for deforestation not linked to food, could create strong new pressures on tropical forests. However, if recent successes can be duplicated in other tropical countries, we can envision the end of deforestation in the next few decades. This would be a truly historic achievement.

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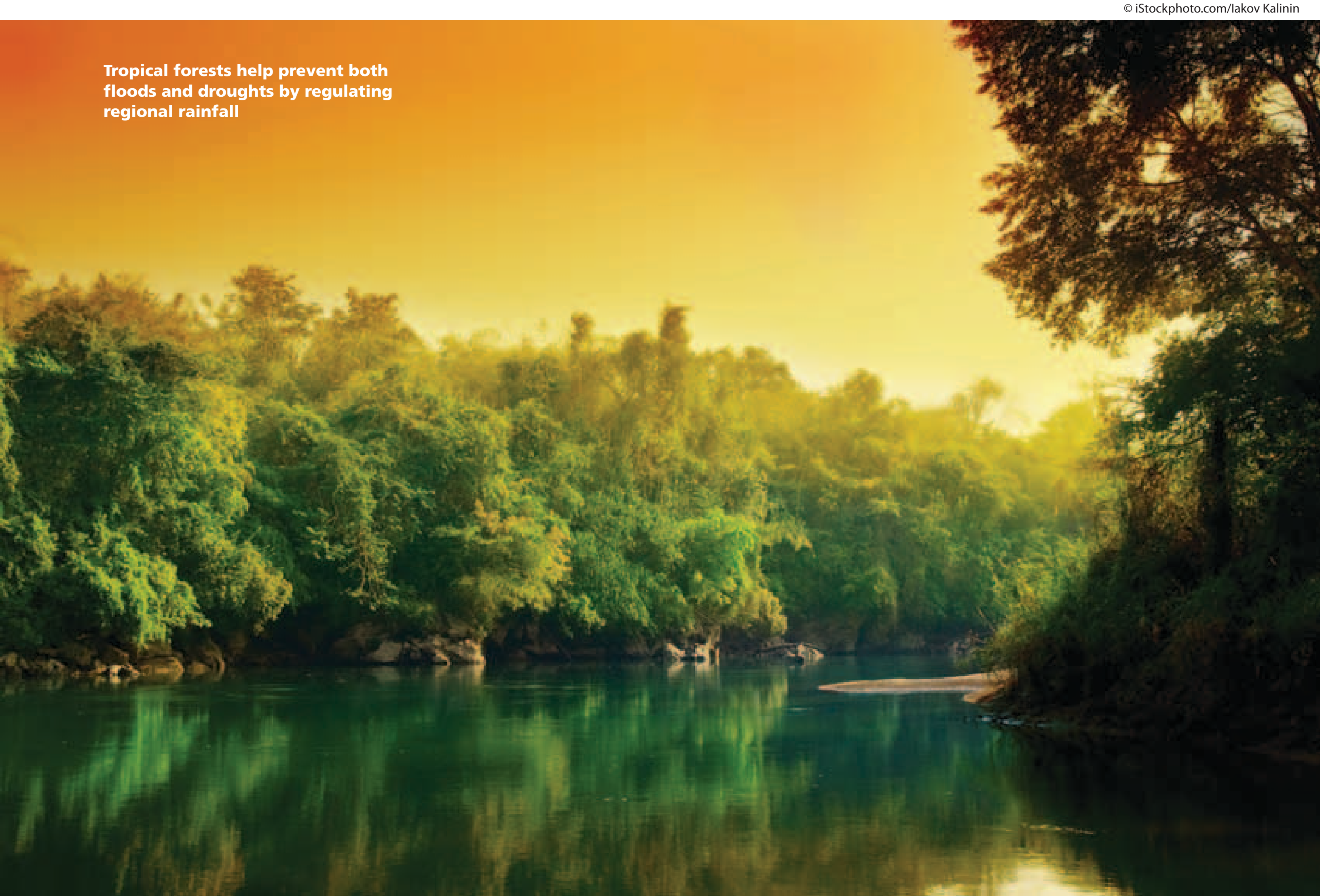


Tropical forests help prevent both floods and droughts by regulating regional rainfall

CHAPTER 1

Introduction

Doug Boucher

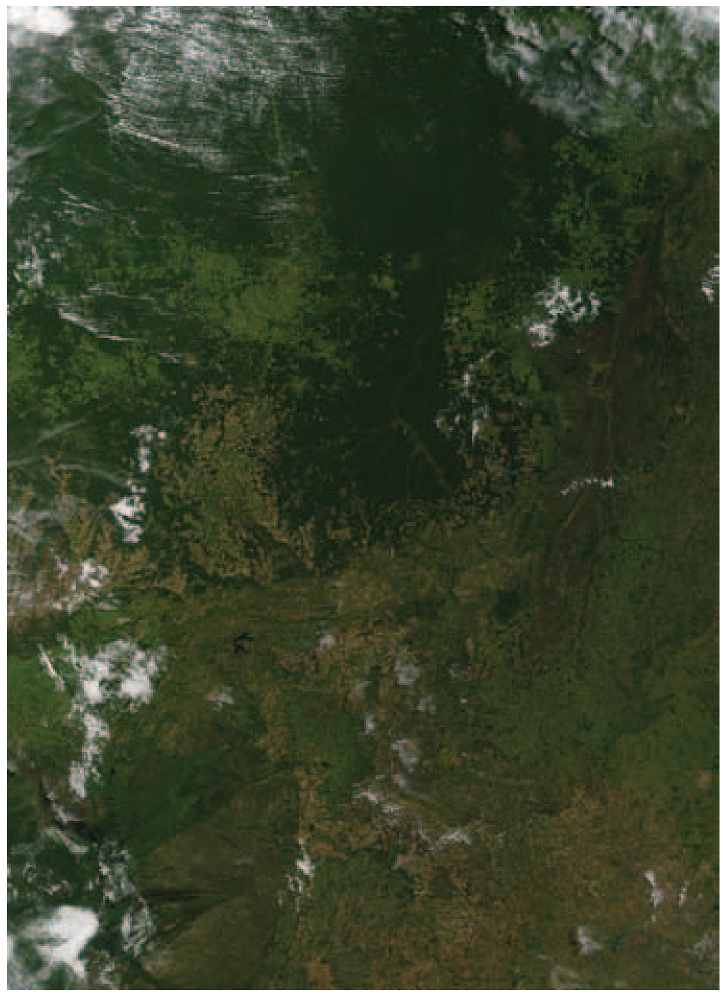
WHY ARE TROPICAL FORESTS disappearing? Why is deforestation happening? Who is clearing tropical forests, and why? These are the questions that this report seeks to answer.

Deforestation and Forest Degradation

Humans have been cutting down forests for thousands of years, practically since they invented agriculture. In many parts of the world, crops could not grow or livestock graze unless the forest was first cleared away. Agriculture requires removal of the trees and shrubs as well as continued weeding. Although the forest could continue being a source of many kinds of foods and useful products, fundamentally the forest and agriculture were in conflict (Rolett and Diamond 2004).

In modern times, deforestation continues even though the societies in which it takes place are very different. Today we live in a globalized world, and the forests of Amazonia and the Congo are connected economically to the urban consumers of Chicago, Rome, and Shanghai. Additionally, our views of deforestation have changed, literally—we can now see the clearing of forests taking place in satellite images, accessible worldwide to anyone with a computer through Google Earth. These pictures, when carefully compared and analyzed, show us where and when forests are disappearing. When combined with detailed on-the-ground study, they can also begin to tell us why.

In looking at the world from space and comparing it with what we see from the forest floor, we realize that an important distinction needs to be made right from the start. Sometimes the forest is cleared and we can detect evidence in satellite images. Three months ago there was forest here; now it is cattle pasture. This is what scientists called "deforestation," strictly speaking—before, the land was forested, and now it is not.



Jacques Descloitres, NASA Earth Observatory Collection

Deforested areas (light green and brown) contrast with intact rain forest (dark green) in a satellite image of the Mato Grosso region of Brazil

But there are also important changes that are more difficult to see from space because most of the trees and the canopy remain, even though below it the forest has been disturbed. This is called "forest degradation;" it eliminates some trees and causes the loss of carbon but does not remove the forest canopy. It can happen, for

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example, because a fire sweeps through the understory or grazing livestock eat or trample seedlings and saplings. Or, as is very common in diverse tropical forests where most tree species have no commercial value, selective logging may have removed a few large trees but left the forest canopy pretty much intact. Although there has been exciting progress in detecting these changes from space in recent years (e.g., Asner et al. 2005), they remain much harder to see.

Degradation is harder to study than deforestation not only because of the difficulty of seeing and measuring it—how many trees were killed, how big were they, and how much carbon dioxide was released as a result—but also because it is hard to follow what happens next. On the one hand, if there is no further disturbance the trees that were destroyed can be replaced by the growth of new ones, and the emitted carbon can be restored (Rice, Gullison, and Reid 1997). Over time, therefore, the net effect of forest degradation could be small, with new trees and carbon replacing those eliminated by degradation. On the other hand, degradation can continue and eventually open up the canopy, effectively converting degradation into slow-motion deforestation. Furthermore, degraded forests have been shown to be considerably more likely than intact ones to be completely deforested in the following years (Foley et al. 2007). Thus, the impact of forest degradation, already hard to estimate, can vary over the long run from minor to devastating.

Deforestation and forest degradation are key causes of climate change, responsible for about 15 percent of global warming pollution (UCS 2009). The reason is simply that trees contain enormous amounts of carbon—it makes up about 50 percent of the weight of the wood. When they are cut, this carbon is released into the atmosphere as carbon dioxide. This happens whether they are burned, left to rot, or converted into paper; it is just a matter of how long it takes.

The term "deforestation" is used as shorthand for "deforestation and forest degradation" in much of this report, but we clarify when we mean only deforestation as opposed to degradation. Although it is easier to combine them into a single word, they are very different when one is actually trying to measure and analyze them.

A Global Approach

In this report we focus specifically on the drivers of deforestation—the reasons why deforestation happens. Thus, until the final chapters we tend to ignore questions such as what ought to be done about it, what kinds of policies can reduce and eventually eliminate

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What was once an intact tropical rain forest is becoming a palm oil plantation in Sumatra, Indonesia

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Soybean fields on deforested land in Brazil, adjacent to intact tropical rain forest

Deforestation and forest degradation are key causes of climate change, responsible for about 15 percent of global warming pollution worldwide. The reason is simply that trees contain enormous amounts of carbon—it makes up about 50 percent of the weight of the wood.

it, what it will cost, and who should pay for this reduction and how. However, we do occasionally reference solutions and policies throughout the report—especially "REDD+" because it is currently widely supported and has proven to be a successful solution. Reducing emissions from deforestation and forest degradation, plus related pro-forest activities (REDD+) is the term for a mechanism that provides compensation to tropical countries for reductions in deforestation—making the forests worth more standing than cleared. These questions of what ought to be done, how, and who should pay are vital, and we have written several reports on the subject (Elias and Lininger 2010; Boucher 2008) and plan to write additional ones in the future.

Our approach is global. The focus is on the tropics simply because in the twenty-first century almost all net deforestation is in the tropics. Trees and forests get cut down in other parts of the world, but they also grow back, and on average the temperate and boreal parts of the planet actually have more regrowth than cutting. In other words, they are a net "sink" for carbon dioxide, with more being taken out of the atmosphere by forest growth than is released into it by deforestation and degradation (FAO 2010). Thus, we concentrate on the tropics—roughly, the part of the world between the equator and about 30 degrees north or south latitude.

This includes nearly half of the 200 or so countries on Earth, but from the point of view of deforestation they are not at all equal. In fact, just two of them, Brazil and Indonesia, contain more than half of the world's tropical forest and account for more than half of the global warming pollution due to deforestation (FAO 2010). Only a dozen or so countries (including Brazil and Indonesia) are responsible for over 90 percent of the global warming pollution due to deforestation. Thus in this report, the larger tropical forest countries receive more attention.

Because our approach is global, the differences between countries, and even more so within countries, get less attention. Looking at the planet's tropical forests as a whole, we have to gloss over many details and complexities that become very evident when doing in-depth research in a particular place. We draw extensively on the large literature that has come out of this research. But when states and provinces are compared, and even more so when districts, counties, municipalities, and watersheds are the focus, the details and local exceptions become clearer at the expense of generalizations and overall trends. Without denying the importance of these details, we concentrate on the trends at the broader scale—large countries, continents, and the world as a whole. We do not ask what drives deforestation in a particular place, but rather, what drives it on this planet.

Which Drivers?

A very large number of forces, conditions, and agents have been considered "drivers" of deforestation at one time or another (Rudel et al. 2009; Geist and Lambin 2002). They include such varied phenomena as palm oil plantations, roads, poor governance, cold war concerns about communism and fear of peasant unrest, trade liberalization, corruption, and the fact that humans evolved in savannas, not forests.

To simplify this complexity, distinctions are often made among the types of drivers, such as proximate versus ultimate or agents versus underlying causes. Since our focus is on global, not local, causes of deforestation, we look at drivers on just two of these levels. In Chapter 2 we consider the overall global demand underlying deforestation, separating it into two components: population and diet. In other words, we simply ask: how many people are there on this planet and what do they consume? (Lambin and Meyfroidt 2011). Ultimately, it is this global demand that underlies deforestation.

On the other hand, it is important to look at what happens directly on the ground where the forests are being cleared. After describing the diversity of forests and drivers of deforestation across the tropics (see Chapter 3), we look at these agents of deforestation in the core of the report (see Chapters 4 through 9). Who clears tropical forests, and what do they do with the land after clearing it? This divides the global demand into the different kinds of sectors and industries, including soy, beef, palm oil, timber, and fuels from wood. This necessarily sacrifices some information, but has the advantage of looking at the causes of deforestation in terms of simple, easily understandable elements, such as beef cattle and the steak that comes from them.

Stephen Hylden

Tropical rain forest in Ecuador

Deforestation Today

In our view, deforestation is not an irrational act, in the contexts in which it takes place. People and corporations often clear the forest for good reasons, usually economic ones. That is not to say that we see the agents of deforestation as examples of *Homo economicus* or their decisions as being made in a "free market," for the economy is embedded in a political and cultural context that may often lead to deforestation even when it is not the course that leads to the maximum long-term profit. It is simply to acknowledge that money plays a critical role in deforestation in the twenty-first century.

This matters because the agents of most deforestation today are businesses. Deforestation has changed from a "state-initiated" process to an "enterprise-driven" one (Rudel 2007). The major agents of deforestation are corporations that analyze it as an economic

Deforestation has changed from a "state-initiated" process to an "enterprise-driven" one. The major agents of deforestation are corporations that analyze it as an economic alternative, and choose it instead of other options because it is advantageous in terms of dollars and cents.

alternative, and choose it instead of other options because it is advantageous in terms of dollars and cents.

Furthermore, they make these decisions in a finite, globalized world. Thus reductions in deforestation in one area, by limiting supply and raising prices, can increase the pressure for deforestation elsewhere. Sometimes the same companies—e.g., multinational timber companies—can actually move from one place to another; but even without this, the demand for deforestation will be displaced (or "leak") to other places due simply to the operation of the global market (Lambin and Meyfroidt 2011). Like a balloon that is squeezed on one end, there will always be pressure for it to push out at the other end. This does not mean that deforestation never decreases, but simply moves. Leakage is not 100 percent; as Lambin and Meyfroidt stated, "the glass is still half full." But in a globalized world, it always must be assumed that the drivers of deforestation are mobile and the forces of the market will move them around the world.

Nevertheless, success is possible. We conclude our report with two chapters (see Chapters 10 and 11) outlining how the world can achieve "development without deforestation" and describing what has already been done by several countries to reach it. These examples show that despite the global reach of the drivers of deforestation, they can be beaten. Strong action by civil society and governments can pressure businesses to choose alternatives to deforestation. More rapidly than anyone expected even five years ago, global deforestation has decreased. With continuing efforts, we can reduce the loss of forests to zero in our lifetimes. After thousands of years of clearing, humanity can truly make deforestation history.

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Rio de Janeiro, Brazil

CHAPTER 2

Population and Diet

Doug Boucher

THE DEMAND FOR LAND THAT leads to tropical deforestation comes fundamentally from the expansion of global agriculture. Recently the Organisation for Economic Co-operation and Development (OECD) and the Food and Agriculture Organization of the United Nations (FAO) predicted that the world will require a 70 percent increase in global food production by the year 2050 (OECD-FAO 2010: 14). What are the trends that underlie this and similar predictions? To what extent do they make the loss of tropical forests inevitable? This chapter considers the underlying trends that drive deforestation by analyzing the reasons for growth through global demand, now and in future decades.

People and What They Eat

A common way to estimate the demand for food is with the equation population multiplied by per capita consumption (Lambin and Meyfroidt 2011). It identifies how many people there are and, on average, how much they eat. This simple approach ignores a great deal of the complexity involved—numbers of young versus elderly, male versus female, active or sedentary, and dozens of other variables—but does separate the numbers from the ways in which people live. It also isolates the effects of processes that have been found to be fairly predictable for at least a few decades into the future, such as those pertaining to demography. With diet, too, there are trends to provide some basis for prediction.

Concentrating on food also ignores all the other ways that land can be used. Indeed, even leaving aside non-material uses such as recreation and spiritual fulfillment, the focus on food chooses to look at only the first two of what we can call "the five Fs":

- **Food**—eaten by people (e.g., rice, bread, fish, meat, milk)
- **Feed**—eaten by our livestock (e.g., pasture grass, soy meal, sorghum, maize, alfalfa)
- **Fiber**—used for clothing (e.g., wool, cotton, linen, silk)
- **Fuel**—interpreted broadly to include both biofuels (ethanol and biodiesel) and other bioenergy sources (e.g., wood for cooking fuel, heat, or electricity generation)
- **Forest**—interpreting this broadly also, as shorthand for the products of both forests (wood, paper, bushmeat) and other natural ecosystems such as savannas.

The focus on population and diet, specifically how many people exist and what they eat, is helpful when initially approximating the future demand for land.

Currently, food and feed are the prevalent drivers of the tropical deforestation that is the subject of this report. But the other three, particularly fuel, could become quite important drivers of deforestation in the future.

Still, despite all that it leaves out, the focus on population and diet, specifically how many people exist and what they eat, is helpful when initially approximating the future demand for land. This demand is not the same as the demand for deforestation. As we will see in later chapters, the best successes in reducing deforestation have come from removing the link between these two factors. However, it indicates the underlying economic pressure that any attempt to reduce the drivers of deforestation will have to confront.

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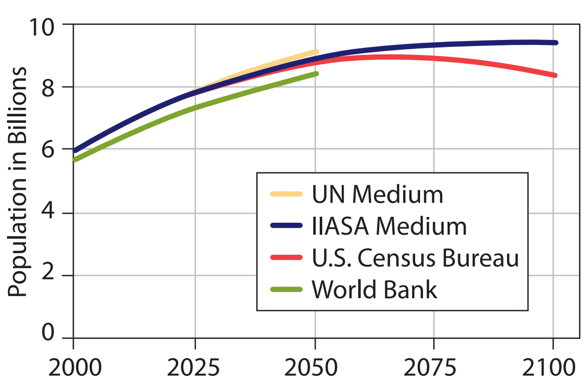
Malthus and Reality

Over two centuries ago the Reverend Thomas Malthus argued that population, growing exponentially, would inevitably overtake food production, leading to starvation and misery among most of society. Since then his prediction has been endlessly debated and compared with alternative explanations (e.g., Boserup 1965). His theory represents a way of thinking that is still very prevalent in the minds of many educated people.

However, in the past half-century it has become clear that two of Malthus' main points were wrong. The global population has not grown exponentially—for exponential growth means that the per capita growth rate is constant (e.g., it may be 2 percent per year, or 3 percent or 0.5 percent, but it stays the same year after year). Rather, the global growth rate of population has dropped steadily and is now just over 1 percent per year and continuing to decline (Bongaarts 2009). More countries are going through the "demographic transition," the process by which declining death rates (which make the population grow faster) are followed by declining birth rates (which reduce population growth to zero or even negative rates). Most developed nations now have stable or declining populations; Latin America is close to this and China's fertility may already be below replacement level (Hvistendahl 2010). On every continent and in nearly every country, per capita growth rates are declining toward zero or less, and we are likely to reach a peak global population somewhere between 8 and 10 billion (the current level is just about 7 billion) in the second half of the twenty-first century (Figure 2.1) (Lutz and Samir 2009).

Malthus' other prediction—that agricultural production would fall behind population growth so that per capita food availability would decline—has also been proven wrong. In fact, food output has outpaced population growth for several decades. In the period from 1990 to 2007, for example, global per capita food production increased by an average of 1.1 percent annually (Lambin and Meyfroidt 2011). This growth has come about despite a shift in diets that tends to increase inefficiency and restrict total food availability.

Figure 2.1. Projections of Future Population



Projections of global population agree that it will grow to about 9 billion in the latter half of the twenty-first century, with some predicting that it will decline thereafter. Estimates are by demographers from the United Nations (UN), the International Institute for Applied Systems Analysis (IIASA), the United States Census Bureau, and the World Bank.

Source: Population Reference Bureau 2001.

The Dramatic Population Change: Urbanization

Despite the failure of Malthus' predictions, there *is* a population shift happening in the developing world that is critical to deforestation, although not nearly as often discussed as population growth. This is urbanization: the massive migration of people out of rural areas to the city. Already, Latin America's population is about 75 percent urban, and Asia and Africa are expected to become majority-urban within the next two decades (Montgomery 2008). While the growth of enormous cities of many millions of inhabitants is impressive, the other side of the coin is just as important: rural populations in many developing countries have peaked and begun to decline. In the two largest tropical forest countries, for example, the rural population has been dropping—in absolute terms, not just as a share of the country's total—for many years. This is true, for example, in Brazil since the 1970s and Indonesia since the 1990s.

Urbanization and rural population decline are important because they mean that the regions where food is produced and the places where it is consumed are more and more distant. The majority of food is eaten in urban areas, whether they are in the same or distant countries and whether they are in industrialized or developing nations. Thus it is now urban markets in developing countries and export markets in both developing and developed ones creating the demand that drives deforestation (DeFries et al. 2010). Not only are subsistence farmers, who produce only for their own consumption but not for the market, now rare (see Chapter 9), but farmers are less likely to be selling their products to their rural neighbors. Rather, they are feeding urban consumers living hundreds or thousands of kilometers away.

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Along with population growth, migration of people out of rural areas and into cities is increasing

Because rural populations have stabilized and tropical farmers are now distant from those who eat the food they produce, deforestation is now driven by global markets, not local populations. Although there are exceptions, more and more the globalized economy is what matters to the fate of tropical forests.

Associated with this change is the development of long agricultural supply chains in developing countries, often with supermarkets as a key element. In Brazil, for example, supermarket chains account for 42 percent of food sales to consumers and independent supermarkets account for another 44 percent (Chapter 13 in Steinfeld et al. 2010). Food exports, too, are dominated by highly capitalized supply chains, involving not only farmers and ranchers but also banks, slaughterhouses, food processors, and exporters, with sales of the final products dominated by retail chains such as Walmart, Carrefour, and Tesco. Similar long-distance "teleconnections" have now been established through global markets for livestock feed, such as soy, maize, and fish meal (Naylor et al. 2006; Nepstad, Stickler, and Almeida 2006).

Because rural populations have stabilized and tropical farmers are now distant from those who eat the food they produce, deforestation is now driven by global markets, not local populations (DeFries et al. 2010). Although there are exceptions—in particular in Africa (Fisher 2010)—more and more the globalized economy is what matters to the fate of tropical forests.

What You Eat and the Land You Need

If global population growth is expected to slow and eventually stabilize at about 25 to 30 percent above its current level, why do the OECD and the FAO project that we will need 70 percent more food in just 40 years? The answer is consumption: the overall demand for food per person is expected to rise significantly, as it has in recent decades. At first glance this seems to defy

When societies become more prosperous, there tends to be a shift in diet toward food that is more resource-intensive to produce (e.g., meat), thus requiring larger amounts of land to feed the same number of people. What people eat changes how efficiently their consumption turns fertile land into healthy people—with lower efficiency for the diets of the rich than for those of the poor.

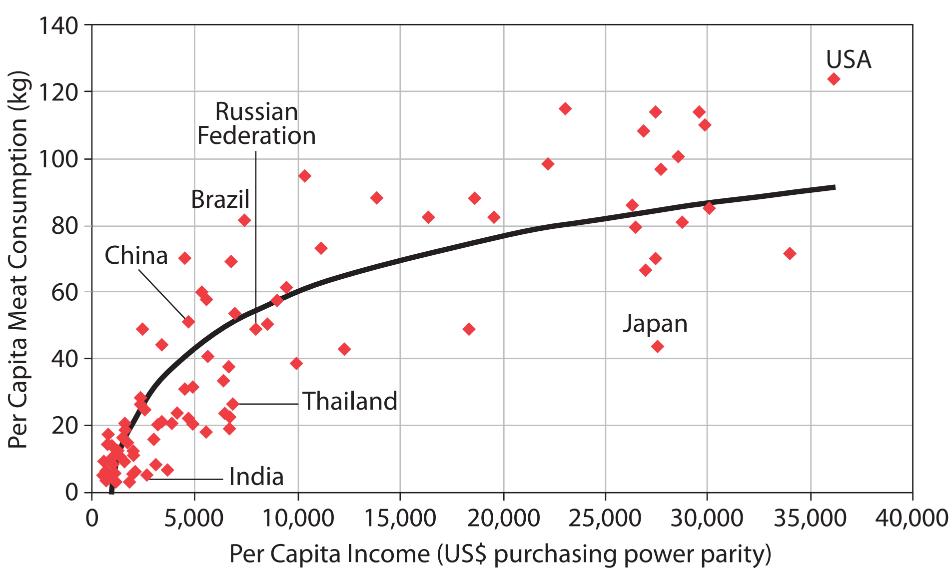
common sense—have people really been eating that much more food? Certainly, we do not expect people to begin eating four full meals daily instead of three. Then how can consumption per capita have been rising, and how can it continue to go up?

On one level, common sense is correct. There really has not been that much change in *how much* food people consume, whether measured by weight (e.g., kilos, pounds) or by energy content (e.g., calories, megajoules). Averaged over a whole population, people tend to consume from somewhat below 2,000 to above 3,500 calories per day (Gerbens-Leenes, Nonhebel, and Krol 2010). While global population has repeatedly doubled in the last few centuries, per capita consumption probably never has, even once. But what has changed a great deal is *what kind* of food people eat (Galloway et al. 2007). This has important implications for land use and deforestation. When societies become more prosperous, there tends to be a shift in diet toward food that is more resource-intensive to produce (e.g., meat), thus requiring larger amounts of land to feed the same number of people (Figure 2.2). What people eat changes how efficiently their consumption turns fertile land into healthy people—with lower efficiency for the diets of the rich than for those of the poor (Gerbens-Leenes, Nonhebel, and Krol 2010).

The principal, although not exclusive, reason for this is that with increasing affluence, people tend to consume foods higher in the food web. They eat more animal products—beef, chicken, pork, eggs, and milk—so the transformation of food plants into edible calories goes through two steps, not one. Plants convert sunlight into food by photosynthesis. Then animals eat those plants, in the process creating meat, but losing a lot of the original stored energy of the plants.

Although estimates on how inefficient it is to eat animal products vary depending on the type of animal and how it is calculated, all estimates agree that it is high. Wirsenius, Hedenus, and Mohlin (2010) estimate the food/feedstock conversion efficiency (amount of edible food produced relative to total plant production) for eating cereal grains at 78 percent and for other

Figure 2.2. Relation between Countries' per Capita Income and Their Meat Consumption in 2002



Although there is considerable variation even at similar levels of income (e.g., compare Brazil and Thailand or the United States and Japan), meat consumption shows a clear tendency to increase and then level off as income increases.

Source: Steinfeld et al. 2006.

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Chicken is a more efficient type of livestock than beef, but consuming cereal grains and vegetables is even more efficient

vegetable products at 60 percent, but just 20 percent for poultry, 18 percent for pork, 15 percent for dairy products, 13 percent for eggs, and a mere 2 percent for beef. Galloway et al. (2007) estimate that non-ruminant livestock (principally pigs and chickens) convert 26 percent of their feed into meat but ruminants (principally beef cattle) convert just 5 percent. Gerbens-Leenes and Nonhebel (2002) calculate the amount of land in Europe needed per year (in square meters) to produce a kilogram of edible food as 0.3 for vegetables, 0.5 for fruits, 0.5 for beer, and 1.4 for cereals, compared with 1.2 for milk, 3.5 for eggs, 7.3 for chicken, 8.9 for pork, 10.2 for cheese, and 20.9 for beef. However you calculate it, eating high on the hog—or even more, high on the cow—is a lot less efficient and requires much more land than eating low on the wheat.

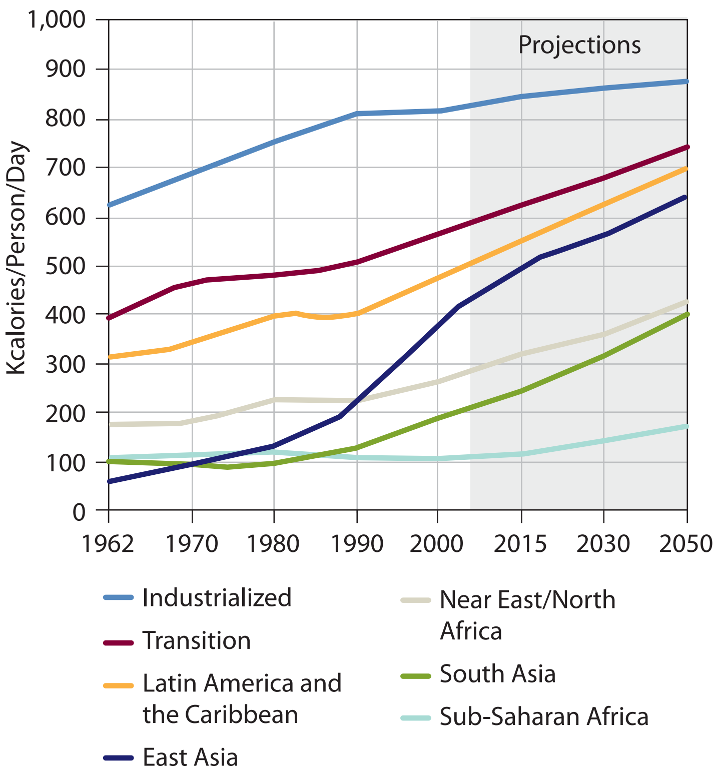
Different Animal Products and the Demand for Land

All animal products are not the same. Notice that, according to the numbers just quoted, eating beef requires between 3 and 10 times more land to produce an equal amount of food as eating either chicken or pork. Although all three types of meat have increasingly become part of the diet, the trends for each are quite different.

Chicken and pork—the more efficient, non-pasture-dependent kinds of livestock—have been growing considerably faster than beef. In the developing world consumption of all three has grown, but most rapidly for chicken and least for beef. In industrialized countries meat consumption per capita stayed steady from 1992 to 2002, but with a shift toward less beef and more chicken (Chapter 2 in Steinfeld et al. 2010). The United States actually reached its highest per capita rate of beef consumption in 1976, and is now about 30 percent below that (Corum 2011).

The production of beef requires considerably more land because it uses pasture, while chickens and pigs are fed almost exclusively on grains and protein meal. Beef cattle's conversion of pasture grasses into meat is several times less efficient than their conversion of grain into meat, and chickens and pigs essentially are unable to do it at all (Galloway et al. 2010). So in tropical

Figure 2.3. Past Amounts and Future Projections of per Capita Consumption of Livestock Products



Consumption is expected to increase considerably in the developing world, but remain relatively constant in industrialized nations.

Source: Steinfeld et al. 2006.

countries, where cattle are raised almost exclusively on pasture and not grain, the amount of land needed to produce a pound of beef will be especially large.

In the long run, as developing countries' consumption of animal products approaches that of industrialized ones, its growth will slow down. The fraction of animal products in the diet, even in the richest countries, does not tend to go beyond about 30 percent (Gerbens-Leenes, Nonhebel, and Krol 2010). Put another way, people do not typically consume much more than 900 calories per day in the form of livestock products, even in the most carnivorous of regions (Figure 2.3).

Some developing nations are well on their way to closing this gap. Latin America already averages over 500 calories per day, and is expected to reach about 700 by 2050. East Asia (mostly China) is just behind, with 450 calories per day now and a projection of 650 for the year 2050. On the other hand, Sub-Saharan Africa's level is just over 100 now and expected to still be under 200 in 2050.

While increasing livestock consumption in the poorer developing countries would be an improvement in nutritional terms, the levels of animal-product consumption in industrialized countries have clearly passed the point where they are beneficial to health. These foods' high level of fats, especially saturated fats, have been linked to heart disease, cancer, diabetes and obesity; this is particularly the case for beef and pork (Chapter 12 in Steinfeld et al. 2010). Increasing knowledge of these health effects may be one of the reasons for the shift away from beef in favor of chicken that we have witnessed over the past few decades (Corum 2011).

Slowing Growth in Both Population and per Capita Consumption

As we have seen, both population and consumption are likely to grow in the coming decades, but not without limit. Population growth is likely to add about 25 to 30 percent to the global demand for food, but then level off and perhaps decrease. Changing diets, in the direction of more livestock consumption, will keep increasing the pressure on farmland for a longer period, but this too will level off even if all developing countries reach the levels now characteristic of industrialized ones. Furthermore, the trend away from beef consumption will have an opposite effect, reducing the need for land corresponding to a given level of meat eating.

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The production of beef requires considerably more land than the production of chicken or pork

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Within the next two decades, the majority of Asia's population is expected to live in cities such as Bangkok, Thailand

What this means is that although the increasing demand for more food will continue for several more decades, it will not last forever. Over the twenty-first century it is likely to increase more and more slowly, eventually reaching a peak and either leveling off or dropping from there. Getting through the next few decades is likely to be the most serious challenge.

All this, however, is assuming that the key aspect of agriculture in terms of its demand for land will continue to be the production of food. This is currently the case, but could change if non-food land demand—e.g., for biofuel and bioenergy, urban expansion, or industrial forestry—becomes important. In this respect, it is notable that in the projections of additional land use in 2030 recently reviewed by Lambin and Meyfroidt (2011), the demand for additional food producing land (cropland and grazing land) makes up only 28 to 38 percent of the total increase.

In the short run, the drivers of deforestation are likely to remain those that are important today. But as the chapters to follow will demonstrate, they can both increase and decrease fairly quickly, and in a globalized economy they can respond to changes in one country by shifting to another. This "leakage" happens not only in response to policies such as REDD+ (reducing emissions from deforestation and forest degradation, plus related pro-forest activities) (see Chapter 11), but is a fundamental economic feature of the urbanized, globalized world of the twenty-first century. This report offers evidence that the drivers of deforestation can be dealt with effectively, so that the world can reach the end of this century with both intact tropical forests and a better-fed populace. But if the fundamental connection between land and food is broken, then the future for both our planet and its people will be hard to predict.

If the fundamental connection between land and food is broken, then the future for both our planet and its people will be hard to predict.

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Soybean production causing deforestation in the Brazilian Amazon

CHAPTER 3

Tropical Forest Regions

Pipa Elias and Calen May-Tobin

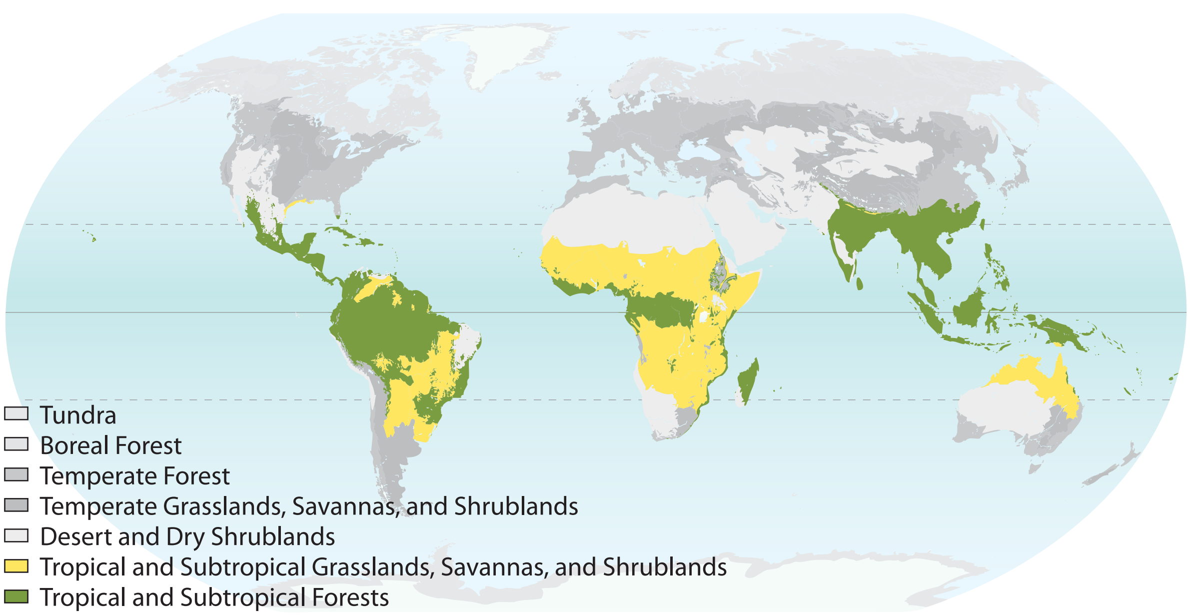
THE ECOSYSTEMS IN THE TROPICS are vital components of a healthy, functioning Earth and hold some of the richest biodiversity in the world. For people living in the tropics, forests provide shelter, food, and medicine, and they capture the imagination of those who may never set foot there. Within each tropical biome there is a great deal of diversity, and volumes would be necessary to describe their intricacies. However, even a brief introduction to the forest and savanna ecosystems of the tropics shows their variability. There is no one "tropical forest"—not the rain forest or any other kind. They have to be seen as plural.

Despite the beauty and importance of tropical forests, they are rapidly disappearing around the globe. Approximately 48 million hectares (ha) of these varied tropical forests, an area larger than the state of California, were cut down between 2000 and 2005 (Hansen, Stehman, and Potapov 2010). Deforestation differs among forest types as well as among geographical regions. This chapter will explore both the regional differences in forest types and the major drivers in each region.

What Makes a Tropical Forest?

The tropics are the part of Earth between 23.5 degrees north and 23.5 degrees south of the equator (Figure 3.1).

Figure 3.1. Map of the World's Terrestrial Biomes



This map highlights the world's tropical and subtropical forests (dark green) and tropical and subtropical grasslands, savannas, and shrublands (yellow).

Source: UNEP-GRID-Arendal 2009; Olson et al. 2001.

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Tropical savanna in Uganda

This part of the planet has just two seasons: wet and dry. However, even within the tropics, ecosystem subdivisions can be made based on the length of the rainy and dry seasons. Across the broad tropical landscape the gradual transition from rain forest to dry forest to savanna is mostly a function of rainfall during the growing season, with rain forests receiving the most and savannas the least. This transition takes place as one moves north or south from the equator, where consistent rain supports tropical rain forests. Rain forests have either no or very short dry seasons, causing the trees to remain green and grow throughout the year. Around 10 degrees north and south of the equator the rain becomes more seasonal and land cover tends to transition to dry forest or savanna. Dry tropical forests, with their longer dry seasons, have deciduous trees that lose some or all of their foliage at the beginning of the dry season, similar to the forests of the eastern United States. In areas with even less rain and/or more frequent fires, the forests gradually transition to savannas, which have a few trees but are mostly covered with grasses and shrubs. Within each of these ecosystems most ecologists make even finer distinctions, but in this chapter we focus on the three main biomes of the tropics: tropical rain forests, tropical dry forests, and tropical savannas.

Tropical Rain Forests

Tropical rain forests have large trees that are green year-round due to the consistent levels of rain they receive. This evergreen forest is abundant, inspiring, and a constant source of new scientific discoveries.

Most tropical rain forests lie close to the equator—between 10 degrees north and south. There are three major regions of rain forests, separated by oceans: Southeast Asia, Central Africa, and Amazonia, each with different species and structure. The tropical rain forest biome covers about 17 million km^2, or about 12 percent of Earth's ice-free land surface (not including extreme areas like Antarctica). Of this area, approximately 20 percent was used as pasture or cropland in 2000 (Ramankutty et al. 2008). This estimate does not include land that had been previously converted but subsequently abandoned. However, while human use has affected more than 20 percent, there are still vast areas of undisturbed rain forests.

Tropical Dry Forests

Tropical dry forests are lush and green through their rainy growing seasons, but unlike tropical rain forests they are dominated by deciduous trees that lose their leaves and go dormant during the dry season. The characteristics of these forests, such as average tree height and presence of deciduous species, are dependent on average rainfall, with wetter forests having taller trees and more evergreen species compared to drier ones.

Most tropical dry forests are between 10 and 25 degrees north and south of the equator. In the Americas, dry forests are situated south of the Amazon rain forest as well as northward along the Pacific Coast of Central America and into Mexico. In Africa tropical dry forests are extensive across many parts of the continent, extending to the north, east, and south of the Congo Basin rain forest. In addition, tropical dry forests cover almost all of India, extend into parts of China, and are a major type of land cover in Australia.

The tropical dry forest biome covers about 6 million km^2, or about 4 percent of Earth's ice-free surface. Of this area, over 50 percent was used as pasture or cropland in 2000 (Ramankutty et al. 2008). Why have dry tropical forests been more extensively cleared than tropical rain forests? First, clearing them is physically easier, since the trees are smaller and will easily burn during the dry season. Second, the dry season in these areas helps reduce the year-round threat of pests and diseases that limit crop and livestock production in rain forest areas.

Tropical Savannas

Savannas are vast landscapes of grasses with scattered trees. The wet season in savannas can be short, preventing this ecosystem from being a rain forest. The length of the dry season often combines with lightning-induced or human-set fires to prevent the vegetation from growing into dry forest because fires suppress tree growth but help grasses flourish. Africa has large areas of savanna in part because of the combination of dry seasons with millions of years of human inhabitation.

African savannas are famous for their diverse and abundant wildlife. They cover the landscape south of the Sahara Desert in the eastern part of the continent along the Indian Ocean, extending back westward south of the Congo Basin rain forest all the way to the Atlantic. In South America savannas span south-central Brazil and reach into much of Venezuela and Colombia. In Brazil fire dominates the savanna landscape and has created the *cerrado* (Box 3.1), while in Venezuela and Colombia periodic flooding creates the unique landscape of the *llanos*. Savannas are also prevalent just south of the dry forest in northern Australia, and in parts of Southeast Asia. The savanna biome covers 20 million km^2, or about 15 percent of Earth's ice-free surface. Of this area approximately 50 percent was used as pasture or cropland in 2000 (Ramankutty et al. 2008).

The Role of Tropical Forests

While tropical rain forests, dry forests, and savannas account for only about 31 percent of ice-free land cover, they are a critical component of the earth system. For example, more than 50 percent of all known plant species grow in tropical forests (Mayaux et al. 2005). Forest cover in the tropics is critical for preventing soil erosion during strong rains. Furthermore, these forests

BOX 3.1.

The Brazilian *Cerrado* Ecosystem

Covering almost 20 percent of Brazil, the *cerrado* is a unique and biologically valuable savanna-like ecosystem. As with other tropical savannas, fire is a key component of ecosystem maintenance. The *cerrado* actually has many vegetation types, ranging from open grassland to areas of dry forest. What makes this area different from other savannas is that the *cerrado* is incredibly diverse. There are over 160,000 species of plants, animals, and fungi. Besides being a habitat for many species, this ecosystem also serves as a breeding ground for numerous forest bird species (Oliveira and Marquis 2002). The *cerrado* is a very species-rich tropical savanna, and researchers believe that fire created such diversity (Simon et al. 2009). For example, many of the plant communities in the *cerrado* are closely related to trees in the Amazon rain forest; however, those in the savanna have evolved to survive fire, which would destroy the related species of the rain forest. Within the *cerrado* tree cover can range from a full canopy of these fire-adapted trees to marshes and grasslands with sparse or no trees.

The *cerrado* has supported the economic growth of Brazil, with over 50 percent currently under human use and 30 percent of that planted with crops (Oliveira and Marquis 2002). Many conservation groups are working to protect this unique ecosystem by improving laws affecting the area, bringing its uniqueness into global consciousness, and working to develop sustainability of ranching and farming in the area. In response to pressure to conserve the *cerrado*, not just the more spectacular Amazon forest, the Brazilian government has committed to reducing its rate of deforestation 40 percent by the year 2020.

Doug Boucher

A mix of vegetation types and signs of agriculture in the Brazilian *cerrado*

and savannas support the livelihoods of many communities. For example, the miombo woodland, an extensive (2.7 million km^2) tropical dry forest in central and southern Africa, is inhabited by 75 million people and is the source of wood or charcoal that provides energy for 25 million urban dwellers (Campbell et al. 2007).

Carbon in Tropical Ecosystems

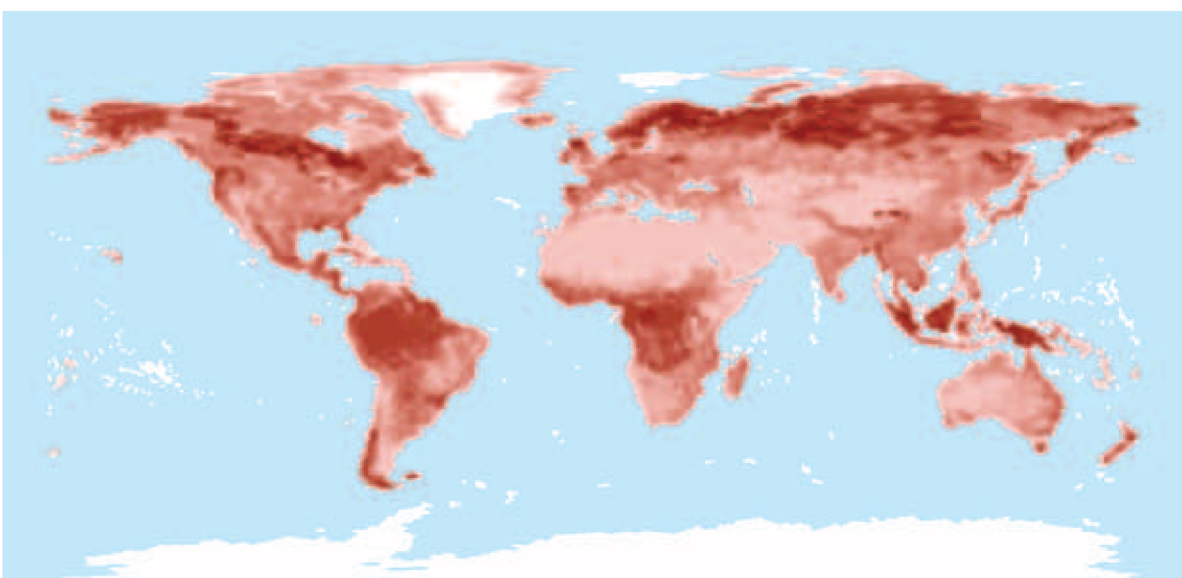
Year-round growth allows the trees of tropical rain forests to grow very large and thus accumulate a lot of biomass in the ecosystem. Since biomass is about 50 percent carbon, more biomass means more carbon in the forest. Rainforests have so much biomass and are so widespread that they store a lot of the world's carbon (Figure 3.2). In fact, the Brazilian Amazon alone accounts for about 10 percent of the world's terrestrial carbon (Tian et al. 1998).

Because the amount of carbon is so high on a hectare of tropical rain forest, when the area is cleared a great deal of the carbon in those trees is released into the atmosphere as carbon dioxide. Countries that clear a large amount of rain forest cause high levels of global warming pollution.

Rain forest trees grow so big and so fast that, with the exception of tropical forests on peat soils (see Chapter 6), most tropical rain forests have less carbon in their soils than above ground, in the trunks of the trees. Contrast this with many temperate ecosystems where most of the carbon is stored in the soil. Because tree biomass/carbon is so high on a hectare of tropical rain forest, when the area is cleared a great deal of the carbon in those trees is released into the atmosphere as carbon dioxide. Therefore, the countries that clear a great deal of rain forest cause high levels of carbon emissions.

Since they do not grow year-round, dry tropical forests have smaller trees and less biomass than rain forests. This means that clearing a hectare of dry forest will release less carbon dioxide than a hectare of rain forest. Similarly, the fire dynamic of the savanna prevents this biome from accumulating a lot of biomass. For this reason, many African countries that have large amounts of deforestation when measured in area (hectares), contribute relatively small amounts to global warming because the amount of carbon dioxide released by clearing each hectare of their dry forests and savannas is not large.

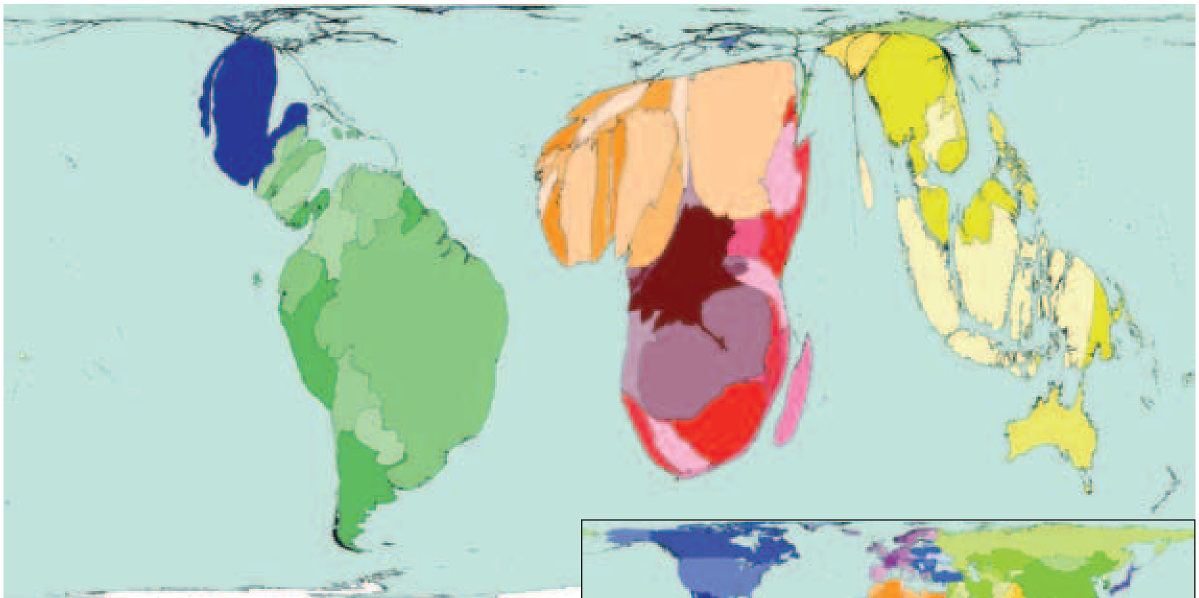
Figure 3.2. Average Carbon Density of the World's Forests

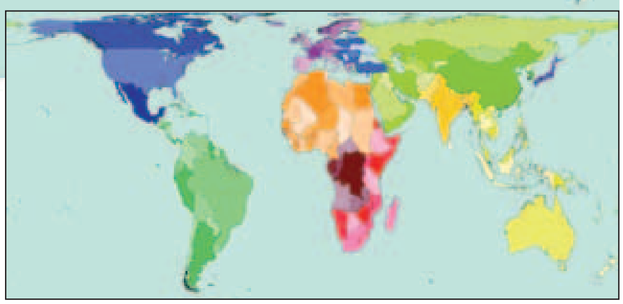


Tropical forests have some of the world's highest carbon densities, as is illustrated here by the dark areas in South America, Africa, and Indonesia.

Sources: Strassburg et al. 2010; Ruesch and Gibbs 2008; IGBP-DIS 2000.

Figure 3.3. Map of the World's Countries Drawn Proportional to Their Forest Loss





In this depiction of percent forest loss from 1990 to 2000, countries are skewed to be larger if they lost a higher percentage of their forests. An unskewed map is shown to the right.

Source: SASI Group and Newman 2006.

Differences in Drivers of Deforestation between the Continents

Tropical forests are those most threatened by human destruction. Figure 3.3 shows that most countries that lost forest cover between 2005 and 2010 were countries with tropical biomes.

Across the tropics there are a few overarching similarities in the causes of deforestation. In all regions, from the 1960s until around the mid-1980s or early 1990s, the major force behind deforestation was government action (Rudel 2007). Government policies varied from region to region, but generally provided incentives for the colonization of forest, such as cheap land, and investments in infrastructure (e.g., road building) that made this colonization easier. However, in the 1980s a shift in most countries away from government action, recessions that left many countries without the means to pay for such efforts, and the end of the cold war (which caused fears of social unrest among landless peasants), led to the decline of direct government investment of this sort (Rudel 2007). Since the early 1990s deforestation has been primarily "enterprise-driven" and in many cases this has been by

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Soybean cultivation in Brazil has been a major cause of deforestation

large businesses, although governments still contribute to these efforts indirectly (e.g., through tax incentives for businesses to build roads) (DeFries et al. 2010; Rudel et al. 2009). In addition to economic changes, increasing consumption by growing urban populations is also a major factor of deforestation (see Chapter 2) (DeFries et al. 2010). The types of enterprises that drive deforestation differ among the different regions (Figure 3.4).

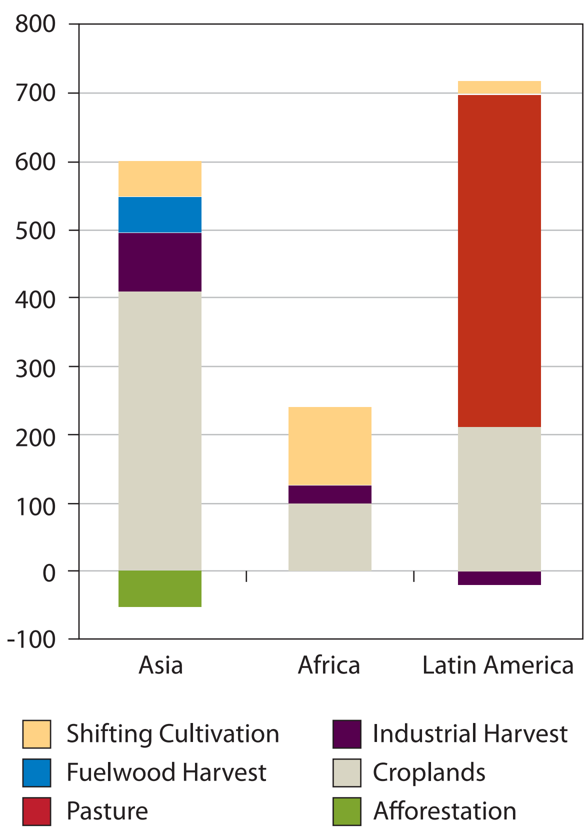
Drivers of Deforestation in Latin America

Latin America has the largest tropical forest area in the world, and has also led the world in forest clearing over the last 30 years, with about 22 million hectares cleared between 2000 and 2005. It thus had just under half of all tropical deforestation during that period (Rademaekers et al. 2010). While tropical forests stretch from Mexico in the north to Paraguay in the south, the vast majority of Latin American forests are located in the Amazon Basin, mostly in Brazil. This country is such a dominant player that from 2000 to 2005 it accounted for 3.1 million hectares of the 4.3 million deforested per year across all of Latin America (Rademaekers et al. 2010).

Much of the forest conversion and emissions from land use in Latin America over the last few decades has been due to the expansion of large-scale crop and pastureland (Houghton 2010). South America added 35 million hectares of new pasture land, almost enough to cover the entire state of Montana. Crop expansion was much smaller, with 5 million hectares of new cropland in the 1980s and 1990s. Central America, by contrast, added only a fifth of the amount of pasture but half the amount of cropland as South America during that same period, and much of this clearing is still attributed to small farmers (Rudel et al. 2009). The vast majority of agricultural land throughout Latin America came from intact tropical forests (Gibbs et al. 2010). Additionally, between 1.2 and 1.9 million hectares of forest are selectively logged annually (Asner et al. 2005).

Brazil is the world's second largest producer of both beef and soy; these industries were worth $18 billion and $13 billion, respectively, in 2008 (FAOSTAT 2010). Beef, soy, and sugar cane combined accounted for around 60 percent of Brazil's agricultural gross domestic product (GDP). Following the 2006 moratorium on soy expansion in the Amazon (see Chapter 4), pasture for cattle remains the largest driver of deforestation in the Amazon. Expansion of land used for biofuel production is expected to add increasing pressure on land in the near future (Lapola et al. 2010). Beginning in 2005, Brazil made a commitment to reduce its deforestation rate 80 percent by the year 2020. It has already made great strides toward meeting that goal—by 2010 Brazil had already reduced its deforestation rate by 67 percent while still expanding its cattle and soy production (see Chapter 10).

Figure 3.4. Sources of Carbon Emissions from Deforestation and Degradation in Tropical Regions

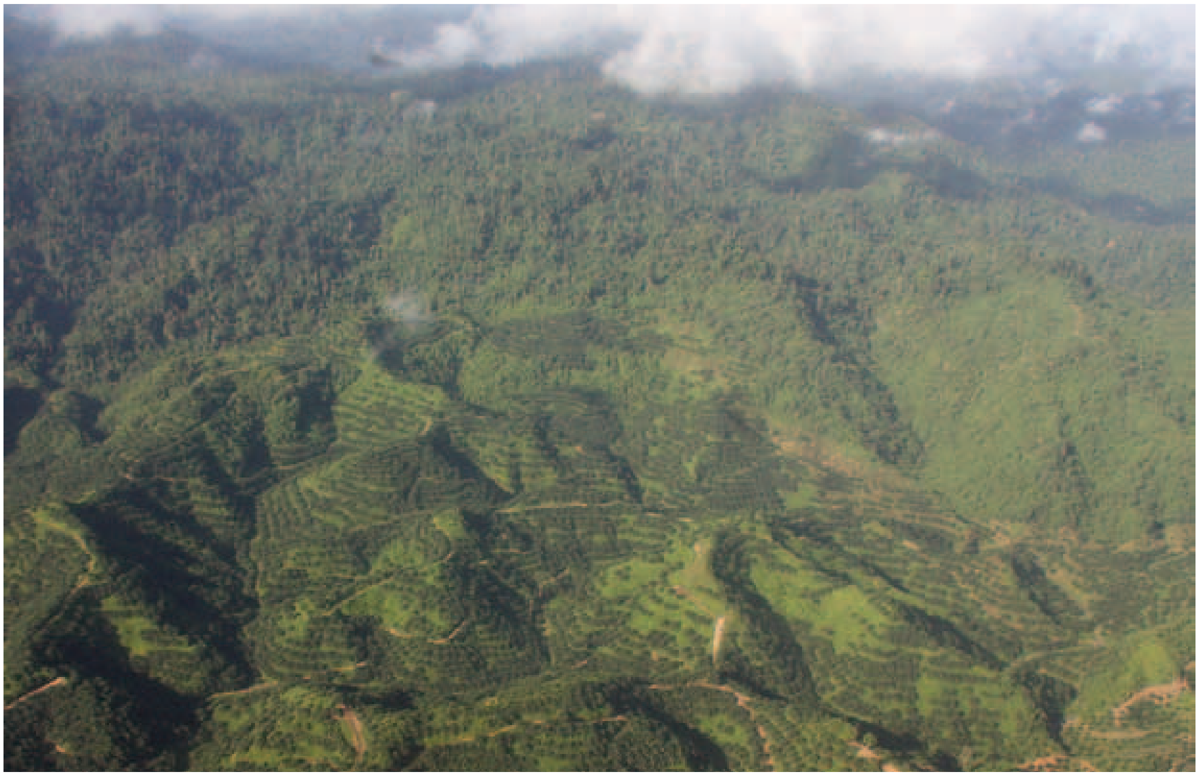


Carbon emissions from tropical deforestation and forest degradation in Asia, Africa, and Latin America averaged over the period 1990–2005. "Croplands" includes soy in Latin America and oil palm in Asia. Most timber harvesting in Asia is included in "Industrial Harvest." Units are billions of tons of carbon per year.

Source: Houghton 2010.

Drivers of Deforestation in Asia

While Asia has the smallest extent of tropical forest, it has some of the world's highest deforestation rates. From 2000 to 2005 it had the highest percentage of its tropical forests cleared of any region, at around 2.9 percent (Hansen et al. 2008). The largest part of the current deforestation in Asia is occurring in Indonesia, which cleared about 3.5 million hectares of forest between 2000 and 2005 (Hansen, Stehman, and



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In Southeast Asia, palm oil plantations drive deforestation

Potapov 2010). In fact, Indonesia and Brazil combined made up about 60 percent of the forest cleared in the humid tropics over that period (Hansen et al. 2008). Malaysia, Cambodia, and the Philippines also experienced large amounts of deforestation during that time (Rademaekers et al. 2010).

Much of the forest conversion across tropical Asia was driven by large-scale agricultural and timber plantations. Southeast Asia had over 17 million hectares of tree plantations by 2000. These plantations are mainly palm oil, rubber, coconut, and timber (especially teak). While rice and rubber still dominate continental Southeast Asia, palm oil and timber are the prevailing types of plantations on the Southeast Asian islands (Gibbs et al. 2010).

Palm oil, rubber, and coconut accounted for 20 to 30 percent of all cultivated land, and palm oil was responsible for 80 percent of expansion of Asian plantations in the 1990s (Rademaekers et al. 2010). Indonesia and Malaysia are the world's largest producers of palm oil, producing around $5 billion each year (see Chapter 6).

Drivers of Deforestation in Africa

Africa has the second largest expanse of tropical forests, but some of the lowest deforestation rates. From 2000 to 2005, about 11.5 million hectares of forest were cleared in tropical Africa (Hansen, Stehman, and Potapov 2010). Sudan, Zambia, Tanzania, Nigeria, and the Democratic Republic of Congo (DRC) had the largest areas of deforestation (Rademaekers et al. 2010). However, as mentioned above, most of these countries are covered by dry forest and savanna (the DRC is the exception); therefore, they contribute relatively little to global warming.

Given that global demand continues to grow for products that have driven deforestation in other regions, there is concern that deforestation rates will increase in African countries with large areas of forest but low deforestation rates.

Unlike Asia and Latin America, African deforestation remains dominated by small-scale processes, not by large-scale globalized agriculture (DeFries et al. 2010; Fisher 2010). Sixty percent of new agricultural land in the 1980s and 1990s came from intact forests and went mostly to small-scale and subsistence

BOX 3.2.

The Forest Transition and Displacement

The concept of forest transition links natural resource use with development (see Chapter 11). In essence, it states that a country begins with a low level of development but high level of intact forest, and begins to develop by using the resources from these forests (cutting trees for timber, clearing land for agriculture, mining minerals in forests). Forest cover declines more rapidly as the country develops. As the country's natural resources begin to wane, the economy shifts to less land-intensive activities and the deforestation rate declines. In the final stage of the process, countries begin to have increases in their forests, either because abandoned land grows back to secondary forests or due to intentional planting programs. Early-stage countries with abundant forests and low rates of deforestation are sometimes known as high forest, low deforestation (HFLD) countries (Meyfroidt, Rudel, and Lambin 2010).

The forest transition has already occurred in most developed countries, like the United States, Japan, and many European countries, and is manifesting itself in more developing countries, such as China, Vietnam, El Salvador, Gambia, and India. Programs to reduce emissions from deforestation and forest degradation (REDD+) attempt to provide incentives for deforesting countries to value their forests and conserve them. This will allow these countries to develop without overexploiting their forests and thus pass more rapidly through the forest transition.

A major concern with REDD+ and similar programs, however, is that deforesting activities will simply "leak" from current deforesting countries to HFLD countries (Meyfroidt, Rudel, and Lambin 2010). In other words, these programs might conserve forest in one country but have no overall effect on global deforestation.

farming (Gibbs et al. 2010). Small-scale timber harvesting and charcoal production also contribute to deforestation. The lack of large-scale agriculture is due in part to weak governance and limited infrastructure (Rudel et al. 2009). Given that demand continues to grow for products that have driven deforestation in other regions, there is concern that deforestation rates will increase in African countries with large areas of forest but low deforestation rates (HFLD countries).

Doug Boucher

Tropical rain forest destruction leads to the loss of diverse and vital global ecosytems

For instance, Asian timber companies have recently expanded into the Congo (Rudel et al. 2009). There is also fear that declining deforestation rates in other regions will lead to an increase in deforestation in Africa (Box 3.2).

Conclusion

This chapter highlighted the diverse types of tropical ecosystems throughout the world. Vast areas of these ecosystems are being lost each year due to deforestation. This destruction leads to the loss of diverse and vital global ecosystems, and ultimately to globally significant emissions of heat-trapping gases. This chapter also highlighted the general reasons for this loss and how it differs across regions. There are many reasons why these tropical ecosystems are threatened—from conversion to agricultural land to logging for timber. The remainder of this report delves deeper into each of the major drivers of tropical deforestation. Understanding the drivers of deforestation and their interactions with both regional and global economies will help us design sustainable ways to meet the demand for the commodities that drive deforestation, and help us conserve the precious resources that remain.

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Soybean production has
expanded into the Amazon

CHAPTER 4

Soybeans

Doug Boucher

OVER THE PAST TWO DECADES soybean cultivation in the Amazon by large, commercial farmers has undergone a dramatic transformation. In just a few years, it grew to become one of the main causes of Amazon deforestation. However, in just as short a period, the strong response of civil society resulted in a voluntary moratorium on its expansion into forests, reducing its role as a driver of deforestation. Soybean production continues to grow, but no longer at the expense of the planet's largest rain forest.

An Unusual Plant

The soybean, known to scientists as *Glycine max*, is not just a run-of-the-mill plant. Like many of the members of its family, the Leguminosae (or Fabaceae, i.e., legumes; other species in the family include peas, beans, alfalfa, acacias, and many other kinds of trees), associate with bacteria that live in their roots and take nitrogen directly from the air in the pores of the soil. This "nitrogen fixation" creates nitrogen fertilizer, and has two important consequences for legumes. First, they can grow successfully in soils that lack nitrogen (including many tropical soils) and generally do not need nitrogen fertilizer as long as the bacteria (named *Bradyrhizobium japonicum*) are present. Second, since nitrogen is the key ingredient of proteins, legumes can produce high-protein seeds.

But even among legumes, soybeans are unusual in that they also have high concentrations of energy-rich oils in their seeds. Most crop plants are specialized to produce either high protein concentrations or large amounts of energy in the form of sugars and oils. Soybeans manage to do both, by moving an extraordinary proportion of their stored nitrogen and energy from all parts of the plant into the seeds as they mature. This mobilization of reserves from the stems, leaves, and roots into the seeds is so extreme that the plant as a whole is unable to survive, dying within a few weeks, but not before producing large amounts of protein- and oil-rich seeds (Sinclair and deWit 1975). With about 40 percent protein and 20 percent vegetable oil by weight in its seeds, the soybean stands out as an extraordinary source of both protein and energy.

Although most people think of soy in terms of traditional East Asian foods like soy sauce, soy milk, tofu, tempeh, and similar dishes, most soybeans are not consumed by people, but by livestock. Chickens, pigs, and cattle eat most of the global soy crop.

Although most people think of soy in terms of traditional East Asian foods like soy sauce, soy milk, tofu, tempeh, and similar dishes, most soybeans are not consumed by people, but by livestock. Chickens, pigs, and cattle eat most of the global soy crop—not the beans themselves, but rather one of the main products that are made from them: soybean meal. Two separate products are produced by crushing the seeds and extracting the oil with solvents, thus separating the solid, protein-rich meal from the liquid, energy-rich oil.

Spreading Worldwide in the Twentieth Century

With this unusual potential, one might think that soybeans would have long been an important crop worldwide, but this is not the case. Although soybeans have been grown in East Asia for millennia, it was only in the twentieth century that they expanded in a major way to other continents and became one of the world's major crops. They first became a key crop in

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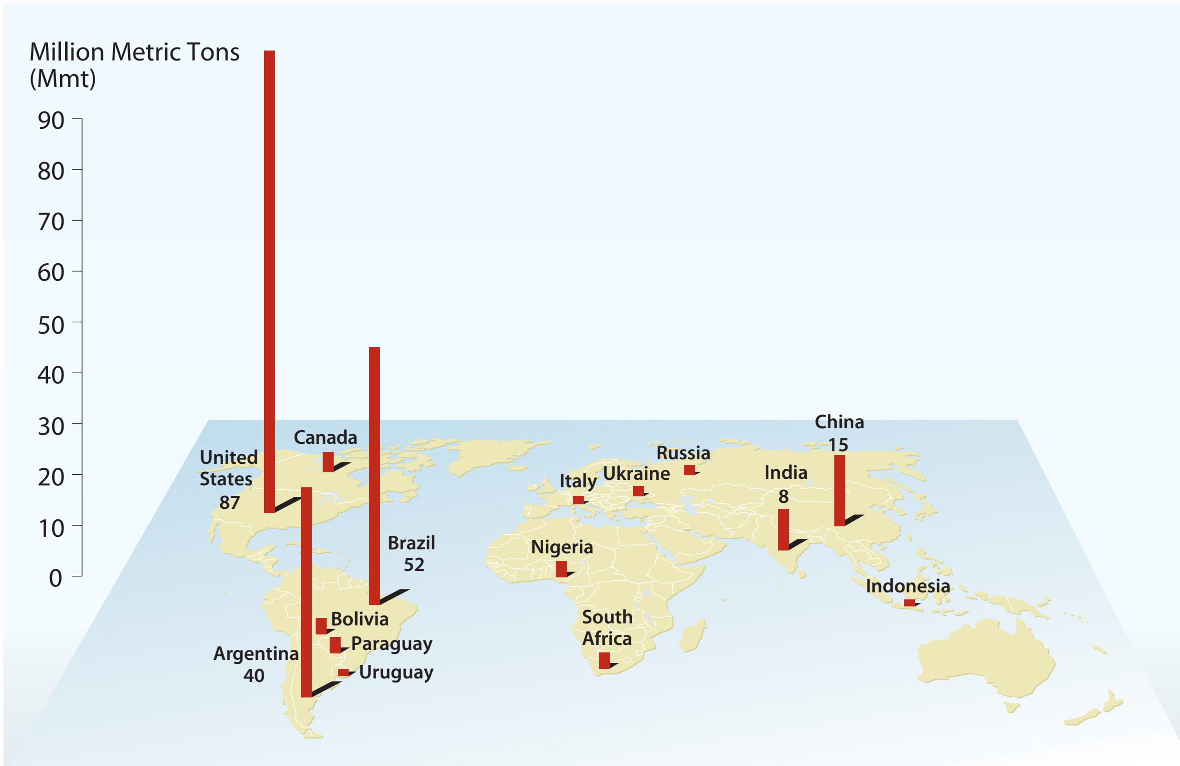
Figure 4.1. Map of Soybean Production by Country, 2006



The United States, Brazil, and Argentina dominate global production, with over 80 percent of the world's total.

Source: United Nations Environment Programme 2009, ©Philippe Rekacewicz, Paris.

the United States, now the world's leading producer with about a third of global production, only after 1910 (Figure 4.1). Often, they are alternated with corn (maize) in the American Midwest, and in warmer parts of North America they can be planted in summer after winter wheat is harvested, thus getting two crops in a single year.

Even more recent is the expansion of soybeans in South America. Up until the 1970s this was mostly in the cooler, temperate parts of the continent in southern Brazil and Argentina, and mostly in natural grasslands or areas previously cleared for cattle pasture. But with the growth of meat consumption and the collapse of the Peruvian anchovy fishery (previously an important source of fish meal for livestock feed) the world demand for alternate sources of protein meal to feed livestock made soy a profitable crop in the global market. In response, Brazilian soybean production expanded, pushing northward into the *cerrado* (see Chapter 3) (Fearnside 2001).

Initially, it was not clear whether soy production would continue moving north from the *cerrado* into the Amazon rain forest. Many tropical rain forest soils are so poor in nutrients that crop production was traditionally thought to be impossible there on a permanent basis (e.g., Greenland and Irwin 1975). In addition, only shifting cultivation was expected to maintain productivity over the long run (see Chapter 9). But starting in the 1970s, long-term experiments by Pedro Sanchez and colleagues in Yurimaguas, Peru showed that by fertilizing not only with the traditional nitrogen, phosphorus, and potassium, but also with micronutrients such as magnesium, copper, and zinc, as well as lime to reduce acidity, one could maintain continuous cultivation with two or even three crops per year over many years (Nicholaides et al. 1985; Sanchez et al. 1982). While the economic and environmental feasibility of doing this was controversial, let alone whether it should be encouraged or subsidized (Fearnside 1987), the results did show that it could be done. Ironically, although the system was developed with peasant farmers in mind, it was large-scale commercial producers who took advantage of it.

Soy Invades the Amazon

In the late 1990s, using new, humid-tropic-adapted varieties, soybean cultivation began to enter the Amazon forest in earnest, growing by 15 percent a year for several years (Nepstad, Stickler, and Almeida 2006). Large farms were cut out of forested areas, often using heavy machinery such as bulldozers for rapid clearing, and soybeans were put into production with substantial amounts of fertilizers and pesticides. While the phrase "growing exponentially" is often misused to mean simply "rapidly," in this case it does apply: from just 9.7 million hectares in 1990, Brazil's soybean area grew to 13.9 million hectares in 2000 and 24.2 million hectares in 2010 (Figure 4.2). Production grew even faster, from 15.8 million tons in 1990 to 39.5 million tons in 2000 to 67.5 million tons in 2010. As a result, Brazil not only increased its livestock production and its per capita meat consumption, but also quickly became a major player in the world trade in oilseeds. Soy exports grew more than tenfold in 20 years, from 2.5 million tons in 1990 to 31.4 million tons by 2010.

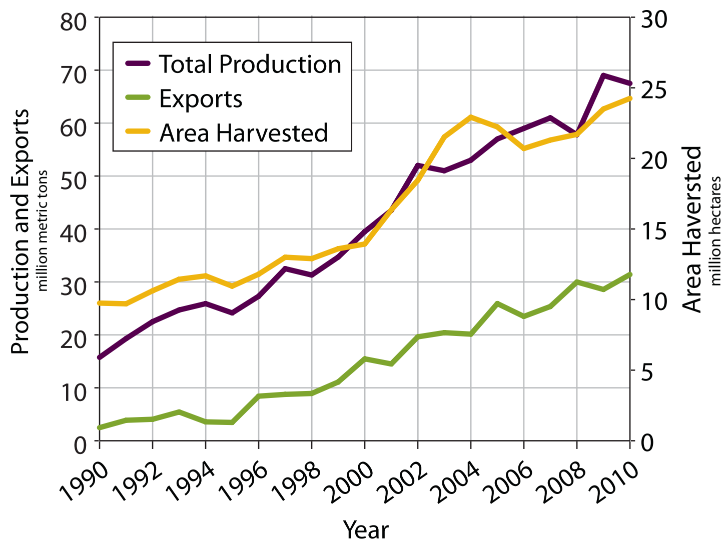
This rapid growth changed the dynamics of deforestation in the southern Amazon in a fundamental way. Deforestation in the Amazon was used to create cattle pasture for several decades, but at the peak of deforestation rates in the early 2000s, soybean expansion was responsible for nearly one-fourth of it (Morton et al. 2006). Additionally, there may have been indirect effects, so that as soybean expansion took over *cerrado* lands farther south, it pushed cattle pastures northward into the rain forest in the state of Mato Grosso, Brazil (see Chapter 5) (Barona et al. 2010).

The new soybean farms were large, with some reaching thousands of hectares in size. In Mato Grosso, where the soybean expansion was heavily concentrated, clearings for soybean planting were more than twice as large as those for pasture. Soybean producers were heavily capitalized, using bulldozers to clear land and tractors and combines to cultivate it. Clearing had to be quite complete in order to use machinery; while cattle can graze around recently-felled trees, leaving stumps or woody debris in crop fields would risk damaging combines and planters.

Farmers relied on fertilizers to supply nutrients and pesticides to control diseases, weeds, and insects. Sometimes rice was planted for the initial year or two before switching over to soy. In some cases a crop of corn would be put into the rotation every three years or so, but most of the acreage was simply monoculture soybeans (Morton et al. 2006). Although soybeans can be produced successfully in the tropics by small farmers, as shown by development projects in southern Africa (Giller et al. 2011), in the Amazon it was overwhelmingly done by big farmers.

As one would expect with the expansion of such a highly commercialized business into the forest, deforestation followed prices. Over several years, Brazilian

Figure 4.2. Brazilian Soybean Production, Harvested Area, and Exports, 1990–2010



Crop years overlap two calendar years, from the middle of one year to the middle of the next, since soybeans are almost all produced in the Southern Hemisphere's wet season (November to May).

Source: FAS 2011.

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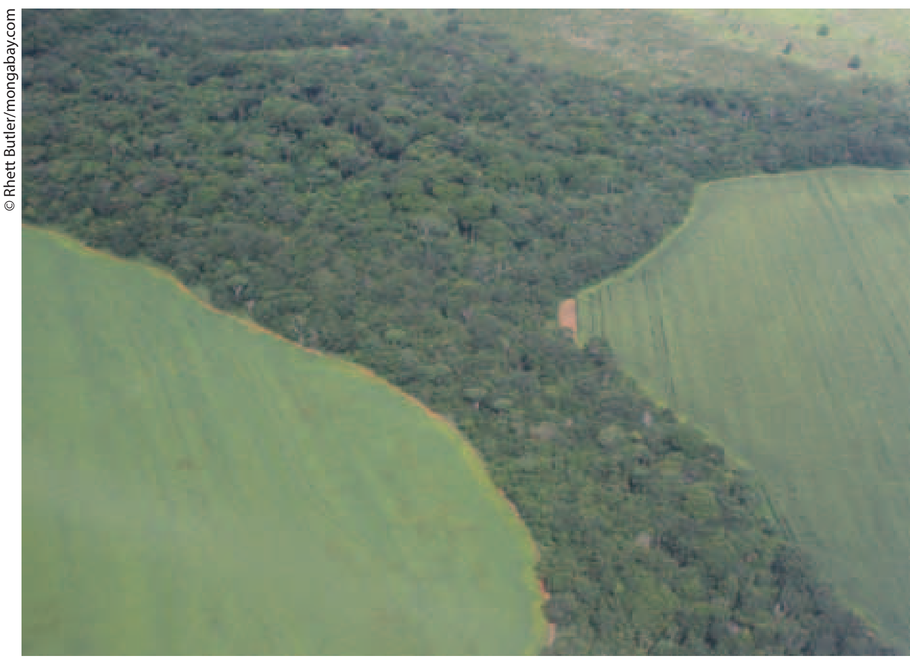

Large-scale soybean production on land cleared from tropical rain forest in Brazil

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Soybean fields

deforestation mirrored the swings in world soy prices, with rapid deforestation in years such as 2003 and 2004 when prices were high. Transportation was also important, with new highways connecting soybean farms to domestic markets in southern Brazil and to the new deep-water ports of Itacoatieara on the Madeira River and Santarém on the lower Amazon River (Nepstad, Stickler, and Almeida 2006). In fact, soy expansion provided the justification for highway construction, especially the new north-south BR-163 from the already-cleared south to Santarem. Deforestation in the Amazon had become "teleconnected," through globalized markets, with expanding chicken, pork, and beef production in Europe and China (Morton et al. 2006; Nepstad, Stickler, and Almeida 2006). By 2005, Brazil was the largest soybean exporter in the world.

Environmentalists Raise the Alarm

As soybean production expanded, academics and environmentalists began to point out the growing threat to the rain forest (Fearnside 2001; Carvalho 1999). Initially there was little response, and deforestation continued unabated, reaching a record level (27,329 square kilometers, or over 6.75 million acres annually) in the 2003/2004 crop year. But over time, there was growing criticism of the policies and institutions that were promoting soybean expansion at the expense of biodiversity, equitable development, and Earth's climate, both in and beyond Brazil.

A critical turning point came in early 2006, with the release of Greenpeace's report *Eating Up the Amazon*. The report linked the soybean industry to deforestation, global warming, water pollution, and even the use of slave labor to clear land. It focused particularly on two multi-national companies: the giant grain trader and exporter Cargill and the world's largest fast food chain, McDonald's (Greenpeace International 2006).

Now that the Brazilian soybean moratorium has been in place for nearly five years, it is possible for scientists to evaluate the effectiveness of the moratorium, and the data show that it has been remarkably successful.

Cargill issued a five-page defense of its actions, but also announced, "In a groundbreaking move, we have informed our suppliers and local officials that, beginning with the next crop, Cargill will only purchase soy from those producers who are in compliance with the Forest Code [which requires farmers to maintain 80 percent of their land in forest if they are in the Amazon basin] or actively working toward full compliance" (Cargill 2006). McDonald's, its reputation still damaged by the "McLibel" trial in Great Britain, in which it had sued its critics and lost, was similarly motivated to try to resolve the issue rapidly.

The Soy Moratorium

Action came within weeks. The two associations that bring together nearly all soybean processors and exporters in Brazil, the Brazilian Association of Vegetable Oil Industries (ABIOVE) and the National Association of Cereal Exporters (ANEC), announced a moratorium on deforestation. Their members would not buy any soybeans produced on any Amazon farmland deforested after June 24, 2006. Initially the moratorium was for one year, but it has been renewed and enforcement improved (by overlaying detailed satellite images of deforestation and soybean fields) each year since (Rudorff et al. 2011).

Now that it has been in place for nearly five years, it is possible for scientists to evaluate the effectiveness of the moratorium, and the data show that it has been remarkably successful. Although questions have been raised about Cargill's performance (Nature Editorial 2011), by comparing the satellite images showing deforestation with views of the same areas in subsequent years, Rudorff et al. (2011) found that by the 2009/2010 crop year, only 0.25 percent of land with soybean crops had been planted in deforested areas since the moratorium began. These fields represented only 0.04 percent of the total soybean area in Brazil. Furthermore, the use of remote sensing to monitor soybean plantings and deforestation beginning in 2009 has increased the area monitored while decreasing the need for costly, weather-dependent, regionally limiting airplane flyovers.

The Industry Continues to Grow

Despite no longer being able to expand onto deforested land, the Brazilian soybean industry remains healthy. Driven by a new price spike, the total crop in 2009/2010 was a record and the forecast for 2010/2011, driven by good weather, was for a 10 percent increase

Most of the global soybean crop is used as livestock feed

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from that level (Caminada 2011). The area in soybeans continues to grow (Figure 4.2) but no longer at the expense of forests. More of the growth in recent years has been due to increases in production per unit of land (yields) rather than expanding area (Union of Concerned Scientists analysis of data from FAS 2011).

However, this is likely to reverse in future years. Brazilian (and Argentinian and Bolivian) soybean yields have grown so rapidly that the soybean "yield gap" between Brazil and the United States (where productivity is highest) has become small (Licker et al. 2010). Thus the potential gain from "catching up" is reduced, and future yield increases are more likely to be similar to those in the United States and other high-productivity regions.

Currently, the United States and Brazil each produce just under a third of the world's soybeans, with Argentina adding an additional fifth. These three countries make up 80 percent of world production, and overwhelmingly dominate the world soybean trade. As demand grows, if soybean production is prevented from expanding into new Amazon forestland in Brazil (and in Bolivia's Santa Cruz region, which accounts for about 0.7 percent of world production), the "leakage" is likely to be to non-forest areas of the United States, Argentina, and elsewhere in Brazil. China, which currently produces only 7 percent of the world's soybeans but is a major importer for its growing livestock industry, may also produce more if Brazilian export growth slows.

Soy Biodiesel

Biodiesel is fuel produced by alcohols reacting with fatty acids from plant or animal sources. Those sources can include palm oil, canola, peanuts, the jatropha plant, and waste animal fat, as well as soybeans. While not used as a fuel for cars or trucks as extensively as ethanol (which can be mixed with or even substituted for gasoline), it is a possible future driver of crop production expansion, and thus of potential deforestation.

Most biodiesel produced in the United States—about 700 million gallons annually compared with 9 billion gallons of corn ethanol—comes from soybeans (Martin 2010). However, in tropical countries palm oil, which yields nearly 10 times as much biodiesel per hectare as soybeans (Brown 2006), is likely to be a more competitive alternative. Even in Brazil, where there are high yields from soybeans and much of the necessary infrastructure already exists, it is not clear that increased

BOX 4.1.

From the Amazon to Your Gas Pump

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Biofuels are becoming more available at gas stations across the United States

Biofuels are often presented as both a solution to global warming and a way to reduce dependence on oil. Governments around the world promote biofuels through mandates that require a certain percentage of fuel to come from renewable resources, as well as tax incentives and other policies. However, to really understand how biofuels affect the environment, one must look past the pump to how biofuels are reshaping agriculture on a global scale (Martin 2010).

In the United States, production of corn ethanol has grown from less than 10 percent of the U.S. corn crop to more than a third today (USDA 2009). This increased demand for corn in the United States leads to increased prices for corn, soybeans, and other crops that compete with corn for land. Because these crops are traded in a global marketplace, changes in biofuel policy in the United States drive up crop prices around the world, accelerating the conversion of forest into agriculture in Brazil and elsewhere (Searchinger 2008).

Corn, soybeans, and even the residue left behind after corn is transformed into ethanol are used as animal feed. Understanding the impact of biofuels on tropical forests requires understanding these linked global markets and how they influence tropical deforestation in the Amazon. Government regulators in the United States and the European Union are working to ensure that biofuels do not lead to the loss of Amazonian forests in exchange for fuel.

Cleared land and soybean fields in Brazil

Jeremy Martin

Soybean processing plant in Brazil

Jeremy Martin

world demand for biodiesel would drive soybean cultivation since palm oil is more productive. Of course, palm oil is another important driver of deforestation (see Chapter 6), so the fact that it is likely to surpass soy as a tropical biodiesel source is not good news for those wanting to protect the forests.

Soy's Future as a Driver of Tropical Deforestation

The case of soy shows how quickly a new source of economic pressure for deforestation can arise and how this pressure can be reduced to very low levels. Some parts of the success story are unique to soy: for example, the overwhelming importance of one country, Brazil (and indeed, of one state within Brazil, Mato Grosso). Once an effective moratorium was in place in a limited region of the globe, the role of soy expansion as a driver of tropical deforestation was greatly diminished. Also, the concentration of the industry in Brazil, with strong control over exports by just a few companies and associations, made it possible for things to change rapidly once these actors decided to move.

What remains in doubt is whether the industry will stop expanding in all areas where it would damage biodiversity. Soy has had a major impact on the *cerrado*, both directly and by displacing cattle pasture from that region northward into the Amazon. While some parts of the *cerrado* are now low-diversity grassland and pasture, others have very high diversity and appreciable stores of carbon (see Chapter 3). These areas are not as spectacular as the rain forest, but from a conservation point of view they are still very valuable (Fearnside 2001). Brazil has committed to reducing deforestation by 40 percent in the *cerrado* as well as 80 percent in the Amazon, but much of the *cerrado* is already cleared.

Nonetheless, soy shows how a rapidly expanding agricultural export industry can continue growing without deforestation. Through a combination of yield increases and use of other lands, the "need" for deforested land can be eliminated. The case is also instructive because it shows how industry can be influenced by societal pressure to commit to zero deforestation and set up an effective technology-based system to enforce it. While the moratorium is not yet permanent, with every year that it continues it reinforces the message that development without deforestation is possible, desirable, and even profitable.

Commercial soybean fields in Brazil

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CHAPTER 5

Cattle and Pasture

Doug Boucher

COMPARED WITH OTHER FORMS of agriculture, cattle production is a fundamentally different way of producing our food. Unlike fruits and vegetables, which people eat directly, beef (and other meat) is produced in a two-step process: plants feed cattle and then their meat and milk feed humans. Beef production also differs from the other two principal kinds of livestock—pigs and chickens—because it mostly uses pasture or harvested forage crops like alfalfa instead of grain crops to feed the cattle. These features explain how cattle pasture has become the main driver of deforestation in Latin America in recent years.

Rumens and Pastures

Cattle are able to eat pasture grasses, which are inedible to humans and most other animals, because of their unique digestive system. As *ruminants*, cattle have a stomach called a *rumen* that contains a collection of beneficial bacteria and other microbes that can break down cellulose. This abundant molecule in plants has a complex chemical structure that makes it difficult for most animals to digest.

With the aid of their ruminant bacteria, however, cattle (and other ruminants such as sheep, goats, deer, and llamas) can break down most cellulose and extract its energy. This allows them to grow on a grass diet, although they grow even faster with protein sources (e.g., soy meal) and grain (e.g., maize). The ability to digest cellulose means that cattle can graze on many kinds of "rangelands," including some that could not produce appreciable amounts of crops because the climate is too dry, the soil is infertile, etc. So, cattle can turn large amounts of inedible plant matter into edible meat and milk (Herrero et al. 2009).

There is a cost, however, and it can be a very large one. This conversion of grass to beef is quite inefficient, and only about 2 percent of what cattle eat ends up as meat that people can consume. Thus, even in the European Union, where productivity is relatively high, it takes about nine hectares of permanent pasture plus about three hectares of cropland to produce one ton of meat. This compares with less than one hectare of cropland to produce one ton of poultry or pork (Wirsenius, Hedenus, and Mohlin 2010).

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Using cattle to produce food for humans is inherently *extensive*, meaning it requires large amounts of land to generate relatively small amounts of food. Supplementing pasture with feed grains and legumes can reduce the amount of land needed, even taking into account the land where feed is grown. However, the process still requires much more land than the alternatives—not only plant-based foods but also other animal products such as chicken, eggs, and pork (Wirsenius, Hedenus, and Mohlin 2010).

The result is that about 70 percent of the land used for agriculture globally is pasture (3.4 billion out of 4.9 billion hectares) (Steinfeld et al. 2010) (see Chapter 3). However, only about 33 percent of the protein and 17 percent of the calories consumed by humans come from animals (Herrero et al. 2009). Of that amount over two-thirds comes from pigs and poultry, not from pasture-fed ruminants (Chapters 6 and 12 in Steinfeld et al.

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2010). Thus just 6 to 11 percent of humanity's food comes from those pastures that make up 70 percent of the agricultural lands we use.

Cattle Colonize the Americas

While cattle are not native to the New World, they were introduced by the Spanish within a few years of 1492 and have been an important part of the humanized landscape of the Americas for centuries (Crosby 1986/2004). Much of the Pacific coast of Mexico, Central America, and South America, as well as the temperate grasslands of Argentina, was converted to cattle pasture early on, but large-scale expansion into the tropical forest lowlands is a more recent phenomenon.

In Central America this expansion occurred as part of the push into the wet eastern coast of the isthmus from the long-settled and drier western coast, and did not begin until the latter half of the twentieth century. In South America it involved movement into the Amazon lowlands from all sides—south from Venezuela and Colombia, east from Ecuador and Peru, and north from Bolivia—but most intensively and rapidly in Brazil, where cattle production moved from the long-settled southern part of the country northward and westward into Amazonia. As with soybeans (see Chapter 4), the most dramatic changes in Brazil have occurred in just the past few decades.

Export-led Expansion in Brazil

Under the military dictatorship in the 1960s and 1970s, Brazil's development of the Amazon was promoted and subsidized, and the cattle industry began to penetrate into the region. However, the cattle boom really took off in the 1990s, driven by growth in exports (Nepstad, Stickler, and Almeida 2006). This was favored by changes in currency exchange rates. Then in the 2000s the elimination of foot-and-mouth disease, which formerly prevented shipments of beef from Amazon states overseas, permitted a further increase in exports (Kaimowitz et al. 2004). While domestic beef consumption grew slightly, the big jump was in exports, which increased seven-fold in a decade. A fourth of Brazil's beef production now comes from the Amazon; the country is the largest beef exporter in the world (Cederberg et al. 2011).

As new land was converted to pasture in the Amazon, in the south pastures were converted to crops or abandoned so that Brazil's pasture area hardly increased

The Amazon rain forest is being cleared to make room for cattle

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Deforested cattle pasture in Guatemala

above the level reached in the mid-1970s. The economic advantage of the move northward was not because the Amazon lands were better pastures. In fact, cattle productivity (carcass weight/hectare/year) in the Amazon was more than 40 percent less than the national average in 1996, and was still 30 percent less a decade later (Cederberg et al. 2011). But the cost of land was much lower in the north, so it still made economic sense to expand there (Kaimowitz et al. 2004).

Cattle Consume the Forest

While cattle pasture previously required little new clearing of forest as it expanded into savannas, temperate grasslands, or long-deforested areas in southern Brazil, in the Amazon the forest was in the way. Thus the expansion northward led to large-scale deforestation. Usually the forest was cleared and burned, with very little of the timber used (Kaimowitz et al. 2004). The point was to clear the land, and the trees were simply an obstacle to be removed. With the clearing of forest increasing the value of the land five- to ten-fold, cattle ranching in the Amazon could be profitable even though productivity was low (McAlpine et al. 2009).

The result was widespread deforestation as the industry moved into the rain forest. At both the state and municipal levels, deforestation correlated with the growth of the cattle herd (Kaimowitz et al. 2004). While sometimes the transition to pasture would pass through an intermediate cropping stage for a few years, and pasture might later be abandoned and begin changing back to secondary forest, overall the trend was strongly from forest to pasture (Cederberg et al. 2011; Ramankutty et al. 2006; Fearnside 1997). Although soy became an important driver for a certain number of years (see Chapter 4), pasture was by far the predominant new land use in the deforested region, occupying over 85 percent of the agricultural land in the "legal" Amazon (Kaimowitz et al. 2004).

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The Role of Fire

Fire is a key component of deforestation for pasture. Land clearing is concentrated overwhelmingly in the dry season in tropical forest regions, particularly in the wetter regions. Thus in the "arc of deforestation" along the southern edge of Amazonia, most forest clearing takes place during the dry season between June and November when the cut logs and branches can be burned after clearing. This initial clearing and burning leads to the loss of half or more of the forest's carbon (Chapter 5 in Steinfeld et al. 2010).

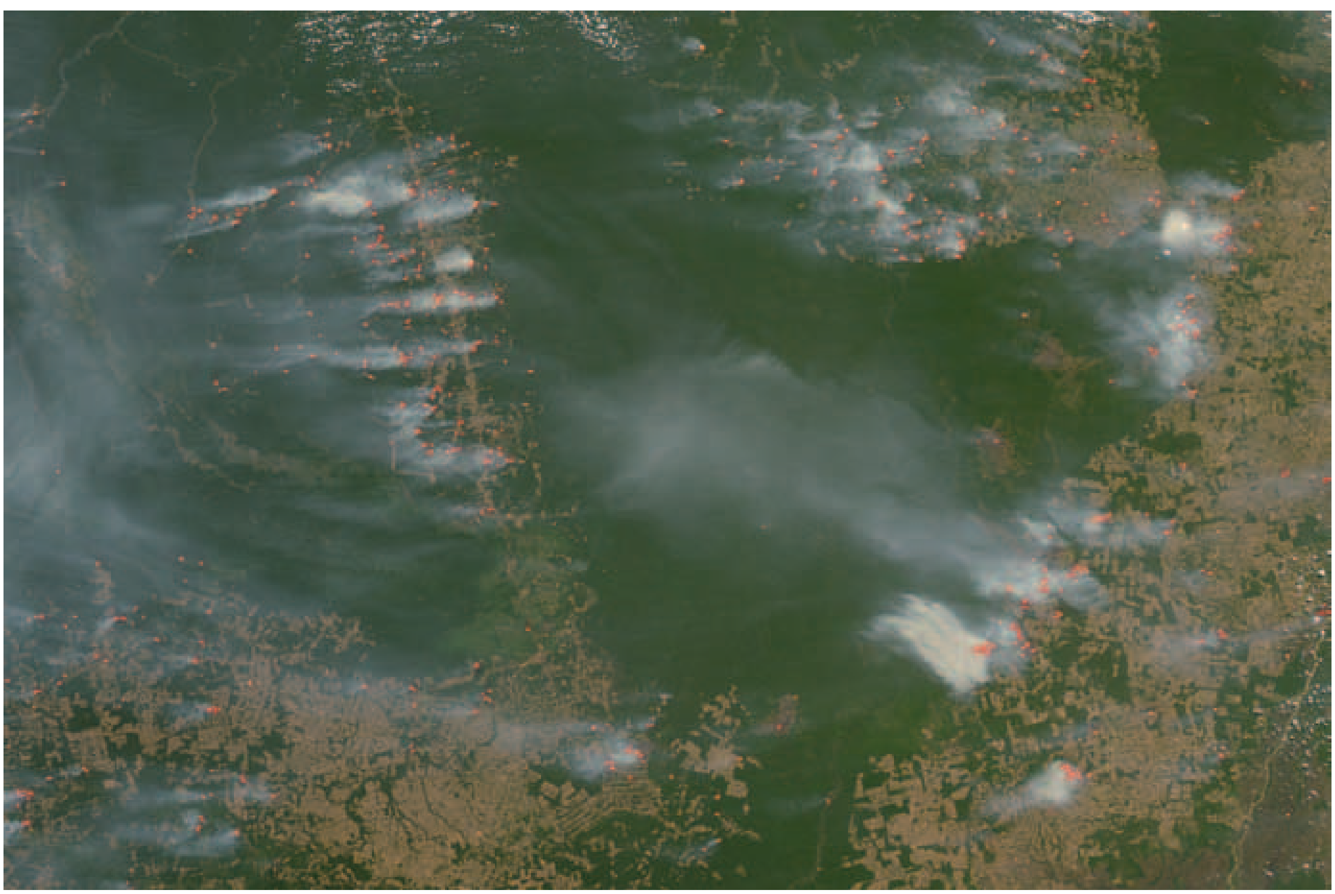
However, burning continues in subsequent years, since fires are an effective way to stimulate continued pasture growth during the dry season. Normally the productivity of pasture grasses slows greatly as the rains diminish, but burning helps them re-sprout from the roots and thus produce a new supply of tender shoots at a critical time. It also helps maintain the pasture by killing weeds, as well as the saplings of trees and shrubs that would otherwise colonize and eventually shade out the grass.

These repeated dry season fires tend to cause a net loss of additional carbon from the system, as well as other nutrients. This results in continued emissions of carbon dioxide, promoting global warming. It also causes losses of nitrogen and other nutrients from the soil (Chapter 5 in Steinfeld et al. 2010). Over the long term, the productivity of pasture declines and it may eventually need to be abandoned.

A Low-Productivity Industry

While the Brazilian cattle industry showed the same pattern of rapid export-driven expansion northward into the Amazon as the soybean industry (see Chapter 4), it was quite different in some important ways (Morton et al. 2006). Unlike soy, cattle production was extensive rather than intensive, with low levels of investment per hectare, frequent abandonment of the cleared land, and a low level of productivity. As soybean production entered an area, it would often displace cattle ranching farther into the forest, since the potential profits were considerably greater from soy for those who could make the necessary investments (Barona et al. 2010).

Amazon cattle ranchers used the land wastefully, even compared with their compatriots farther south. Stocking rates (animals per hectare) were low, and slow growth rates of the animals led to low rates of meat production per year as well as per hectare (McAlpine



Jesse Allen, NASA Earth Observatory Collection

Satellite photo showing fires set to clear forest in the Amazon et al. 2009). Supplemental feeding with energy-rich grains and protein meal was rare, despite the boom in soybean production in the same region. Pastures were seldom improved with legumes and hardly ever fertilized; abandoning them and clearing new areas from forest was more profitable. With the prevailing abandonment rates in the 1990s, barely half of the cleared land would remain in production over the long term (Cederberg et al. 2011). Employment levels in ranching were low, and ownership was highly concentrated

The rising Brazilian environmental movement pushed not only for strong government action, but also for direct steps by the cattle industry at all points along the supply chain.

in a small number of owners. All in all, the cattle industry was based on using small amounts of capital and labor combined with the large extensions of cheap land that could be obtained by clearing the forest. That, plus the rapid growth of export demand, was enough to make it profitable.

Pressure Builds on the Industry

With the growth of the environmental and social movements in Brazil in the 2000s and the commitment of the new government of Luis Inacio Lula da Silva to reduce deforestation, a more skeptical view of the industry as the principal agent of deforestation was inevitable. However, for the first several years of Lula's administration (beginning in 2003), actions to reduce deforestation emphasized the creation of protected areas and recognition of indigenous lands, as well as enforcement actions against illegal logging. These steps did in fact bring down the deforestation rate substantially (Ricketts et al. 2010). Additionally, the rising Brazilian environmental movement pushed not only for strong government action, but also for direct steps by the cattle industry at all points along the supply chain.

With the publication of two widely publicized reports by Brazilian non-governmental organizations (NGOs) in April and June 2009, the pressure became irresistible. Amigos da Terra Amazonia Brasileira's *Time to Pay the Bill* and Greenpeace's *Slaughtering the Amazon* (Amigos da Terra 2009; Greenpeace 2009) showed how cattle pasture creation played an overwhelming role in destroying the Amazon forest. The reports placed the responsibility not only on the ranchers, but on the banks that financed deforestation, the slaughterhouses that bought the meat, the exporters that shipped it abroad, and the government policies that directly and indirectly subsidized the whole process. As with the soybean industry three years before (Rudorff et al. 2011), these two organizations demanded a moratorium on deforestation, calling for players throughout the supply chain to take action.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Soybean production often displaces cattle ranching further into the forest

The Beef Moratorium

While ranchers objected loudly, the other parts of the export supply chain, recognizing their vulnerability to bad publicity, quickly realized that they needed to deal with the controversy. The action of the World Bank, which quickly canceled its loan for Amazon expansion by Bertin, S.A.—Brazil's largest beef exporter and the second largest in the world—showed the financial risk. Within days, major supermarket chains in Brazil announced they were suspending purchases of beef from Bertin.

Because slaughtering, packing, distributing, and exporting were concentrated within a small number of large businesses, it was clear that deforestation could be stopped through purchasing power. So in July 2009, the major slaughterhouses and distributors announced they would refuse to buy cattle from any ranch that expanded its pasture at the expense of the forest.

Enforcement was based on overlaying the boundaries of each ranch (its "polygon") with the satellite photos showing deforestation, which are made public on the Web by the Brazilian National Space Research Institute, INPE. Either a ranch would have to provide the polygon information to the slaughterhouse or (since boundaries of some ranches are poorly delimited, and ranchers are often reluctant to share this information even when they have it for fear of government action against them) demonstrate that it was located at least 10 km away from any deforestation area.

It is too early to assess the success of the Brazilian beef moratorium, which only went into effect two years ago. However, the success of the soy moratorium, operating in the same region and enforced using similar satellite technology, is an indication that the same approach can work with beef.

Other related industries have now been brought into the beef moratorium. For example, leather from the hides of Amazon cattle is also exported, and can end up in products like shoes, handbags, and cars. This is not as important as beef as an economic driver of pasture expansion—the hides are relatively low in quality and only worth selling as a by-product of beef—but it

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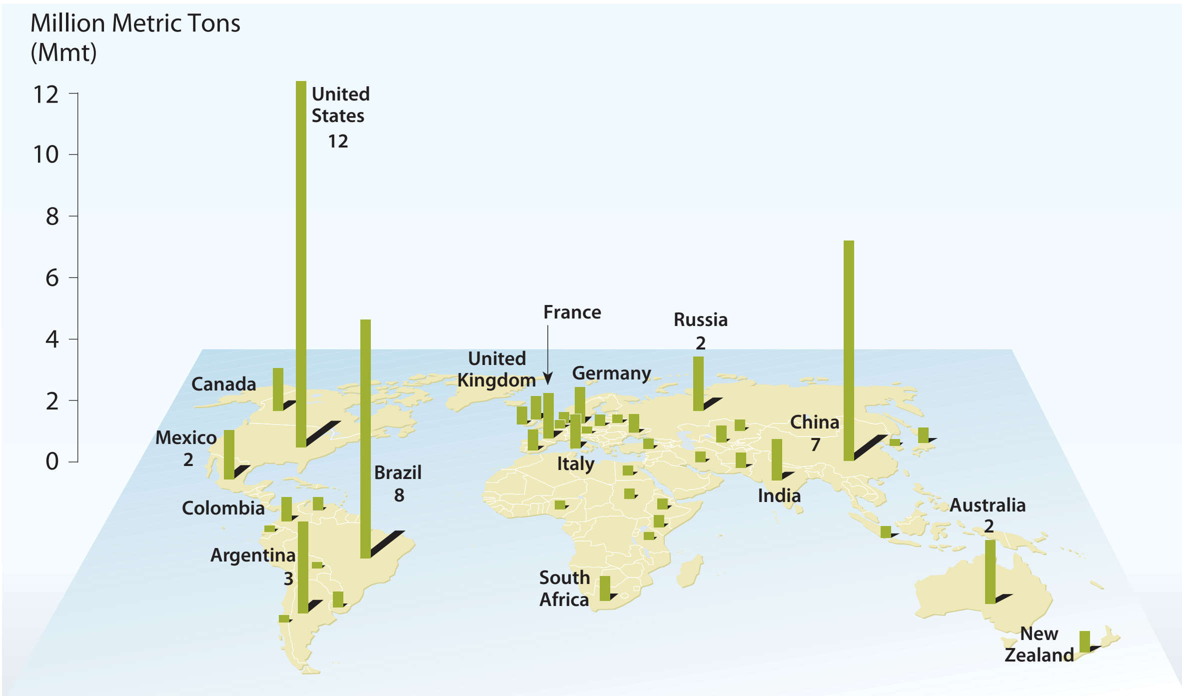
Aerial view of cattle in the Brazilian Amazon

Figure 5.1. Map of Beef Production by Country, 2006



Among tropical forest countries, only Brazil has a substantial share of global production.

Source: United Nations Environment Programme 2009, ©Philippe Rekacewicz, Paris.

does provide some additional income to ranches. Thus, NGOs such as the National Wildlife Federation have been working with leather companies to ensure that none of their products come from pastures created by deforesting the Amazon rain forest.

There are also other products from Brazilian cattle, but they are of minor importance in relation to deforestation. The country's milk and dairy products come almost exclusively from the cooler areas in the south, not from the Amazon. Beef tallow and waste products from slaughterhouses can be used to create biodiesel fuels, but this is only done in tiny amounts, and nearly all of Brazil's biofuel is in the form of ethanol derived from sugar cane.

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Other Countries

This chapter has concentrated on the Brazilian Amazon because it is the best-studied example of pasture expansion as a driver of deforestation, and because it is the cause of much more forest loss than in any other country (Figure 5.1). Wassenaar et al. (2007) estimated that 17 million hectares of forest would be lost to pasture in Brazil over the first decade of the 2000s; the estimate for the next largest country was Colombia at only 3.4 million hectares, followed by Bolivia and Peru at 1.5 million hectares each.

In Colombia, as in Brazil, cattle pasture expansion has played the leading role in tropical deforestation, with crops occupying only a small proportion of cleared land (Etter et al. 2006). Production has been extensive and productivity low, and until recently export to the United States and Central America was prohibited because of foot-and-mouth disease (McAlpine et al. 2009). Cattle were introduced into savanna areas such as the *llanos* many decades ago but only recently have moved farther southeast and entered the forested lowlands of the Orinoco and Amazon in large numbers. Once deforestation begins in an area it tends to proceed rapidly, with forest cover declining from 85 percent to below 20 percent in the space of 15 years (Etter et al. 2006). While showing some of the same patterns as Brazil, pasture-driven deforestation in

Colombia has differed in that the influence of the export market has been small and there has been no beef moratorium yet. Furthermore, deforestation seems to follow the rivers rather than expansion of the road network (Armenteras et al. 2006).

The cattle industry has also been a principal driver of deforestation in other Latin American countries, with exports being important in some (as in Brazil) but minor in others (as in Colombia). In the Amazon, where almost all of the remaining forest is found, there is some indication that its importance increased from the 1980s to the 1990s, while in Central America the reverse trend may have occurred (Rudel et al. 2009).

The extensive nature and low productivity of tropical pasture-based beef production is an underlying reason why it can be an important driver of deforestation, but it also suggests an alternative future: increasing production by increasing productivity per hectare.

In contrast to its overwhelming role in the Americas, cattle ranching is not an important driver of deforestation in Africa and Asia (Rudel et al. 2009) despite the fact that some Old World regions have high densities of cattle, such as East Africa and South Asia (Figure 9-1 in Steinfeld et al. 2010). This is partly due to their extensive grasslands. In India, the trend has actually been one of major reforestation rather than deforestation. It is worth mentioning that, despite the well-known fact that Hinduism prohibits eating "sacred cows," the subcontinent's cattle herd is a vital source of both dairy products and power for plowing and transport (Harris 1966).

Cattle Pasture and Future Deforestation

The extensive nature and low productivity of tropical pasture-based beef production is an underlying reason why it can be an important driver of deforestation, but it also suggests an alternative future: increasing production by increasing productivity per hectare. There is certainly a great deal of room for improvements such as higher stocking rates, more productive pastures, rotational grazing, and breeds better adapted to tropical conditions (Steinfeld et al. 2010; Herrero et al. 2009). Some of this kind of improvement has already taken place in Brazil, with ranchers planting legumes and higher-quality grasses to improve pasture and finding ways to increase stockings (maintaining more head of cattle per hectare).

Such changes are generally referred to as "intensification," meaning using less land. On the other hand, "intensification" is often taken to mean the use of more inputs such as feed grains and protein supplements, or concentration of animals in CAFOs (confined animal feeding operations). When used this way it raises many questions concerning its environmental and social impacts (Gurian-Sherman 2011; Steinfeld et al. 2010; Herrero et al. 2009; Gurian-Sherman 2008). Furthermore, there is a fundamental issue regarding whether feeding grain and soy to cattle is the best way to produce protein for people. Even without considering vegetarian alternatives or comparing health effects, the big difference in the efficiency of pigs and chickens versus beef cattle as producers of meat suggests that encouraging less consumption of beef and more pork and poultry would be a better approach (see Chapter 2) (Wirsenius, Hedenus, and Mohlin 2010; Steinfeld et al. 2010).

But even in the short term the encouraging initial results of the beef moratorium in Brazil suggest that deforestation due to pasture expansion can be stopped without waiting for major changes in diets or production systems. Deforestation has dropped to record low levels in Brazil despite major spikes in world food prices and continued steady growth of both the country's cattle herd and its beef exports (Boucher 2011). Combined with the example of nations in the Old World in which large cattle herds are not driving deforestation, this suggests that although pasture expansion has been a major driver of deforestation in the past, it does not have to be in the future.

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Harvested palm oil fruits

CHAPTER 6

Palm Oil

Earl Saxon and Sarah Roquemore

PALM OIL PRODUCTION HAS MORE than doubled in the last decade, now dominating the global market for vegetable oil (FAO 2011). Most palm oil is produced on large industrial plantations, driving tropical deforestation in Indonesia and Malaysia. The harvested area of palm oil in Southeast Asia has tripled in just a decade. In Indonesia, palm oil area grew by 11.5 percent annually from 1997 to 2000, and by 15.8 percent annually from 2000 to 2007 (Figure 6.1). To a much lesser extent, palm oil production also occurs in a few South Asian, South American, and West African countries (Figure 6.2, p. 52).

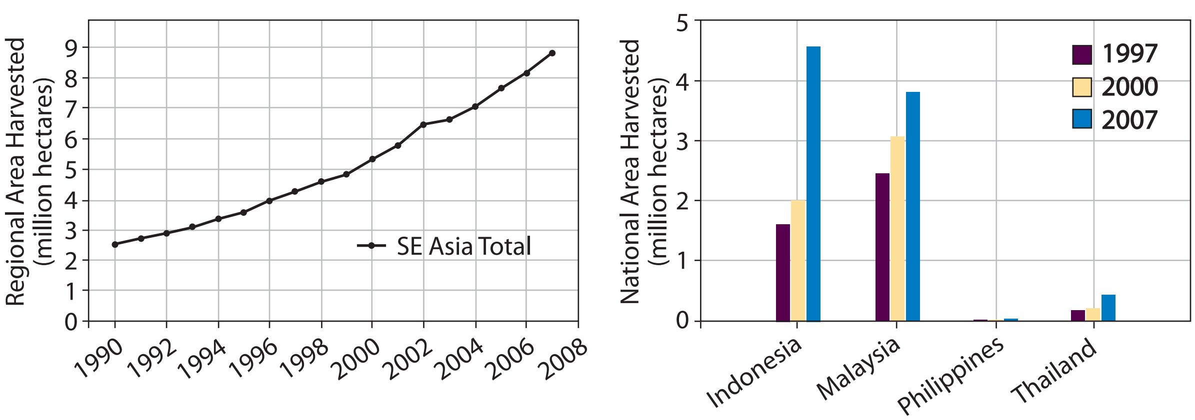
Though palm oil plantations represent a limited proportion of global deforestation in terms of area, they are a disproportionately large source of global warming emissions because they are often established on land converted from swamp forests. When these wetlands are drained, their carbon-rich peaty soils decay, releasing large amounts of both carbon dioxide and methane. Thus the expansion of plantations onto peat soils is an important source of the emissions that cause global warming.

Cultivated palm trees produce a high yield of oil per hectare and can be grown on land that is not suitable for other crops. Combining plantation crops with small-farmer palm fruit harvests and ownership of oil processing mills has proven very profitable. Fortunately, it is possible to reduce much of the emissions and deforestation from existing palm oil production and eliminate them completely from future production without much disruption to the global palm oil supply.

Palm Oil Is Everywhere

Palm oil is pressed from the fruits and seed kernels of the oil palm tree *Elaeis guineensis*, which is native to West Africa. This edible oil is widely used for cooking in developing countries and in thousands of widely

Figure 6.1. The Rapid Growth in Area Harvested for Palm Oil, 1990–2007



Note that oil palm trees take several years to grow to harvestable size, so these data lag three or four years behind the data for area planted and even further behind those for area cleared for plantations.

Source: FAO 2011.

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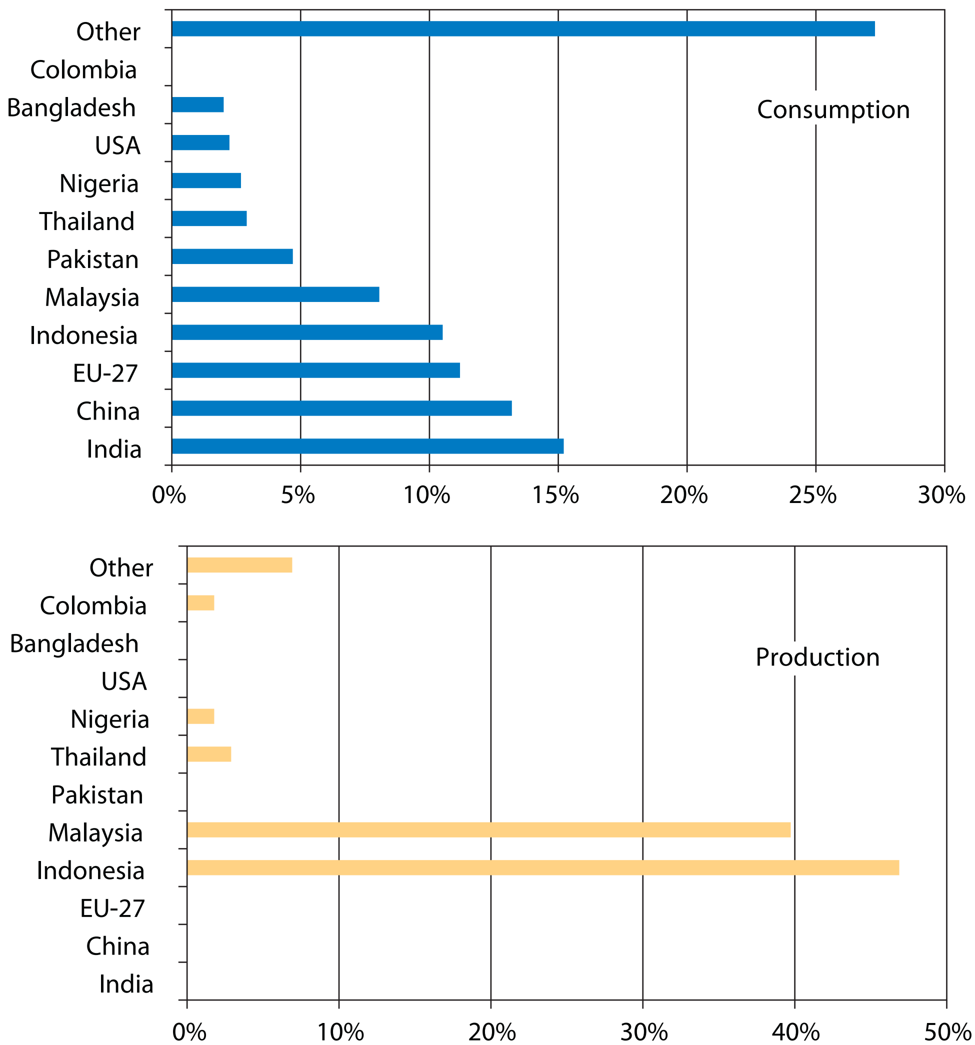
Figure 6.2. Consumption and Production of Palm Oil by Country, 2009–2010



Palm oil is both produced and consumed predominantly in developing countries. (Total production was 44.8 million metric tons).

Source: AOCS 2011.

used products in the food industry, as well as for soaps, detergents, lubricants, and cosmetics. It has also recently been developed as a feedstock for biodiesel fuels.

The oil is highly saturated, making it solid rather than liquid at room temperature. This makes it an appealing ingredient for many food, household cleaning, and toiletry products. Palm oil is ubiquitous in developed countries' manufactured products, but it is used only in very small amounts. In fact, the United States only imports 2 percent[1] of globally produced palm oil.

As the world's cheapest edible oil, it is now the primary cooking oil for many people in developing countries in Asia, Africa, and the Middle East. In 2009/2010, four Asian countries imported 35 percent of the global supply: India, China, Pakistan, and Bangladesh. Domestic markets in Indonesia, Malaysia, Nigeria, and Thailand met their own needs, consuming 24 percent of global production. The demand in these countries is large and growing. Since the primary consumer base in these regions is large, growing, and highly price-sensitive in regard to staple food products, major reductions in the production of palm oil could potentially lead to higher global edible oil prices (FAS 2010).

The European Union (EU) imported 11 percent of globally produced palm oil, and a diverse group of other

1 While the United Statees has a minor role as a consumer of palm oil, U.S.-based corporations control a significant portion of the trade among developing countries (NWF 2010).

countries accounted for the rest (Figure 6.2). The European import numbers were higher than other developed nations because the EU Commission created a novel export market for palm oil by mandating partial substitution of fossil fuels by biofuels for electricity generation. Indonesia, presently a fossil fuel exporter, has major plans to use palm oil as a fuel supply in its domestic transport sector (Sheil et al. 2010). While energy crops, in principle, offer a renewable energy resource, studies suggest that the carbon footprint of palm oil is substantial due to deforestation and ongoing emissions from drained peat lands (Danielsen et al. 2008). Concern about deforestation associated with palm oil plantations has raised barriers to more widespread acceptance of palm oil as a biofuel in Europe.

Industrial Palm Oil Enterprises

In addition to the substantial global demand, two factors favor palm oil's production on an industrial scale. First, large refineries are more efficient than small ones. Second, fresh fruit must be processed within 24 to 48 hours of harvest to avoid spoiling (FAO 2002). Commercial palm oil production requires industrial-scale refineries to be located near concentrated supplies of fresh fruit for quick processing. Therefore, land-extensive plantations and capital-intensive processing plants are highly profitable and entirely dependent on one another.

Integrated agro-industrial palm oil enterprises are located principally in Indonesia and Malaysia. Both countries previously developed extensive tree plantation economies based on natural rubber. Malaysia was the first to dominate world production and trade of palm oil, but Indonesia's generous approach to land grants and foreign investment led to a boom in forest clearing for palm oil plantations. Indonesia overtook Malaysia as the largest producer in 2006, but expansion continues in Malaysia, including deforestation of peatlands (SarVision 2011; Wetlands International 2010). Indonesia now has a larger palm oil plantation

BOX 6.1.

The Battle of the Fats: Trans vs. Saturated

Most, if not all, of the pre-packaged snack food, fast food, and baked goods we buy contain either saturated fat, trans fat, or both. Saturated fat and partially hydrogenated vegetable fat (or trans fat) are utilized because the high level of saturation makes them solid rather than liquid at room temperature. This extends shelf life, decreases the need for refrigeration, and allows goods to maintain the correct texture. Trans fats are created through a chemical process that purposely changes the makeup of vegetable-based fats and oils to give them properties that are naturally occurring in animal fats and saturated oils, like palm oil. The use of trans fats in processed foods increased in the 1960s, 1970s, and 1980s because of widely publicized health risks associated with saturated fats and cardiovascular disease (Eckel et al. 2007).

However, studies conducted in the 1990s showed the health risks of trans fats, which many argued were worse than saturated fats (e.g., Mensink and Katan 1990). In 2003, the U.S. Food and Drug Administration mandated that, as of January 1, 2006, all food labels must include trans fats as a separate line in the nutrition information (FDA 2003). This labeling drove food companies to try to avoid trans fats and/or lower their amount in food—in many cases opting for palm oil to replace the trans fats. Removing the trans fat from food allowed them to label the food item "trans fat free," which was appealing to many consumers. Cities in the United States, such as Philadelphia and New York, have banned trans fats in all food service establishments. European countries, including Denmark and Sweden, have also banned trans fats (Pérez-Ferrer, Lock, and Rivera 2010; Philadelphia Department of Public Health 2007; New York City Department of Health 2007; Stender and Dyerberg 2004). This has further increased the use of palm oil in processed foods worldwide and helped drive the demand for palm oil as a cheap, saturated alternative.

Palm oil has been touted by some as a healthy alternative to trans fats. However, numerous widely publicized studies show that palm oil is not a healthy substitute for trans fats. In fact, medical societies such as the American Heart Association expressed concern that replacing trans fats with highly saturated fats and oils, including palm oil, will lead to elevated risk of heart disease (Eckel et al. 2007).

Tropical land occupied by palm oil plantations increased from about 1.55 million hectares in 1980 to about 12.2 million hectares in 2009. Deforestation for palm oil plantations in Indonesia averages about 300,000 hectares—about half the size of Delaware—each year.

area and a greater component of immature trees, guaranteeing its continued global dominance of production and trade (Table 6.1).

Tropical land occupied by palm oil plantations increased from about 1.55 million hectares in 1980 to about 12.2 million hectares in 2009 (IFC 2011). Much of this land was unsuitable for other food crops, and all of it was formerly covered by lowland tropical forests. Most of the deforestation is recent and driven directly by conversion for palm oil plantations. During the period 1990 to 2005, at least 55 percent of plantation expansion in Indonesia and Malaysia entailed deliberate forest clearing (Koh and Wilcove 2008). Deforestation for palm oil plantations in Indonesia averages about 300,000 hectares (three-quarters of a million acres)—about half the size of Delaware—each year. The Indonesian government encourages deforestation by designating vast tracts of forested land for conversion to plantation agriculture and then issuing long-term leases over that land to a small group of influential individuals on very favorable terms.

A comparison of publicly available Indonesian land ownership data for 2005 with subsequent monthly MODIS (moderate-resolution imaging spectroradiometer) satellite data indicates that approximately 8 percent of Indonesia's deforestation between December 2005 and December 2010 took place on pre-existing palm oil, coconut, and rubber plantation leases. Pre-existing timber plantation concessions account for 15 percent of observed deforestation. Seven percent of deforestation in that five-year period occurred on pre-existing commercial logging concessions and 2 percent on pre-existing protected areas. Two-thirds of deforestation occurred on unknown tenures, including concessions issued after 2005 (Hammer 2011). Comparable results are found in the published literature: 16.5 percent of deforestation in Kalimantan and Sumatra between 2000 and 2008 occurred on land designated by the Indonesian Ministry of Forests for conversion to timber plantations or estate crops (Broich et al. 2001).

Conversion of primary forests to palm oil plantations accounted for more than 10 percent of deforestation in Indonesia and Malaysia between 1990 and 2010 (Koh et al. 2011). A more reliable allocation of deforestation among all national and global drivers would require comprehensive current land tenure data (Brown and Stolle 2009).

Large palm oil plantations in Indonesia have been established on forested land leased to influential families with commercial interests in nearby paper pulp mills. For example, the Widjaja family controls the Sinar Mas Group, which owns one of the largest paper producers in the world, Indonesia-based Asia Pulp and Paper, and also owns both one of the country's dominant palm oil growers, P.T. SMART, and one of the

Table 6.1. Indonesia's Increasing Dominance of Global Palm Oil Supply and Trade

	Global Supply (Mmt)	Indonesian Supply (Mmt)	Indonesian Supply (% of Global)	Global Exports (Mmt)	Indonesian Exports (Mmt)	Indonesian Exports (% of Global)
1999/00	21.8	7.2	33%	14.0	3.9	28%
2001/02	25.3	9.2	36%	17.7	4.3	24%
2007/08	41.1	19.7	48%	32.2	14.6	45%
2010/11	48.0	23.0	48%	37.3	18.4	49%

Indonesia overtook Malaysia as the largest palm oil producer in 2006, and now has a larger palm oil plantation area and a greater component of immature trees, guaranteeing its continued global dominance of production and trade.

Mmt = million metric tons
Sources: FAS 2011; FAS 2010; FAS 2009.

BOX 6.2.

Lobbying to Destroy Forests

Over the past year, an aggressive public relations and lobbying campaign has emerged for the destruction of tropical forests (Butler 2011). Pro-deforestation advertisements worth millions of dollars have appeared on media websites such as CNN.com and in newspapers like the *New York Times*. These advertisements are being bought by groups like World Growth International, a nonprofit "pro-growth" organization that refuses to list its funders (Booth 2010) but has strong ties to the palm oil industry (Hurowitz 2011). The campaign portrays opponents of tropical forest clearing as enemies of improved food security for the poor in developing countries and as defenders of an uncompetitive U.S. timber industry.

Much support for this pro-deforestation campaign comes from the Sinar Mas Group, which includes Asia Pulp and Paper (Indonesia's largest paper producer) and P.T. SMART (one of Indonesia's largest palm oil growers) (Butler 2011; McIntire 2011). The timber and palm oil industries are currently under legal, political, and consumer pressure to bring their environmental, human rights, and labor standards into line with international standards.

Perhaps the most surprising fact in the story of this pro-deforestation lobby is their political allies in the United States. This campaign has gained the support of parts of the conservative political movement known as the Tea Party. The Institute of Liberty and Frontiers of Freedom, both groups associated with the Tea Party, have joined the pro-deforestation movement under the free-trade banner "Consumers Alliance for Global Prosperity" (Hurowitz 2011; McIntire 2011). Tea Party activists may be surprised to find out that they are campaigning for an Indonesian multi-billion-dollar conglomerate and against the American forest industry.

largest palm oil refineries, Golden Agri-Resources (GAR). Selling the timber harvested while clearing land generates the capital needed to establish the palm plantations. This timber harvest can bring in revenues on the order of U.S. $10,000 per hectare, making the combination of logging followed by palm oil plantations one of the most profitable options for tropical forest exploitation anywhere (Fisher et al. 2011). The timber harvest can also provide the feedstock needed to make up the shortfall that pulp mills experience before their own timber plantations can provide sufficient pulp wood (Uryu et al. 2008). Consequently, the rate of palm plantation clearing has outpaced the rate of palm plantation planting, creating a backlog of underutilized land.

Deforestation is seen by some in the palm oil plantation industry (World Growth 2010) as a small price to pay for the economic benefits that the industry provides to rural growers and workers, and its contribution to the global food supply. Substantial further expansion is planned. The amount of expansion that occurs on current forest land is a critical choice facing the small number of palm oil producing countries, as well as the developers, refiners, and investors who

Deforestation is pushing orangutans to the brink of extinction

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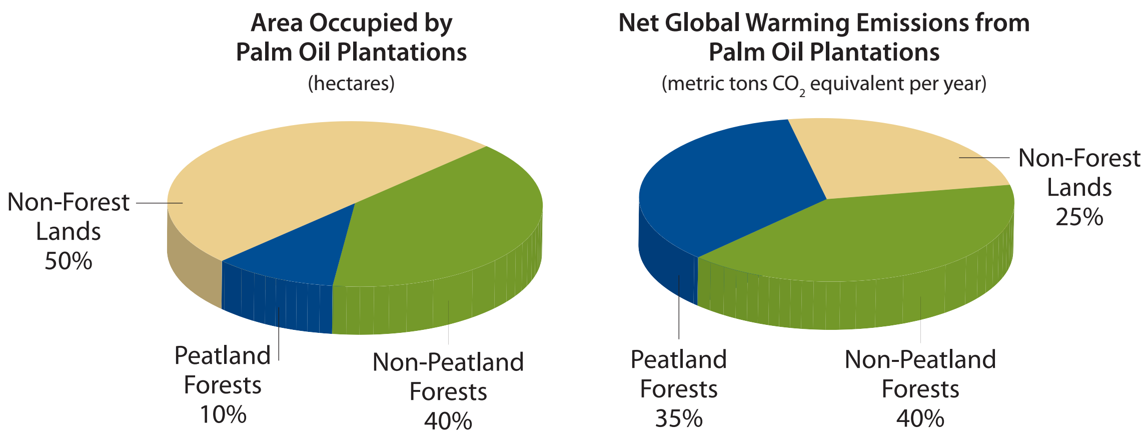
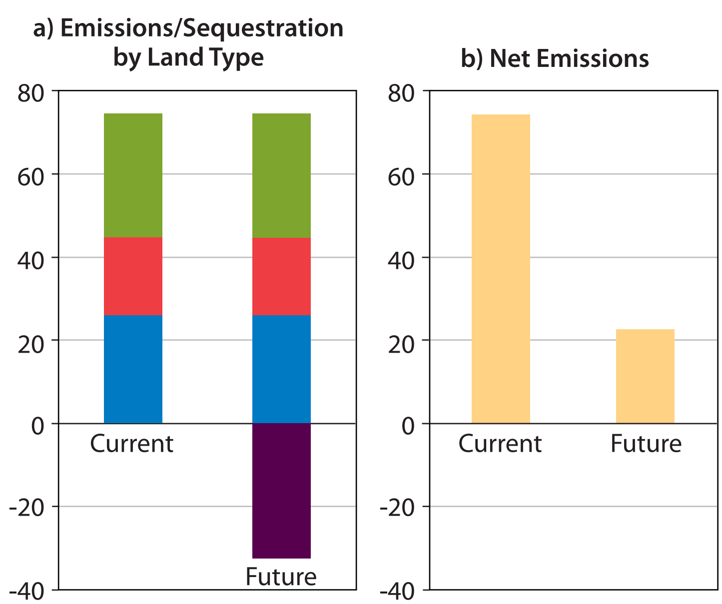
Figure 6.3. Area and Emissions of Palm Oil Plantations in Indonesia and Malaysia, by Land Type



Because forested land, especially forested peatland, has a high carbon density, the production of palm oil on deforested lands causes disproportionately greater emissions of global warming emissions than an equal area of non-forested land. Area data for plantations established prior to 2003 from Koh et al. (2011); emissions estimates from Chase and Hansen (2010).

Figure 6.4. Global Warming Emissions from Palm Oil Plantations in Indonesia and Malaysia under Current Conditions and a Future Scenario



a) Emissions under current land allocations (deforested non-peat forestlands = green, previously deforested lands = red, deforested peatlands = blue) compared with emissions under a future scenario in which palm oil production is doubled but all new plantations are established on degraded grassland (purple), delivering net sequestration.

b) Net emissions under current land allocations and the same future scenario as above.

Vertical scale is metric tons CO_2 equivalent per year. Area data for plantations established prior to 2003 from Koh et al. (2011); emissions estimates from Chase and Hansen (2010).

provide the land and finances that the expanding palm oil industry requires (Greenpeace International 2007).

The Climate Footprint of Palm Oil

The climate footprint of palm oil has two distinct components: emissions due to deforestation and emissions inherent in growing and processing palm oil (Figure 6.3). Emissions due to deforestation can be significantly avoided, if not altogether eliminated, by more prudently choosing the land on which plantations are established (Figure 6.4).

Palm trees, like all green plants, take in carbon dioxide and release oxygen during photosynthesis. The carbon dioxide is stored as organic carbon in their trunks, roots, leaves, and fruits. However, even when fully grown, the aboveground biomass of the palm trees is less, and often much less, than 20 percent of the aboveground biomass of the natural tropical forest that the palm trees replaced.

Furthermore, carbon sequestration by palm oil plantations is not permanent. After their productive life of about 25 years, the trunks of old palms may be used for timber or mulched in the field. This results in their carbon gradually returning to the atmosphere. Carbon from roots and leaves is partly lost back to the atmosphere through rotting or burning, and partly transferred as inorganic carbon to the soils. Some carbon in the fruits and seeds is lost as methane—a more powerful heat-trapping gas than carbon dioxide—produced in waste sludge ponds, while the rest remains in the processed oil until it is burned or eaten.

Every stage of palm oil production also requires fossil fuel inputs in the form of mechanized land preparation, chemical fertilizer, local and long-distance transportation, and industrial processing. A complete life-cycle carbon model, based on palms grown in established plantations, estimates that growing and refining each metric ton of crude palm oil (CPO) produces the equivalent of 0.86 metric ton of carbon dioxide (Chase and Henson 2010). That is about the

Emissions due to deforestation can be significantly avoided, if not altogether eliminated, by more prudently choosing the land on which plantations are established.

Palm oil plantation on land that was once a forest

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same amount of emissions released by burning 98 gallons of gasoline (EPA 2010). CPO production on previously cleared mineral soils can be minimized through better agricultural practices, particularly greater care in using nitrogen fertilizer, and through commercially sound improvements at refineries, such as co-generation of electricity.

Since the climate footprint associated with processing palm oil is the same regardless of where it is grown, the size of the total effect depends on what land was used to establish the plantation. If a new plantation replaces an earlier one, it causes no additional emissions from land use change. Emissions are greatest if the new plantation replaces forest on peat soils and less so if it replaces forest on mineral soils. Plantation establishment can even result in negative emissions (carbon sinks), if palms are planted on deforested and degraded grassland.

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Aerial view of palm oil plantations and tropical forest in Southeast Asia

Plantations Converted from Forests and Peatlands

Peat soil is found in raised bogs and swamp forests, consists principally of decomposed plant material, and is very rich in carbon. High and irreversible global warming emissions occur when forested peat swamps are cleared and planted with palm oil because the water table, which must be maintained at about 0.75 m below the soil surface to avoid root rot, is lowered. This allows the peat to be exposed to air, both on the plantation site and across the adjacent wetlands traversed by drainage canals. Once exposed, peat quickly decays and readily burns. In addition, when exposed to water in the drainage canals it may decay anaerobically, producing methane. Since it is the uppermost levels of peat that are affected, the impacts of drainage and deforestation on peatlands are the same whether the peat bed is thick or thin.

Up until 2002, about 11 percent of palm oil plantations in Malaysia and Indonesia were established on deforested peat swamps (Koh et al. 2011). The proportion is likely to have increased since then, as peat swamps are appealing for plantation developers. Since few other crops could be grown on these soils, there is little commercial competition for them.

Mineral soils consist predominantly of sand, silt, and clay particles. They have much less organic material than peat soils, and most of their carbon is limited to the thin topsoil. Especially in the tropics, forests on mineral soils consequently have much less belowground carbon than peat swamp forests, though they typically have more aboveground carbon biomass. Consequently, the carbon emissions in the first year after conversion both for plantations replacing intact primary forest on mineral soil (+47 to -225 metric tons of carbon per hectare, with negative figures indicating emissions to the atmosphere) and for plantations replacing forest on peat soil (-52 to -245 metric tons of carbon per hectare) are very similar. However, due to the ongoing exposure of peat, plantations replacing forest on peat soil continue to emit carbon for many years. Thus their losses over a 25-year period are in the range of -169 to -723 metric tons of carbon per hectare (RSPO 2009b: 20). Koh et al. (2011: 4) come to a similar conclusion.

Land cleared for a palm oil plantation adjacent to one of Indonesia's national parks

Since the global warming emissions from processing palm oil are the same regardless of where the processing occurs, the determining factor in the amount of total emissions is the type of land that was converted to a plantation to produce the palm oil.

Degraded, logged, and secondary forests on mineral soils have significantly lower carbon stocks than intact primary forest on similar soil. Even so, the release of global warming emissions from their deforestation remains consistently greater than the carbon subsequently captured by the palms.

Plantations Grown on Grassland

Vast, previously cleared, tropical lowland areas are infested with fire-prone cogon grass (alang-alang, *Imperata cylindrica*). Palm plantations on land reclaimed from this invasive species provide a net carbon sink because the trees store more carbon than the grass. Land reclamation further reduces emissions by preventing grassland fires from invading adjacent forests. An important consideration for the long term is that reclaimed cogon grassland, like peatland, is unsuitable for staple food crops, while new palm oil plantations on mineral soils may limit opportunities to increase production of other important food crops including paddy rice.

Fulfilling the Palm Oil Demand without Driving Deforestation

Excluding palm oil plantation development from peatlands and forests need not impede the development of the industry or demand for palm oil (Dehue, Meyer, and van de Staaij 2010). Indonesia has sufficient cogon grassland and cleared, unplanted plantation leases to accommodate its projected doubling of palm oil output over the next 10 years, with limited use of existing agricultural land and without additional deforestation or incursions onto peatland (Wicke et al. 2011; WRI 2011; Koh and Ghazoul 2010; Verchot et al. 2010; Fairhurst and McLaughlin 2009). The government of Indonesia has acknowledged that its needs

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Aerial view of peatland being drained and cleared in Borneo

for cropland expansion up to 2020 can be met with existing agricultural lands, without using degraded forestland or converting tropical forest to plantation (BAPPENAS 2010: 46).

Targeting deforested and degraded grassland for expansion of the palm oil industry would allow time for some of the country's previously logged and secondary forests to recover their lost forest cover and carbon stocks.[2] These forests are found on organic peat soils rich in carbon as well as mineral soils with low soil carbon content. Though they may take centuries to recover their original carbon stocks, degraded, logged-over, and secondary forests usually have the potential to recover naturally and to sequester substantial amounts of carbon, an important climate mitigation service. If they are on drained peat soils, it may be necessary to restore the natural water balance. If they are on dry mineral soils, it may be necessary to work actively to reduce fire risks on adjacent land.

Demanding Better Palm Oil

Consumer, development, and environmental non-governmental organizations campaign for companies that produce or use palm oil to adopt stricter standards for palm plantations (Greenpeace International 2007). While these campaigns have yet to significantly slow deforestation or global warming emissions, growing consumer awareness of the environmental and social impacts of palm oil plantations has led to the creation of the Roundtable on Sustainable Palm Oil (RSPO), an association of growers, industrial users, and non-governmental organizations (Paoli et al. 2010).

A small percentage of palm oil production is certified by RSPO as compliant with its voluntary standards. The present standards (RSPO 2007) require environmental impact assessments to be conducted and considered in management planning. They include some provisions regarding high conservation value (HCV) forests and areas of peat, but certification does

2 Confusion arises when the term "degraded forestland" is used interchangeably with the term "degraded land." The latter is best applied specifically to cleared land infested with fire-prone cogon grass, usually on hills with shallow mineral soils and low carbon content.

not require producers to protect all forests or all peatlands. In 2009, the RSPO Greenhouse Gas Working Group recommended a maximum allowable emission rate per metric ton of crude palm oil (RSPO 2009a). Their recommendation would rule out the conversion of forests and peatlands with high carbon density, but it has not been adopted by the RSPO. Instead, the Working Group was tasked to continue its analysis (RSPO 2009c), and is due to report in 2011 (RSPO 2010). Until the RSPO adopts stricter emissions standards, the "sustainable" palm oil it certifies cannot be considered truly sustainable.

Targeting deforested and degraded grassland for expansion of the palm oil industry would allow time for some of the country's previously logged and secondary forests to recover their lost forest cover and carbon stocks.

The World Bank Palm Oil Strategy External Advisory Group (2010) also recommended that swamp forests on peat should not be converted to palm oil plantations because of the significant global warming emissions that result. There was significant support for this position during the group's consultation phase (Palola and Bramble 2010), but the final version of the World Bank Group Framework and International Finance Corporation Strategy for Engagement in the Palm Oil Sector contains more limited provisions than those recommended by the External Advisory Group. It only provides safeguards for "high carbon stock peatlands and high carbon stock primary tropical forest" (IFC 2011). It does not define high carbon stock or protect carbon stocks of logged and secondary forests. Under these limited provisions, the World Bank Group can still provide financial support for any plantation development and mill construction in locations with peatlands or forests nearby. Clearly, if peatlands and forests are within the commercial supply area of a mill, they will be converted.

In conclusion, palm oil need not be a driver of deforestation or a major source of global warming emissions. The Indonesian and Malaysian governments, foreign donors, the palm oil industry, and international financial institutions can demonstrate a workable model for low-carbon or even carbon-absorbing economic development in export agriculture, if they choose.


Julia Lo/Global Environment Centre

Peatland being burned to make way for palm oil in Malaysia

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CHAPTER 7

Timber and Pulp

Pipa Elias

FORESTS CAN BE A RENEWABLE source of materials. Most people use wood products every day—furniture, paper, plywood, building material, railroad ties, and newsprint are all made from wood. Unlike fossil fuels and metals, wood supply is renewable, and compared to steel, concrete, plastic, and brick, wood is a low-energy and low-emissions material for packaging and building, especially when it is not the cause of deforestation (Aulisi, Sauer, and Wellington 2008; Fruhwald, Welling, and Scharai-Rad 2003). There is a role for forest management to meet some of the global demand for these products; however, unsustainable wood harvesting has many negative environmental impacts. International trade in wood products creates a market worth billions of dollars per year, and some of the wood products are made from tropical trees extracted from primary forests or other unmanaged areas.

Wood is utilized across the world in many ways. Unprocessed wood is used mostly as a fuel (see Chapter 8). Processing logs usually leads to one of two materials: timber or pulp. Timber is made by cutting and sawing logs, and is used for products like furniture, railroad ties, plywood, utensils, tools, or as building material for bridges and buildings. The term "timber" is used differently across the world; in this chapter it refers to any solid wood product cut from a log. Pulp is the product of chemically treating wood, leaving only the fibers. It is used to make many kinds of paper including newspaper, writing paper, paperboard, and toilet paper; therefore, the industry is often referred to as "pulp and paper." Both timber and pulp products can be recycled to various degrees, and many of the products listed above can be made from recycled material.

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Wood can be used to produce timber or pulp, which is used to make paper

Global Demand for a Renewable Resource

The global market for wood and wood products creates pressure on tropical countries to destroy their forests and produce cheap timber and pulp. This demand has increased logging (the cutting and removal of trees) of tropical forests and is a major driver of deforestation. If demand for furniture, paper, building materials, and other wood products continues to increase, primary tropical forests will likely remain at risk for logging.

Furthermore, logging can interact with other drivers of deforestation. In many instances logging creates partially cleared areas, which become accessible by logging roads, and can therefore be more easily converted to agriculture, preventing the forest from growing back. Logging and land use conversion are closely connected, because timber sales from logging may provide the money used to replace the forest with a new agricultural business or timber plantation. In other tropical forests, logging is used only to remove the dense forest so that agriculture can move into the area, leaving the trees to rot or be burned to make room for the new

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field or pasture. On the other end of the spectrum are forests recovering from unsustainable practices. These secondary forests can help recover the lost tropical forest area, and in some cases be a source of timber. Secondary forests can be managed to supply products for generations, but doing so will require careful planning and management.

If demand for furniture, paper, building materials, and other wood products continues to increase, primary tropical forests will likely remain at risk for logging.

Selective Logging: Unmanaged Demand for Valuable Trees

Degraded forests are areas where some kind of human action—usually logging, grazing, or fire—has affected the forest but the area has not been totally cleared. Degradation can mean loss of trees, shrubs, carbon, biodiversity, and soil nutrients, and in extreme cases can alter a forest for many decades. Forest degradation mainly occurs because there is a demand for wood products, and natural forests are being used, but not fully cleared, to supply these products.

In most cases, degradation begins with the removal of just a few highly valuable or useful trees per hectare, but the combination of tree removal and the associated damage to residual trees can destroy from 28 percent to as much as 62 percent of the trees in the forest (Gerwing 2002). This removal of only highly valuable species, without cutting the whole forest, is known as selective logging. Although tropical forests are richly diverse, relatively few of their tree species are used by the timber industry (Southeast Asia is an exception, as detailed in the section Production from the Tropics). Economically, it is important to have access to these select trees, yet the rest of the species are ignored because financially there is no reason to take them out of the forest. Since taking wood out of the forest costs money to put it on a truck, pay the driver, and pay for gasoline, there is no reason to remove trees that will not sell for at least as much as the costs associated with their removal and hauling.

The damage due to selective logging can dry out the forest and leave it more susceptible to fires and expansion of other extractive activities (Box 7.1), which cause further degradation. However, it is difficult to measure rates of forest degradation since either on-the-ground monitoring or analyses of high-resolution remote images are necessary (Asner et al. 2010). In recent years it has become clear that forest degradation

BOX 7.1.

Degradation from Harvesting Non-Timber Forest Products

Communities that depend on forests can support their livelihoods in many ways beyond timber. The forest also produces fruit, seeds, medicine, meat, and oils—all known as non-timber forest products. In some cases the roads built for selective logging can increase access to remote forests, leading to unsustainable extraction of non-timber products and degradation of the forest (Laurance et al. 2006). For example, unsustainable hunting can degrade the forest because loss of animal species affects the entire forest system, changing seed-dispersal pathways, food webs, plant herbivory patterns, and populations of plant pests (Nasi and Van Vliet 2009).

On the other hand, sustainably sourced non-timber forest products can encourage forest protection and support community development policies and plans (Kusters, Achdiawan, and Belcher 2006). For example, in Brazil large areas of the Amazon are specifically set aside as extractive reserves. In these areas the forest is protected from clearing, but communities are involved in managing and harvesting non-timber products, most often natural rubber. Such broad policies to protect the forest while allowing for production of non-timber forest products may be necessary to ensure that the income from products is not used, in turn, to log the forest (Escobal and Aldana 2003). In addition to non-timber forest products, incentive policies that include direct payments for environmental services, such as conservation management of forests, can be competitive with timber and agricultural products and simultaneously support forests and communities (Hardner and Rice 2002).

is a widespread problem in the tropics. For example, from 1972 to 2002, 2.9 million hectares in Papua New Guinea (almost 9 percent of the forests there) were selectively logged (Shearman et al. 2009). In addition, a detailed remote sensing study of the Peruvian Amazon estimated that degradation through selective logging accounted for 27 percent of the area disturbed by humans (Asner et al. 2010).

A recent global estimate using satellite imagery calculated land areas that were selectively logged between 2000 and 2005. It found that about 28 percent of the humid tropical biome in Asia and Oceania was selectively logged in this time period, compared with 20 percent in Africa, 18 percent in South America, and 5 percent in Central America and the Caribbean. Globally, this means up to 20 percent of the world's humid tropical forests were subjected to some wood removal between 2000 and 2005 (Asner et al. 2009).

In many cases although very few of the trees are removed by selective logging, it is still a step toward complete forest cover loss. In the Amazon, degradation leads to complete forest cover loss in subsequent years about 25 percent of the time, and globally between 1990 and 2000 28 percent of new agricultural land was created at the expense of degraded and secondary forests (Gibbs et al. 2010; Foley et al. 2007).

Through deliberate and careful efforts, degraded forests can be restored or managed for sustainable production. Restoration techniques include protecting the degraded forest from future unsustainable extraction, taking actions to prevent fires, and replanting key species (Elias and Lininger 2010).

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Industrial logging in the Amazon

Timber Cutting and Forest Clearing

Where Does It All Go?

Global gross annual output of wood is about 3.5 billion cubic meters (United Nations Environment Programme 2009). Table 7.1 lists annual production rates of many wood products, both globally and from the tropics. Comparing tropical production (column 3) with global production (column 2), it is clear that tropical logging produces only a small portion of the world's wood products. However, it is likely that greater production in the future will come from developing

Table 7.1. Annual Production of the Most Common Wood Products, 2009

Product	Global Production	Tropical Production[1]
Newsprint	32.6 Mmt	2.6 Mmt
Printing and writing paper	105 Mmt	15.3 Mmt
Plywood	80.3 Mm^3	13.3 Mm^3
Sawnwood (wood cut into boards, lumber, planks, etc.)	362,000 Mm^3	72.8 Mm^3

Wood is measured in cubic meters. A cubic meter (m^3) is about 35 cubic feet—a volume that would make a very comfortable doghouse for a large dog like a Saint Bernard. Paper products, on the other hand, are measured by weight (FAO 2010). Note that the FAO data is self-reported by countries, and therefore, subject to error and non-comparability.

Mmt: million metric tons
Mm^3: million cubic meters

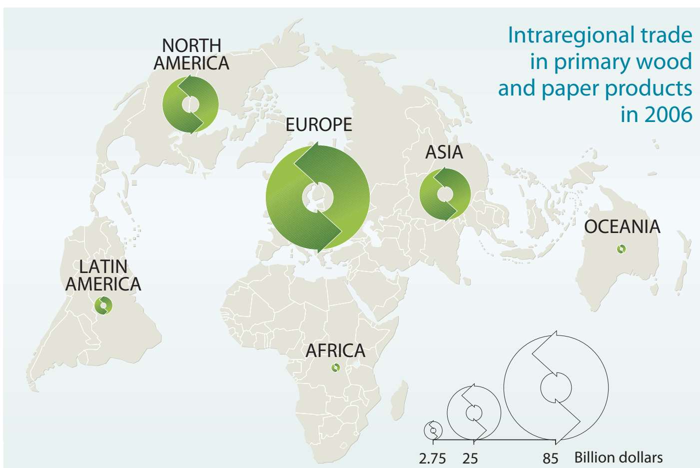
1 Values compiled from available data for those countries included as tropical production countries in International Tropical Timber Organization 2009.

countries, since the rate of deforestation and plantation expansion is very low in North America and Europe, costs are lower in developing nations, and tropical climates are suitable for fast-growing trees (United Nations Environment Programme 2009).

Global trade of paper and primary wood products—including unprocessed logs and lumber that are not manufactured into secondary products like furniture or pre-fabricated houses—is a multi-billion-dollar business (Figure 7.1). In the United States many of these paper and primary wood products come from regional trade with Canada. Also, the growing demand in rapidly industrializing nations (e.g., Brazil, China, and India) has and will likely continue to affect international trade (Whiteman 2005).

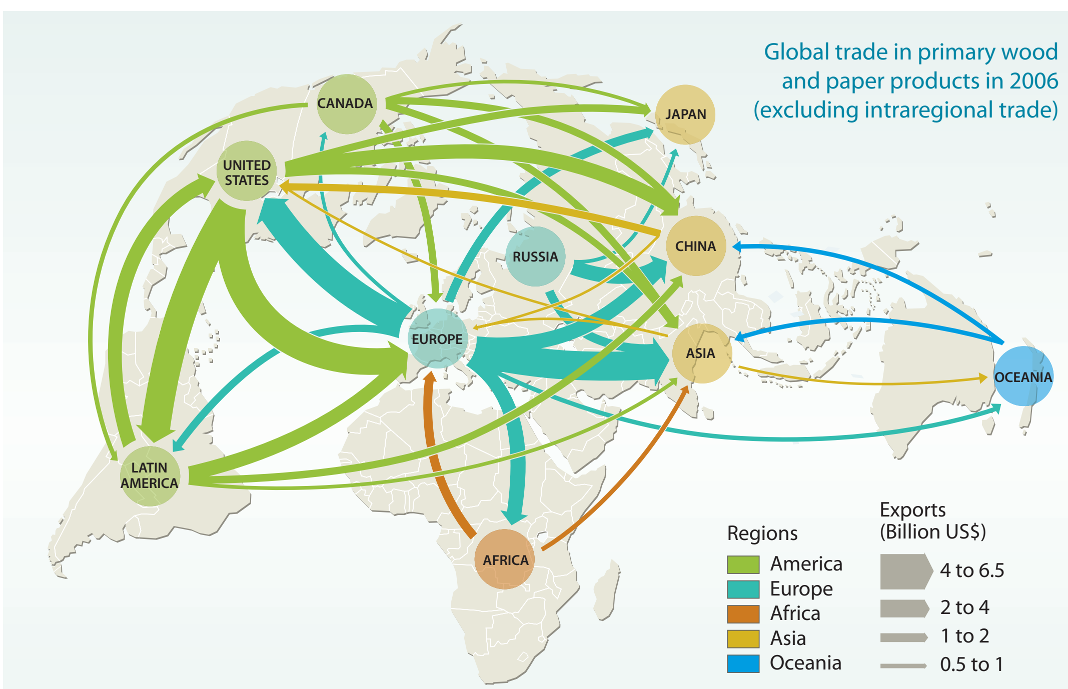
Secondary wood products (e.g., furniture) also create a demand for wood. In 2000, the top 15 exporters of furniture included six developing countries: Brazil, China, Indonesia, Malaysia, Mexico, and Thailand (Kaplinsky et al. 2003). However, some of this furniture is made from wood that was imported. China, for example, imported $93.5 million worth of pre-cut wood from Brazil, $85.4 million from Indonesia, and $66.2 million from Malaysia in 2008 (FAO 2011).

Figure 7.1. Global Trade of Primary Wood and Paper Products, 2006



Intraregional (top) and international trade (bottom) of primary wood and paper products shows a multi-billion-dollar industry dominated by exports from industrialized countries. These figures show only primary wood products, and do not include furniture and a few other pre-fabricated products.

Source: United Nations Environment Programme 2009, © Philippe Rekacewicz, Paris.



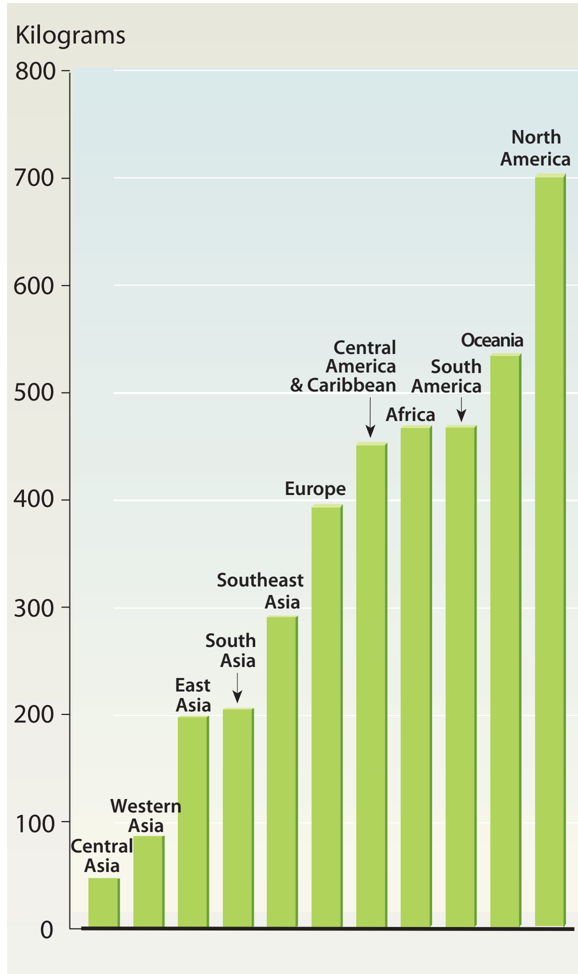
Most of the exports of furniture and other wood products go to Canada, the United States, Europe, Japan, Australia, and New Zealand. Together, these countries are responsible for 85 percent of global end-use consumption of logs (Contreras-Hermosilla, Doornbosch, and Lodge 2007). However, international trade of tropical hardwoods has been decreasing in the early years of the twenty-first century (Ghazoul and Sheil 2010).

Over the past decade the largest increase in demand for forest products has been in pulp and paper. Current demand in Asia is so high that even though production within the region is growing, it is still a net importer (Aulisi, Sauer, and Wellington 2008). Pulp and paper is a big business, even in developing countries. Integrated paper product companies, which own their entire value chain from the forests to the chemical treatment and paper production facilities, are increasingly important. In 2006 Oji Paper of Japan had the highest revenue among global integrated paper product companies at $10.4 billion. The fifth and sixth highest were Asia Pulp and Paper of Singapore at $4.4 billion and Suzano of Brazil at $1.4 billion (Aulisi, Sauer, and Wellington 2008).

Timber and pulp are becoming an important part of the economies of many tropical nations. However, there is very little benefit to the communities losing their forests. Large, often multi-national, forest product companies leave very little income from logging in local communities.

Over the past few decades there has been a general shift in production and demand of wood products. In the past most demand came from developed countries, and this was met through domestic or regional production, but now new countries are cutting their timber to meet the increasing global demand for wood products, as well as the growing demand within their own countries (Ghazoul and Sheil 2010). For example, global production of paper and paperboard increased by 40 percent worldwide from 1996 to 2005, while consumption of paper and paperboard products from the United States dropped by 7 percent just between 1999 and 2003 (Ince and Buongiorno 2007). There were similar trends in consumption and export of U.S. wood products, with pulp, lumber, plywood, logs, and wood chips peaking in the late 1990s and now declining.

Figure 7.2. Per Capita Wood Consumption by Region, 2004



North American wood use is highest and Asian is lowest, with similar mid-level consumption rates in Europe, Africa, and Latin America.

Source: United Nations Environment Programme 2009, ©Philippe Rekacewicz, Paris.

Therefore, at the same time that demand is growing in rapidly expanding economies like China, the demand of developed countries (Figure 7.2) now benefits from a supply chain by which low-price tropical logs become low-price global furniture and paper. However, there is very little benefit to communities losing their forests. Large, often multi-national, forest product companies leave very little income from logging in local communities (Larson and Ribot 2007). Timber and pulp are becoming an important part of the economies of many tropical nations as they are, or have been, in

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Truck carrying logs out of the Malaysian rain forest

developed countries. For example, timber exports make up 5 percent of Indonesia's exports, 4 percent of Brazil's, 2 percent of Malaysia's, and 1 percent of Thailand's, but fully 24 percent of Gabon's. In the United States, by comparison, forest products account for about 2 percent of exports.[2]

Production from the Tropics

Over the past few decades both timber and pulp production have increased in Asia, Latin America, and other regions outside of the traditional areas of North America and Europe (Aulisi, Sauer, and Wellington 2008). Still, tropical countries make up only a small portion of total global exports (Table 7.1 and Figure 7.1).

Compared with other regions, logging as a direct driver of deforestation is most important in Southeast Asia (Rudel et al. 2009). Indonesia is the leading example of how powerful timber and pulp companies and illegal logging have caused deforestation. Unlike other tropical forests, many parts of Indonesia have very high densities of commercially valuable species, making wholesale logging much more profitable than in other parts of the world (Curran et al. 2004). Many of the tropical forests of Southeast Asia are dominated by trees of the dipterocarp family (Dipterocarpaceae), which is found almost exclusively in this region. This family of trees is dominant and widespread over much of Indonesia, Malaysia, southern Thailand, and part of the Philippines, where it accounts for the majority of the biomass. Logging dipterocarps can be very successful because many of the species that compose the family can be grouped together (e.g., as "meranti") for logging, production, and marketing (Primack and Corlett 2005). Furthermore, markets in Indonesia accept a wide range of logs from many species, sizes, and quality (Corlett 2009). Finally, palm oil plantations, a common enterprise for which land is converted, require years rather than months to start generating income. Timber income helps support businesses during this lag time.

Timber and palm oil concessions from federal and regional governments play an important role in deforestation in Indonesia. Currently all Indonesian forests fall into one of three use categories: production (about 56 percent), protection (about 26 percent for protecting ecosystem services), and conservation (about 18

2 These values were calculated by comparing FAOStat export values with the International Trade Centre's Trade Performance values (*http://www.intracen.org/menus/countries.htm*).

percent for protecting their intrinsic value) (Arnold 2008). In the production category, the government allows deforestation and land use conversion, but even protected areas are subject to illegal logging (Broich et al. 2011; Curran et al. 2004).

While logging is particularly important in Southeast Asia, there are other regions where timber and pulp are driving deforestation as well. In Brazil, the timber industry, both legal and illegal, is extensive but often overshadowed by high levels of forest conversion caused by other drivers of deforestation (see Chapters 4 and 5) (Lawson and Macfaul 2010). While traditionally timber has not been an important driver of deforestation in Africa (Fisher 2010), it may be growing in importance. In Central Africa,[3] 30 percent of the forest is under logging concessions, including 45 percent of Gabon's land area. This means the areas planned for logging could change over in the next decade (Laporte et al. 2007; Laurance et al. 2006). In the Democratic Republic of the Congo, logging roads are expanding at a rapid rate and commercial logging for valuable timber species, like African mahoganies, is expected to increase in the future (Laporte et al. 2007). However, a recent analysis concluded that increasing government management of timber land planning in South America and Central Africa could promote sustainable forest practices by providing financial incentives to keep land areas forested over the long term (Karsenty et al. 2008).

Illegal Logging

Some of the wood production from the tropics occurs as illegal logging, which includes removing trees from protected areas, failing to pay taxes and fees for timber, cutting protected species, stealing wood from the rightful owners, and/or removing more timber than allowed from a given area. Illegal activities can occur anywhere along the production chain that transforms a standing tree to a wood product like furniture or paper (Contreras-Hermosilla, Doornbosch, and Lodge 2007). Illegal logging is difficult to track but is generally considered to be about 40 percent of all logging in the tropics (Contreras-Hermosilla, Doornbosch, and Lodge 2007). In response to a survey, local experts and government officials in five tropical countries estimated that the extent of illegal logging was 70 percent of overall log production in the Brazilian Amazon, 60 percent in Ghana and Indonesia, 35 percent in Cameroon, and 25 percent in Malaysia (Lawson and Macfaul 2010). However, these same officials also thought that, compared with agriculture and legal commercial logging, illegal logging was not the most important cause of forest clearing.

The actors in illegal logging can vary by region and country. In Indonesia evidence suggests that these illegal activities are conducted by large-scale timber industries that have depleted their legal allocations or by palm oil producers looking to expand plantation area (Lawson and Macfaul 2010). Similarly, in other parts of Asia large-scale industries are common agents of illegal logging (Contreras-Hermosilla, Doornbosch, and Lodge 2007).

Optimistically, there is some evidence that illegal logging is decreasing in the tropics due to media attention, consumer campaigns by nonprofit organizations, private sector efforts, and international policies. Unfortunately, in some areas it may also be due to the fact that so much of the forest has already been deforested. Overall, compared with peak rates, a new analysis estimates that degradation was avoided on 17 million hectares of forest between 2000 and 2009 because of reduced rates of illegal logging (Lawson and Macfaul 2010).

Illegal activities can occur anywhere along the production chain that transforms a standing tree to a wood product like furniture or paper.

Logging and the Other Drivers of Deforestation

Demand for wood products can also interact with other drivers of deforestation. In these cases forests are cleared, logs are used, and the area is not retained as forest, but for agriculture. This can occur in two ways: selective logging as a step toward changes in land use or wholesale clearing of a forest with the explicit goal of conversion to agriculture.

Selective logging usually leaves the rest of the forest somewhat degraded, and therefore, easier to clear for crop or pasture. In the Brazilian Amazon, selectively logged areas are four times more likely than unlogged areas to be fully cleared in subsequent years (Asner et al. 2006). In other areas, particularly in Southeast Asia, logging makes it financially possible to convert the land to another use. In these cases, timber sales provide initial income to the businesses clearing the

3 Cameroon, Central African Republic, Equatorial Guinea, Gabon, Republic of Congo, and Democratic Republic of Congo

land, allowing them to convert the land to agriculture for a slow-growing crop such as palm oil. These areas where two sources of potentially substantial revenue provide the impetus for land use change (timber and palm oil) are of particular concern because preventing deforestation by providing incentives for alternatives may be especially difficult and expensive (Fisher et al. 2011).

Finally, in many areas the forest is cleared without timber production. Between 1990 and 2000, intact, undisturbed forests were the source of 55 percent of new agricultural land in the tropics (Gibbs et al. 2010). While in some cases the logs from these forests were sold, there are many instances in which these forests were simply cut and burned to create crop or pastureland—other factors, not wood products, were the drivers of the deforestation (see Chapters 4, 5, and 6) (Lawson and Macfaul 2010; Fearnside et al. 2009).

When plantations are planted to restore degraded areas and then managed in a sustainable way, they may serve to meet the growing global demand for timber and pulp.

Meeting the Demand for Forest Products: Is Sustainability Possible?

The focus of this chapter so far has been degradation or clearing of primary forests—those that are relatively undisturbed and considered native, natural, wild, tropical forests. However, wood production in the tropics can also come from plantation forests deliberately created for extraction. Forest plantations are simply any area with planted trees, and can range from industrial-scale rows of identical trees to small patches of many different hand-planted species (although the first approach is much more common). Plantations can have both benefits and drawbacks, depending on how they are managed and where they are located. When planted to restore degraded areas and subsequently managed in a sustainable way, they may serve to meet the growing global demand for timber and pulp.

Industrial Plantation Forests

Across the tropics about 1.4 percent of the land area is covered with forest plantations. In Africa the proportion is 0.3 percent and in Latin America 0.4 percent, but in the Asia-Pacific region it is almost 5 percent (International Tropical Timber Organization 2009). In the Asia-Pacific region, India and Thailand make up 90 percent of the plantation area, and in Latin America, Brazil accounts for 65 percent.

However, plantation area is rapidly expanding in the tropics. Between 1999 and 2005, the total area of tropical plantations increased at an average rate of 8.6 percent per year (9.4 percent in Asia and the Pacific, 8.8 percent in Africa, and 4.3 percent in Latin America and the Caribbean) (International Tropical Timber Organization 2009). In some countries where deforestation occurred decades ago, plantations were later established in order to increase forest cover. Examples include India, Thailand, and Ghana.

Plantations can produce almost any wood product, and often the trees grow very quickly. In the tropics 24 percent of the monoculture plantations are eucalyptus, 18 percent are pines, 17 percent are rubber, 17 percent are teak, and 9 percent are acacias (International Tropical Timber Organization 2009). *Eucalyptus* is a fast-growing genus that is generally used for pulp and building material. Pine plantations are used most often for building materials and pulp. Rubber plantations are used for rubber and latex as well as wood products like building materials. Some acacia species grow quickly and are used for pulp and paper. However, other species of acacia as well as teak grow more slowly, producing stronger woods that can be used for furniture, beams, and other higher-end wood products. Additionally, some tree plantations are used for non-wood products, like palm oil, rubber, and gum arabic (see Chapters 3 and 6).

It is difficult to determine how much of the world's wood products come from plantations; however, there are indications that production is moving away from primary forests and onto plantations (FAO 2010). India is an example of a country that has increased plantation area and wood production, while keeping most of its remaining primary forests intact (FAO 2010).

As a tool for reforestation, plantations can be beneficial. They can prevent soil erosion, combat desertification, and maintain water quality (Pokorny, Hoch, and Maturana 2010). However, replacing primary forests with monoculture production plantations has many negative environmental impacts. First, monocultures do not provide the same diverse, complex habitat as primary forests, thus reducing levels of animal and plant diversity (Brockerhoff et al. 2008). Also, substituting plantations for primary forests increases carbon dioxide emissions since young, small trees replace the large, old, carbon-rich ones (Liao et al. 2010). Finally, in some cases plantations need intensive management, requiring much water and fertilizer. This can augment water scarcity problems, and fertilizer runoff can cause local pollution (Kennan and Van Dijk 2010).

Restoring Degraded Forests and Reforesting Abandoned Land

Regeneration of degraded forests and reforestation of abandoned fields provide ways to increase tropical forests in places that have already experienced degradation and deforestation. Once reforested, these areas also may play an important role in meeting global demand for wood products, and managing these forests for production can reduce pressure on primary forests. According to the Global Partnership for Forest Landscape Restoration (2009) there are over 200 million hectares of degraded forest or abandoned land in the tropics that could easily be restored.

Mixed-species secondary forests can provide ecological diversity and complexity while supplying wood products (Lamb 1998). Managing these forests will require careful planning regarding where, when, and how to harvest; how to smooth the transition between the species planted in secondary forests and those remaining in primary forests (to improve biodiversity across the entire landscape); and making sure that sustainable management activities are profitable and incentivized (see the summary of relevant literature in Elias and Lininger 2010).

Mixed-species secondary forests can be very productive, and can be deliberately planted on highly degraded sites that cannot naturally regenerate. A study in tropical Australia compared mixed-species plantations and monoculture plantations, finding that most species were more productive (grew more quickly) when planted in mixes than in monocultures (Erskine, Lamb, and Bristow 2006). In addition, mixed-species and complex plantations provide ancillary benefits for animal biodiversity, protection against insect and pathogen attacks, and diversity of wood production.

Recent evidence indicates that substantial amounts of logging can move into other countries from developing countries working to decrease their own logging and increase their forest cover (Meyfroidt, Rudel, and Lambin 2010). Therefore, production from secondary forests, especially those on degraded lands, as an alternative to importing wood may be a critical step in protecting primary forests across the globe.

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The Forest Stewardship Council is a voluntary certification program providing timber producers with the opportunity to meet globally approved standards of sustainable management

Sustainable Management of Tropical Forests

It is likely that wood production from tropical forests will continue to grow over the next several decades. Therefore, to ensure that production does not lead to further destruction of tropical forests, wood products should come from either secondary forests or plantations, and demand growth rates should be slowed.

Strategies

Because tropical deforestation is meeting a global demand for wood products, it is likely that international policies and practices will be needed to adequately address this issue (Meyfroidt, Rudel, and Lambin 2010). Currently two international policies are in place or being developed that may help address timber as a driver of deforestation. Some of the 2008 amendments to the U.S. Lacey Act aimed to ensure that timber supply chains are legal by establishing the first ban on importing illegally sourced wood products (Environmental Investigation Agency 2008). The European Union is working on similar policies (Gulbrandsen and Humphreys 2006). Also in development are programs for direct voluntary, government, or commercial payments for conservation and sustainable management of tropical forests. Two of the most well known are payment for environmental services (PES) programs and reducing emissions from deforestation and forest


Doug Boucher

Reduced-impact logging practices include vine cutting, which prevents vines from pulling down trees that should remain standing

degradation, plus related pro-forest activities (REDD+) (see Chapter 11). These kinds of initiatives may provide income to local communities equal to those of timber concessions (Hardner and Rice 2002).

Reducing demand for tropical wood products may also help minimize pressure on these forests. Replacement—using a different species to create the same product—can be a useful tool in reducing pressure on primary forests. This can promote the use of species found in natural secondary forests or those that can be grown in plantations instead of species from primary forests. Often this simply requires changing consumer demand, but in other cases it may require research to determine how the properties of some species, such as strength, can be replicated by secondary forest or plantation species. Consumers can also purchase products with certification seals from an array of organizations that provide third-party verification of sustainable practices (see Chapter 11).

Recycling wood products has increased significantly over the past two decades, and with political support will continue to do so (Whiteman 2005). Improvements in recycling technology, availability, and financial support have increased, and can continue to increase, recycling efforts, which can further reduce pressures on primary forests.

On managed forests reduced-impact logging techniques may also support conservation. Practices for reduced-impact logging include training loggers, carefully identifying trees to log, cutting fewer trees, using animals (rather than machinery) to remove logs, and harvesting only under favorable soil-wetness conditions (Putz et al. 2008).

Improvements in recycling technology, availability, and financial support have increased, and can continue to increase, recycling efforts, which can further reduce pressures on primary forests.

Successes

There are success stories showing the feasibility of sustainable management of tropical forests. In Mexico, communities balance production and conservation. Forests here provide economic value from both timber and non-timber forest products such as coffee. They are also managed in such a way that protects biodiversity and provides for production over the long term (Bray et al. 2003). Community forestry has been successfully practiced in other countries as well, including Bolivia, India, Nepal, and the Philippines.

Voluntary certification programs provide timber companies with the opportunity to meet globally approved standards of sustainable management. One of the largest certification programs, the Forest Stewardship Council (FSC), has a specific set of criteria for managing tropical forests that is currently used on 16.7 million hectares of tropical forest (Forest Stewardship Council 2011). Voluntary certification programs are unlikely to solve deforestation problems alone; however, they can support government initiatives (Ebeling and Yasué 2009) and provide consumers with an opportunity to affect forestry practices. In the future, certification programs could be expanded to include impacts on a variety of issues of concern to consumers, including application of reduced-impact logging, protection of clean water and biodiversity, sustainable replanting techniques, and local community involvement.

Consumers and activists have also been able to put pressure directly on companies causing deforestation. Campaigns exposing the fact that illegal logging and commodities like palm oil are causing deforestation in Indonesia have had a significant impact on industry. Illegal logging appears to be decreasing, and large producers of palm oil have pledged to stop producing in newly deforested areas (Greenpeace International 2011; Lawson and Macfaul 2010).

Future Growth

International demand for wood creates a market worth billions of dollars per year, some of which is supplied through logging of primary tropical forests. Because supply from developed countries continues to fall while demand grows globally, it is likely that pressure on tropical forests will continue over the next couple of decades, causing degradation from selective logging as well as complete forest clearing. The timber and pulp industries are growing as drivers of tropical deforestation, and if demand continues to increase they can become even more important. However, sustainable production from forests is possible.

There are opportunities to reduce the pressure for deforestation and forest degradation caused by timber and pulp production in the tropics. First, increasing recycling, product replacement, and consumer awareness can help reduce the global demand for wood products from primary tropical forests. Second, production from restored and reforested areas provides an opportunity to supply wood while protecting primary forests. By managing forests on degraded land or abandoned agricultural land, tropical countries can continue to supply wood products while reducing pressure on their primary forests.

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Logging in Guyana

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CHAPTER 8

Wood for Fuel

Calen May-Tobin

FIRE HAS BEEN ESSENTIAL TO CIVILizations for millennia, providing heat in the cold, light in the dark, and warm food. So fundamental is fire that most ancient societies have a myth relating to its "discovery."

Since fire was first harnessed, wood has been the primary fuel for it. Although most of the developed world now gets the majority of its energy for cooking and heating from fossil fuels like coal and petroleum, wood fuels are still a major source of energy for people in developing countries. Here, wood fuels account for between 50 and 90 percent of the fuel used (FAO 2010). As populations in developing countries grew in the 1970s and 1980s, many believed there would be a massive wood fuel shortage and that an increasingly desperate population would move into untouched forests, causing massive deforestation. For the most part, these wood fuel shortages never came to pass, and while there was a large amount of deforestation in the tropics, little of it was a direct result of wood fuel use. However, the common belief that wood fuel collection is a major driver of deforestation has persisted, though there is little empirical evidence to back it up (Cooke, Köhlin, and Hyde 2008).

Even while concerns about wood fuels continue, they are increasingly looked at as a carbon-neutral fuel of the future. Wood fuel use has increased in recent years in the developed world, and more attention is being given to finding sustainable wood fuel for use in the developing world (FAO 2010). This chapter examines beliefs about wood fuels' role in deforestation, reviews the current state of their use in the developing tropics, and highlights some examples of sustainable industries and production methods.

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Charcoal is created by burning logs in a low-oxygen environment using mounds of earth or kilns, such as these in Brazil

Defining Terms: You Say "Fuelwood," I Say "Wood Fuel"

There are some important terms to note when discussing wood fuels. The terms "fuelwood" and "wood fuel" are often incorrectly used interchangeably. **Wood fuel** refers to any energy source that comes from woody biomass. These cover a range of fuels, including fuelwood (sometimes used synonymously with firewood), charcoal, industrial fuelwood, wood pellets, biogas, cellulosic ethanol, and other advanced forms of bioenergy. **Fuelwood,** or **firewood**, consists of any unprocessed woody biomass used to fuel a small fire, most often for cooking or warmth. In the developing world most firewood comes from dead woody material and small trees. **Charcoal** is a wood fuel made from burning wood in a low-oxygen environment. The dense black substance that results is made up mostly of carbon and produces more heat and energy per kilogram than wood. **Industrial fuelwood** refers to using a variety of wood fuels for industrial purposes, whether

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Women carrying firewood in the African Rift Valley

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iron smelting or tea processing. Some industries use charcoal, some use sawdust, while others use logs of specific species to achieve precise temperatures. This report focuses on firewood, charcoal, and industrial fuelwood since they are typically used in the tropics.

In most parts of Sub-Saharan Africa, firewood collection and trade is considered sustainable. Most material collected is already dead, and collection rates are typically below the regeneration rate.

Fuel for Fire: Misconceptions about Wood Fuel Use and the Firewood "Crisis"

Population growth in developing countries during the 1970s and 1980s led to substantial encroachment on forests throughout the tropics (Hiemstra-van der Horst and Hovorka 2009). Forests were cleared at an alarming rate as governments encouraged farmers to establish new agricultural lands (see Chapter 9). As populations increased and forests decreased, many worried that conflicts would arise as forest products, especially firewood, became increasingly scarce. This so-called firewood crisis dominated the policy discussion well into the 1990s (Hiemstra-van der Horst and Hovorka 2009). Further, it was argued that firewood scarcity was a major force leading to deforestation as rural populations cleared forests for new sources of fuel. This resulted in a number of policies that attempted to protect woodlands from firewood collectors and encourage the planting of trees for an additional source of firewood.

Beginning in the mid-1990s, however, researchers began to study the "firewood crisis" and discovered that for the most part, there was no crisis after all, only scarcity in some areas (Egeru et al. 2010). Even in areas where forests were cleared, there was not a shortage of firewood (Cooke, Köhlin, and Hyde 2008). Further, researchers found that in most areas firewood demand was not a driver of deforestation. Most of the forest clearing during that period was a result of agricultural expansion, and while a household might use some of the cleared wood for fuel, it did not cause the clearing. Just because firewood collection occurs on land where the forest was cleared does not mean that it was firewood collection that caused the clearing. It may simply be that the clearing provided firewood.

Furthermore, most firewood does not come from forests, but from trees in lots and woodlands outside of forests; therefore, wood from the clearing of forests was a minor part of the supply (Hiemstra-van der Horst and Hovorka 2009). Also, firewood primarily comes from dead branches or shrubs, not large, live forest trees. Even most firewood collected from intact forests consists of dead matter (Morton 2007).

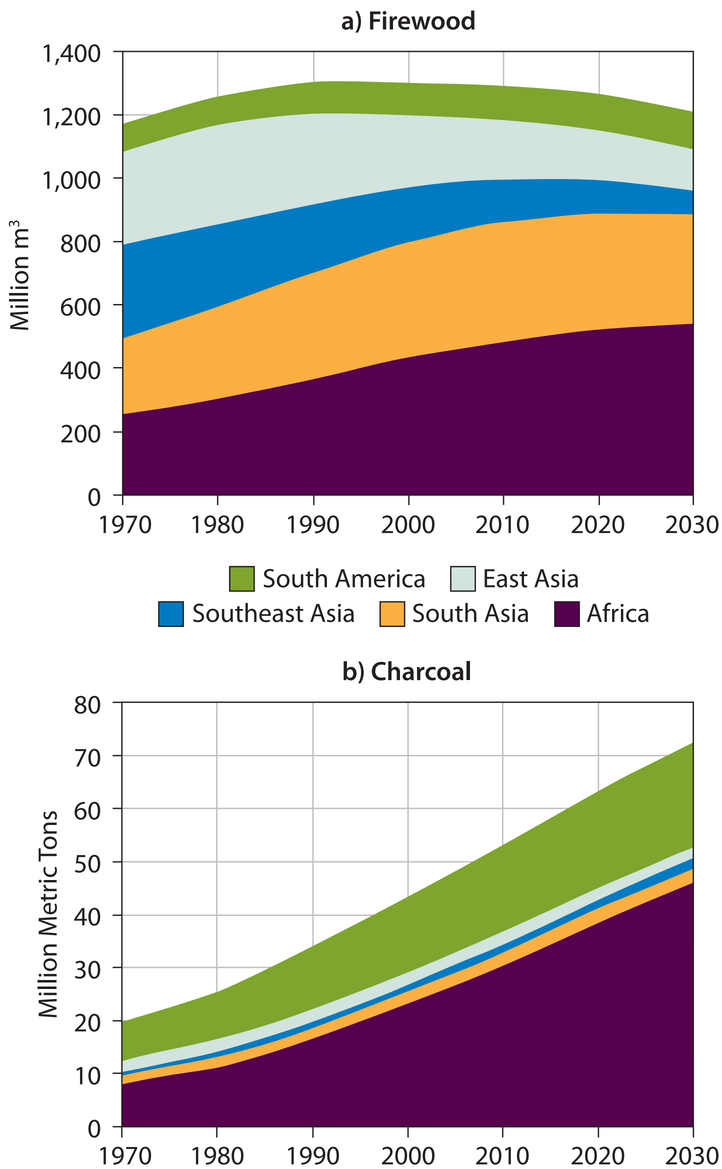
Despite empirical evidence that firewood does not drive deforestation on a large scale, many reports from development groups or NGOs still claim that firewood is a major driver of deforestation (Leplay and Thoyer 2011; Yengoh 2008). These reports use few peer reviewed sources, and those that do usually cite references from before the early 1990s. They tend to make sweeping statements like "small scale agriculture and firewood collection are major drivers of deforestation…" Again, most of these studies indicate that small-scale agriculture was what drove deforestation, so linking agricultural expansion to firewood in this way is misleading.

These studies also relied on misinterpretations of data from the Food and Agriculture Organization of the United Nations (FAO) to demonstrate their point. The most recent FAO data show that between 40 and 80 percent of wood products from tropical countries are used as fuel (FAO 2009). Many refer to this data to argue that firewood is a major driver of deforestation. However, as stated earlier, most firewood comes from outside of forests, consists of dead material, or comes from plantations. Even firewood that does come from forests (and is not already dead material) usually comes from small understory trees or shrubs. So, while the amount of wood collected may be large, it is not causing deforestation.

Fueling the Developing World

Although wood fuel is not a major driver of deforestation on a global scale, it can have significant effects at the local level (FAO 2010). The effects of wood fuels not only differ among regions, but also vary among fuel types, with charcoal being a problem in some areas and industrial fuelwood in others. Across the tropics about 1.4 billion cubic meters of firewood are used each year and around 40 million metric tons of charcoal are produced. Based on a wood-to-charcoal conversion rate of between 8 and 17, the global charcoal supply in tropical countries is between a quarter and a half of the firewood supply (these numbers vary greatly by region) (Figure 8.1).

Figure 8.1. Projections of Future Firewood and Charcoal Use in Developing Regions



a) Firewood consumption is expected to remain constant or decline over the next 20 years. b) Charcoal use is expected to increase over the next 20 years.

Source: Hofstad, Kohlin, and Namaalwa 2009.

Africa

For most regions of the world large commodity agriculture is the major driver of tropical deforestation. However, in Africa the importance local actions like wood fuel collection have in relation to land use change is higher. Particular attention has been paid to firewood use in the semi-arid tropical regions of Africa (Sahel and savanna), since for many years firewood collection

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Collecting firewood in Basankusu, Democratic Republic of Congo

was thought to cause desertification of the Sahel. However, it turned out that drought conditions existed before any expansion of firewood use (Benjaminsen 1993). In fact, most of the firewood came from trees that died off as a result of those droughts. In Uganda, for instance, firewood use seems to be sustainable, since families generally collect from small, fast-growing species (Naughton-Treves et al. 2007).

Most of the firewood is used in rural areas (FAO 2010). It is either self-collected or purchased from small dealers. While in some places women and girls are the primary firewood collectors, one cannot assume that is always the case. There is rather broad evidence from a variety of Asian and African countries that both men and women collect, and men may even be the primary collectors (Cooke, Köhlin, and Hyde 2008). Households tend to buy more firewood, rather than simply collect it, when there is a local scarcity. Farmers also sell firewood as a way to provide extra income (Hiemstra-van der Horst and Hovorka 2009).

In most parts of Sub-Saharan Africa, firewood collection and trade is considered sustainable (Hiemstra-van der Horst and Hovorka 2009). Most material collected is already dead, and collection rates are typically below the regeneration rate. Additionally, supply chains tend to be relatively short.

Charcoal production, on the other hand, has a greater environmental cost than firewood collection. It is made by burning large logs in kilns or in mounds of earth to create low-oxygen environments. Unlike firewood, charcoal usually comes from trunks or large limbs and requires cutting trees (Girard 2002). This means that charcoal requires some land clearing. Some studies suggest that around urban areas charcoal production is a cause of deforestation, but it can also follow timber harvesting and not be the initial driver of deforestation. For example, around the Tanzanian capital of Dar es Salaam researchers found that although charcoal production was heavy in the forest immediately surrounding the city, there were additional rings of degradation beyond that. Farther out, forests of medium-value timber were cleared, and beyond those, forests of high-value timber were cleared. This same pattern was observed at a later date, but all the rings had extended outward. This indicates that timber harvest is the initial deforestation agent, and charcoal production continues the deforestation process when the timber harvest is no longer profitable (Ahrends et al. 2010).

While charcoal may not always be the primary driver of deforestation, it can contribute significantly to degradation and destruction of forests that have already been disturbed (Hofstad, Kohlin, and Namaalwa 2009). In parts of Uganda, the pace of consumption of hardwood is currently faster than regrowth. It is possible to manage these stocks in a way that is sustainable through forestry practices, but those practices currently are too expensive for local producers (Naughton-Treves et al. 2007).

Unlike firewood, charcoal usually comes from trunks or large limbs and requires cutting trees. While charcoal may not always be the primary driver of deforestation, it can contribute significantly to degradation and destruction of forests that have already been disturbed.

Charcoal production, like firewood collection, is still done mostly on small local scales and used as a means of supplementing farmers' incomes. One study demonstrated that, on average, charcoal producers had smaller farms and less capital than farmers who did not participate. Because charcoal is easier to transport than firewood and also produces less smoke and sulfur fumes, it tends to be more commonly used in urban areas. Most charcoal is produced in rural regions and used in urban ones, so producers are not directly linked to consumers. A series of middlemen (traders and transporters) are necessary to complete the supply chain. They gain mostly from the charcoal trade, leaving less money for the producers (de Miranda et al. 2010).

Since the charcoal trade is so dispersed it is difficult for governments to control it (Girard 2002). In some cases massive charcoal production has fueled civil unrest (Box 8.1). Because urban populations are expected to increase (see Chapter 2), demand for charcoal is likely to grow. Thus, the charcoal industry is expected to have an increasing environmental impact.

Industrial fuelwood represents only about 10 percent of wood fuel use in Africa (Canadell, Raupach, and Houghton 2009). For the most part industrial wood fuels come from timber plantations, which are specifically grown for that purpose. Although industrial wood fuel does not come directly from forests, plantations can have an indirect role in deforestation. In one part of Uganda, for instance, the tea industry buys up large tracts of land to grow eucalyptus plantations (Naughton-Treves et al. 2007). This leaves less unused land for agriculture, causing farmers and others to clear forest in order to have sufficient land.

Asia

Asia is the region with the greatest use of wood fuels. Unlike Africa, where most wood fuel production is on a small scale, much of the wood fuels in Asia come from plantations. Of the roughly 8 million hectares of wood fuel plantations in the world, 6.7 million—an area larger than the state of West Virginia—are located in Asia (FAO 2010). Most plantations are located in China and India, countries that have already depleted most of their natural forests. There is some evidence that plantations help alleviate strains on natural forests (Kohlin and Parks 2001). Throughout most of the region wood fuels from plantations are used for preparing crops (e.g., tea and tobacco) and for the brick and ceramic industries. However, in India nearly two-thirds of plantations are non-industrial and the firewood is used for families and communities (Brown 1999). As in Africa, the majority of rural people in Asia rely on firewood as their primary source of fuel, but this is declining in most parts of the region (Hofstad, Kohlin, and Namaalwa 2009; Arnold et al. 2003). Charcoal is not heavily used in Asia.

Latin America

Of all the tropical regions, Latin America uses the least amount of wood fuel. In many Latin American

BOX 8.1.

An Illegal Charcoal Trade Threatens Biodiversity

One extreme example of the negative effects of the charcoal trade is Virunga Park (Nellemann, Redmond, and Refisch 2010). It is located in the Democratic Republic of Congo (DRC) near the borders of Uganda and Rwanda, and is one of the last remaining habitats for the endangered mountain gorilla. Beginning in the 1990s unrest in these three countries made Virunga an epicenter of conflict. Groups of rebels and national armies constantly use the park as their home base. Often these groups raise money by exploiting the land for minerals, timber, and the booming charcoal trade.

The illegal charcoal trade in the park is massive. It is estimated that rebels make around $28 million a

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The charcoal trade is threatening the mountain gorilla

year from this charcoal. Much of the work is carried out by prisoners held by rebels. Not only does this trade provide funds for rebel groups, it also threatens valuable biodiversity. In addition to destroying habitat, the rebels often rely on bushmeat for food. They have been known to kill gorillas in retaliation for charcoal seizures. To help combat the rebels and control the charcoal trade within the park, UNEP recommends strengthening the UN security presence in the region as well as instituting policies like REDD+ to help finance protection of the forest (Nellemann, Redmond, and Refisch 2010).

countries firewood is no longer the primary source of energy for rural populations. Brazil, for instance, introduced subsidies for natural gas use in the 1970s, and as a result many households have switched to propane for cooking and heating. Most wood fuel in the region is used for industrial purposes. In Brazil there is a great deal of concern over charcoal produced for the pig iron (an intermediate product in the iron-making process) and cement industries (Rose, Remedio, and Trossero 2009). Brazil is the largest consumer of industrial charcoal in the world, using around 7 million metric tons a year (Mugo and Ong 2006). While much of this comes from forests, Brazil is increasingly turning to eucalyptus plantations to meet these demands (Mugo and Ong 2006). As in other regions, charcoal use is expected to increase in the future.

Firewood use is expected to remain relatively level over the next 20 years, while charcoal use is expected to increase considerably. This increase in charcoal demand correlates with the expected increase in urbanization, as urban dwellers use more charcoal than rural ones. Therefore, it is worth developing more efficient and sustainable charcoal markets.

A Fuel for the Future?

Wood fuels have long been a major source of energy and are expected to remain so for some time. Firewood use is expected to remain relatively level over the next 20 years, while charcoal use is expected to increase considerably (Figure 8.1). This increase in charcoal demand correlates with the expected increase in urbanization, as urban dwellers use more charcoal than rural ones. There may also be increased competition for wood products if the demand for industrial wood fuels and

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Men gathering wood in Cuba

BOX 8.2.

Benefits of Reducing Charcoal Use

In developing countries, smoke-related illnesses affect many people, like this mother and child in Kenya

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Besides easing pressure on degraded land around urban areas, reducing charcoal use can have a direct effect on public health and climate. Indoor air pollution from charcoal stoves is a major cause of poor health in developing countries (Babanyara and Saleh 2010). According to the World Health Organization, 1.5 million people die prematurely each year due to indoor air pollution from cooking fuels. There are also 40,000 new cases of chronic bronchitis each year from soot and smoke. Reducing the use of charcoal and other domestic wood fuels can greatly improve the health of billions of people living in developing countries.

In addition to affecting public health, soot from biomass burning and other sources, also known as black carbon, is a powerful global warming agent (Hofstad, Kohlin, and Namaalwa 2009). One recent study suggests that black carbon is the second strongest contributor to global warming after carbon dioxide (Ramanathan and Carmichael 2008). Black carbon and other aerosols also play a major role in regional climate patterns (Menon et al. 2002).

other advanced bioenergy increases. Given that charcoal production can lead to forest degradation, such an increase is cause for concern.

Substantial research has gone into making charcoal use and production more sustainable. Many efforts focus on improving the efficiency of charcoal-burning stoves. These have not always been successful because of the high cost of the stoves and fragility of the ceramic liners in the more efficient stoves. However, some projects are successful because of more efficient stoves. Likewise, improving the efficiency of charcoal production can minimize the environmental effects of charcoal. Improved kilns not only decrease the amount of wood needed to produce charcoal, but can decrease the amount of carbon dioxide lost in the atmosphere (Girard 2002).

Switching to plantation species as a means of producing charcoal can also serve to make the industry less environmentally damaging (Girard 2002). In Brazil, for example, efforts are being made to use FSC-certified eucalyptus plantations to supply the charcoal industry (FAO 2010). Improving efficiencies or reducing use can have a number of other benefits as well (Box 8.2).

Another option, particularly for urban areas, is to find an alternative source of energy. Providing electricity to households has been proposed as an alternative to fuelwood. However, at least one study in South Africa demonstrated that even after electrification, many households still relied on firewood (Madubansi and Shackleton 2007). There are a number of reasons for this. First, using electricity to cook is thought to be slow and inefficient. Second, firewood in some cases is cheaper than electricity. Third, cooking and heating with electricity require expensive appliances. There are other options for urban fuel sources (e.g., kerosene or propane), but these also have drawbacks, such as high cost (Knöpfle 2004).

Beyond improving efficiencies, there are some community-level policy options being implemented that can make the trade of wood fuels more sustainable. In Africa a set of policies to encourage community-based wood production (CBWP) has had some success in making wood production sustainable in certain areas

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Using charcoal for blacksmithing in Burkina Faso

(de Miranda et al. 2010). These programs arose because those who lived closest to forests and wood fuel sites were often exploited by urban producers and traders who received exploitation rights from state or national agencies. Under CBWP schemes, communities are given specific rights to their lands by resource agencies and the locals are then responsible for issuing permits. Communities can establish quotas and collect a tax on wood fuels, ensuring that more money stays in the community. In Senegal and Niger, CBWP schemes have led to an increase in forest cover. The nature of the wood fuel markets (many small producers and traders) makes them hard to regulate at a national level, but CBWP programs allow for diffusion of that regulation, which can lead to greater enforcement and sustainability.

Conclusion

Wood fuels are still the major source of energy for much of the developing world. As a whole, wood fuels are not a major driver of deforestation around the globe, but they can have negative effects at the local level. This is particularly true of charcoal production, which is expected to increase in the future. Therefore, it is worth developing more efficient and sustainable charcoal markets. Using fast-growing plantation species rather than slow-growing hardwoods, increasing efficiencies of charcoal kilns and stoves, and finding alternative sources of energy can reduce the impact of charcoal production. Further, developing strategies by which small- and medium-scale charcoal production is controlled and regulated by local communities can make the charcoal trade more sustainable.

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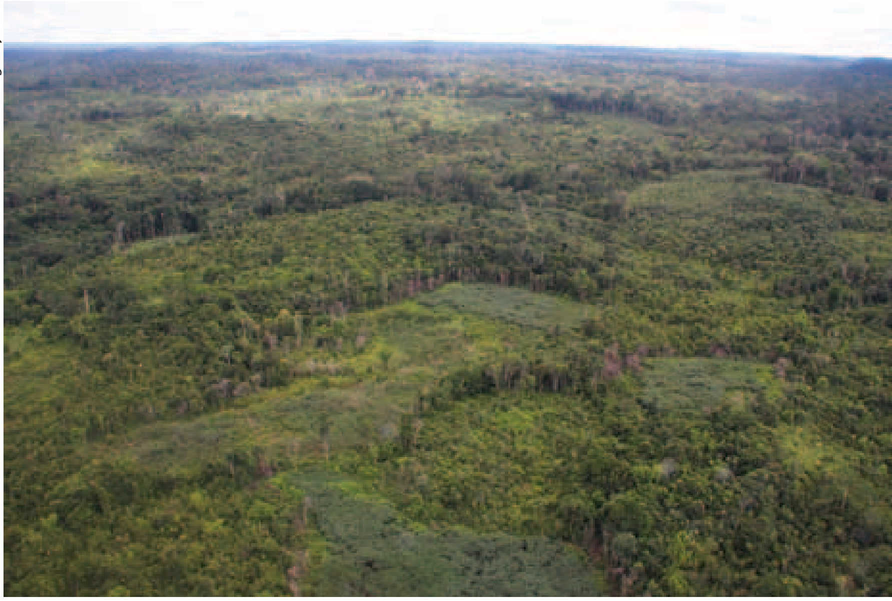
CHAPTER 9

Small-Scale Farming and Shifting Cultivation

Katherine Lininger

THROUGHOUT THE WORLD THERE are about 70 million people living in remote tropical forests and about 800 million rural people living in or near tropical forests and savannas (Chomitz 2007). Tropical forests are important for the livelihoods of many communities and indigenous peoples as a source of food, income, fuel, medicine, and land for farming—which can lead to replacing forests with small-scale agricultural fields. Historically, small-scale farming and shifting cultivation have been seen as major causes of deforestation in the tropics, but this assumption is outdated. Much evidence now indicates that commercial agriculture and other drivers, not small farmers or shifting cultivators, are the main drivers of deforestation in the areas of the tropics in which most deforestation is taking place (DeFries et al. 2010; Rudel et al. 2009; Geist and Lambin 2002).



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Shifting cultivation in the rain forest of southern Suriname

Defining Small-Scale Farming and Shifting Cultivation

Small-scale farming involves growing crops, at least in part, to be used by an individual family, with farming being a significant source of their livelihood. **Subsistence farming**, however, implies that farm production is solely for the family's livelihood and farm products are not sold at a market; most small farmers do sell their crops at local or national markets. **Shifting cultivation**, a type of small-scale farming, typically involves clearing the land, burning much of the plant material, planting and harvesting crops, and then abandoning the plot of land (letting the land go fallow) before moving to a new plot. During the fallow period, the forest vegetation re-grows and can be re-burned at a later date, adding nutrients to the soil for future cropping. Since shifting cultivation in the tropics is mainly practiced on nutrient-poor soils, forest vegetation regrowth and re-burning is important for crop growth. Furthermore, weed, pest, and crop disease populations decline. Fallow periods in a shifting cultivation system vary and can be long enough for forests in abandoned plots to regenerate. Shifting cultivators can therefore maintain a mosaic landscape in which fields move around in the midst of other plots of land that have been abandoned at different times, with plots of fully regenerated or partially regenerated forests, or recently abandoned fields. Shifting cultivation can imply a diverse set of farming practices, and in some cases fallow land is partially planted with tree crops for subsistence use or additional income. Many shifting cultivators are semi-subsistence and small-scale farmers in tropical rainforest areas (Mertz et al. 2009; Hassan, Scholes, and Ash 2005; Giller and Palm 2004).

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Women, like this woman in Kenya, play a major role in small-scale agriculture, particularly in Sub-Saharan Africa

Currently, fewer shifting cultivators can allow for long fallow periods and regeneration of forests because they do not control large enough areas due to population densities, political pressures, and economic demands in tropical regions. The historical system of shifting cultivation, which can be sustainable in areas with low population densities and large land areas, is rare and has mostly been supplanted by agricultural intensification (Chomitz 2007; Sanchez et al. 2005). With higher population densities and increased land pressures, fallow periods become shortened, weeds and pests build up, and soil nutrients and land productivity decline, making the system unsustainable (Hassan, Scholes, and Ash 2005; Sanchez et al. 2005; Giller and Palm 2004).

Shifting cultivation is also commonly known as "swidden" or "slash-and-burn" agriculture. However, distinctions can be made between the terms shifting cultivation and slash-and-burn agriculture. Traditional shifting cultivation refers to systems with long fallow periods allowing for forest regeneration, while slash-and-burn agriculture more generally refers to farming practices in which cutting and burning the forest is involved. Slash-and-burn agriculture may or may not involve long fallow periods, and can be characterized as either large-scale or small-scale. In many places in the tropics, traditional shifting cultivation is practiced by indigenous peoples who have inhabited remote forest areas for a long time, whereas migrant farmers living at the forest edge may be practicing small-scale slash-and-burn-agriculture without incorporating long fallow periods (Sanchez et al. 2005).

Small-scale farmers cultivate many types of crops depending on the region. For example, in Indonesia many small farmers grow rice along with other food crops (Partohardjono et al. 2005). In Cameroon, plantains, cassava, peanuts, cocoa, and maize are cultivated (Gockowski et al. 2005). For tropical regions broadly, some of the most important cereals grown for food include grains like rice, maize, sorghum, and millet. Cassava, sweet potatoes, and bananas are also important foods (Norma, Pearson, and Searle 1984).

Women play a major role in small-scale agriculture, particularly in Sub-Saharan Africa, where they make up the majority of farmers. Women are increasingly involved in small-scale farming in Latin America as well (Mehra and Rojas 2008; World Bank 2007). Thus, when thinking about ways to address deforestation caused by small-scale agriculture, it is important to include women in decision-making processes and the establishment of alternatives to deforestation.

No Longer Major Drivers of Deforestation

Historically, small farmers, and more specifically shifting cultivators, have been seen as the chief agents of deforestation in the tropics. However, recent data indicate that small-scale farmers and shifting cultivators do not cause the majority of deforestation, particularly in those tropical areas with the most deforestation. Regional differences in this trend exist, but in general small farmers are most important in areas where deforestation rates are lowest (Rudel et al. 2009; Geist and Lambin 2002).

From 2000 to 2005, the majority of humid tropical deforestation occurred in Latin America, accounting for three-fifths of forest cover loss, and in Asia, accounting for one-third of the forest loss. The highest percentages of humid tropical forest loss relative to total loss occurred in Brazil (47.8 percent) and Indonesia (12.8 percent) (see Chapter 3) (Hansen et al. 2008). In these regions of high deforestation, case studies indicate that before about 1990, small farmers who responded to government policies encouraging colonization and migration to forest frontier areas were frequently identified as the main cause of deforestation. After

1990, deforestation became more "enterprise-driven" in the Amazon and Southeast Asia (Rudel et al. 2009).

This "enterprise-driven" deforestation in the Amazon has been caused mainly by large-scale cattle ranching (see Chapter 5) and soybean production (see Chapter 4). In Indonesia and Malaysia, palm oil plantations and logging have been the main drivers of deforestation and degradation, especially in recent years (see Chapters 6 and 7) (Wicke et al. 2011; Rudel et al. 2009; Fearnside 2008). The traditional practice of shifting cultivation in Southeast Asia has been declining, and this system is being replaced by permanent cropping and commercial plantations (Padoch et al. 2007).

These commercial enterprises are linked to urban markets and global demand for agricultural commodities, unlike subsistence farmers (Rudel et al. 2009). Migration to cities and urban population growth, and subsequent urban demand for agricultural products, have been shown to be related to increasing tropical deforestation, particularly in Asia and Latin America (see Chapter 2). Similarly, increases in agricultural exports are also linked with additional forest clearing. Most subsistence farmers and small farmers living in rural areas are not connected to international agricultural exports. While small farming operations still play a role in deforestation in the Amazon and Southeast Asia, large-scale commercial enterprises now predominate (DeFries et al. 2010).

Tropical forest loss in Africa, on the other hand, is caused more by small-scale agricultural activities and less by large-scale commercial agriculture (DeFries et al. 2010; Fisher 2010; Rudel et al. 2009). In many parts of Africa, firewood collection and wood fuel for charcoal is another source of income to small farmers (see Chapter 8) (de Miranda et al. 2010; Hiemstra-van der Horst and Hovorka 2009). But, in Africa, deforestation rates are relatively low (Hansen et al. 2008). There is not massive clearing like in many Southeast Asian and Amazon basin countries, and Central African countries with large tropical forests are termed "high forest, low deforestation" countries (da Fonseca et al. 2007). However, large-scale economic development, such as industrial logging, has been linked to deforestation in Central Africa (Laporte et al. 2007).

While Central Africa has large, sparsely populated rain forests, East and West African rain forests are more densely populated and smaller, with diminished forest area. Small farmers in these regions frequently produce crops for urban markets. In addition, in Central America the forests have high population densities and smaller forests, and small farmers still play an important role in deforestation in this region as well (Rudel et al. 2009).

There are also smaller regions of tropical forest where small farmers continue to drive deforestation. In Papua New Guinea, for example, the impact of subsistence farmers is quite significant. From 1972 to 2002 subsistence farming was found to be the second largest cause of deforestation, with 45.6 percent of forest change attributed to it. Yet even here, the main driver of deforestation during these years was commercial logging, associated with 48.2 percent of forest change. In addition, Papua New Guinea is a country with unique conditions that explain this pattern, such as a high rural population. Much of the subsistence farming occurs

Patrick Meyfroidt

Small-scale farming in Vietnam

in highland areas, a type of terrain that makes establishing commercial agriculture difficult (Shearman et al. 2009).

What Causes Deforestation by Small Farmers?

There are underlying reasons for the actions of small farmers and shifting cultivators. Road and infrastructure development in tropical forest regions has given migrant farmers access to previously inaccessible forest areas. In some regions, poverty-driven deforestation can occur if small-scale and subsistence farmers lack resources or secure land tenure and are forced to move into forested areas to grow food and earn their livelihoods (Sanchez et al. 2005; Geist and Lambin 2002). Particularly in Sub-Saharan Africa, small-scale farmers who lack resources for increasing crop productivity on nutrient-depleted soils may use additional forested lands to maintain production and their livelihoods (Palm et al. 2010).

However, the generalization that poverty causes deforestation is not necessarily true, either. Wealthier farmers are better able to deforest land, especially large tracts of land, since deforestation can be costly and difficult (Chomitz 2007). For example, in the state of Para in the Brazilian Amazon, wealthier smallholder farmers deforested at a higher rate than poorer smallholder farmers. Small-scale subsistence farmers with little connection to markets deforest less, highlighting the importance of commercial markets and urban and international demand as underlying causes of deforestation (DeFries et al. 2010; Pacheco 2009).

Much evidence now indicates that commercial agriculture and other factors, not small farmers or shifting cultivators, are the main drivers of deforestation in the areas of the tropics in which most deforestation is taking place.

In the past, government-sponsored colonization programs facilitated the movement of landless migrants to the frontiers of tropical forests (Rudel et al. 2009; Sanchez et al. 2005). In the 1960s and 1970s, the cold war and the Cuban revolution encouraged rural movements for land reform in Latin America and Southeast Asia. Governments responded with colonization programs to provide small farmers with land in remote forested regions, since this was easier than taking land away from large farmers. In order to help this colonization effort, governments built roads into rain forests. With the fall of the Soviet Union and the end of the cold war, this motivation for state-initiated deforestation disappeared (Rudel et al. 2009).

Small Farmers and Forests in the Future

Although small farmers and shifting cultivators are not the main drivers of deforestation in regions where most deforestation takes place, they do contribute to it. In the long run, reducing their impacts on deforestation might be more difficult than reducing deforestation from large-scale commercial agricultural or logging operations (Shearman et al. 2009). Pressure can be applied by citizens and non-governmental organizations to stop large companies from deforesting, funding deforestation, or buying products generated by deforestation (see Chapters 4, 5, and 10). These companies are powerful entities, but they are extremely sensitive to reputational risk. On the other hand, it may be more difficult to develop the new systems that ensure small farmers and shifting cultivators retain their livelihoods without additional deforestation.

Thus, solutions to deforestation must include and benefit local communities. Community forestry involves a group of people practicing sustainable management of forests; social and economic benefits to them are a central goal. This approach can be an alternative source of income to slash-and-burn agriculture for small farmers. In addition, policies that encourage and help farming communities develop agroforestry systems, such as shade-grown coffee or cacao, could provide alternative livelihoods. Intensification of small-scale agriculture can also reduce agricultural expansion into forested areas if the correct incentives are in place (see Chapter 11) (Palm et al. 2010).

The international policy known as REDD+ (reducing emissions from deforestation and forest degradation, plus related pro-forest activities) can place value on standing forests and provide economic incentives for a) reducing carbon dioxide emissions resulting from deforestation and b) increasing sequestration of carbon through forestry practices. In these programs, establishing land tenure and other entitlements for small farmers, indigenous peoples, and other stakeholder groups such as women is important for the inclusion of small farmers in a REDD+ system (see Chapter 11). Such international policies can benefit shifting cultivators and small-scale farmers if structured correctly and equitably (RRI 2011; Mertz 2009).

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CHAPTER 10

Successes

Katherine Lininger and Doug Boucher

THE DRIVERS OF TROPICAL DEFORESTATION are varied, and different strategies to address them are necessary. However, there have been recent declines in deforestation and in the resulting carbon dioxide emissions. These success stories show that solutions are possible and how critical it is to continue reducing deforestation—the most effective approach for addressing global warming.

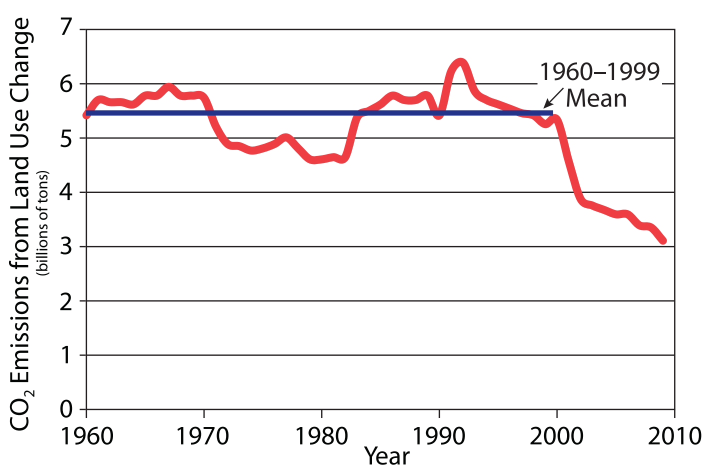
The Global Decline in Tropical Deforestation

Recent data indicate that global tropical deforestation has declined since the 1990s. In the first decade of the 2000s, tropical deforestation was down 18 percent from the level of the 1990s, dropping from 11.3 million hectares per year in the 1990s to 9.3 million hectares per year in the 2000s. Furthermore, the rate dropped from the first five years of the decade to the second five years, principally due to a dramatic decline in Brazilian Amazon deforestation. The rate of primary forest loss, not just total forest loss, has also declined (FAO 2010; Friedlingstein et al. 2010).

In annual estimates of emissions due to land use change since the 1960s, almost all came from deforestation. There was also a decline in emissions in the first decade of the 2000s (Figure 10.1). Emissions have fallen from an average of 5.32 billion tons of CO_2/year in the twentieth century (1960 to 1999), to just 3.23 billion tons in 2009. This is a decrease of 39 percent in just a decade, after four decades with no decrease at all. Furthermore, unlike the case for the previous four decades, the twenty-first century trend has been consistently downward; every single year since 2000 had the same or lower land use change emissions than the previous year (Friedlingstein et al. 2010; Global Carbon Project 2010).

The global decline in deforestation and emissions from land use change is encouraging, but this information hides differences from country to country, with some countries making more progress in reducing deforestation than others. Declines in deforestation in Brazil and Indonesia—the country with the most tropical forest and the country with the most deforestation, respectively—have greatly contributed to this global decline (Friedlingstein et al. 2010).

Figure 10.1. Estimates for Land Use Change Emissions, 1960–2010



Estimates for land use change emissions, almost all of which come from deforestation, converted from billions of tons of carbon to billions of tons of carbon dioxide (multiply by 3.67). The blue line shows the mean for twentieth-century data (1960–1999). In 1960 emissions were 5.32 billion tons, and in 1999 they were 5.17 billion tons.

Source: Friedlingstein et al. 2010.

Brazil's Reduction of Deforestation

In December 2010 the annual summary of data from the Brazilian National Space Institute, INPE, announced another substantial reduction in deforestation. From 2009, Brazil had reduced deforestation by an additional 14 percent, cutting deforestation to 6,451 km²

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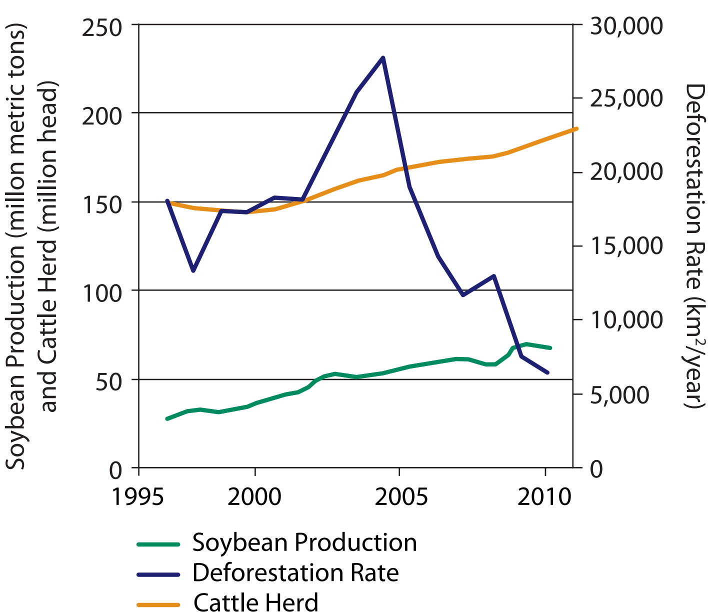
compared with an average of 19,508 km^2 during the baseline period from 1996 through 2005. This is a 67 percent decrease in just five years (INPE 2010a). Brazil established a national plan to reduce its deforestation rate 80 percent by 2020 compared with the baseline decade and to make this goal part of its national law. It nearly reached its goal a decade ahead of schedule (Government of Brazil 2009). Brazil's reduction from its baseline period amounts to 870 million tons of CO_2 annually (Union of Concerned Scientists analysis based on IMAZON 2010 and INPE 2010b).

Brazil's reduction in deforestation has also been fully compatible with increasing agricultural production and significantly reducing hunger and poverty. During the last decade the country has enjoyed a high rate of gross domestic product (GDP) and exported large amounts of beef and soy, despite the world recession (Figure 10.2) (FAS 2011; The World Bank 2011). Moreover, through social programs such as Fome Zero (Zero Hunger) and Bolsa Familia (Family Allowances), Brazil has lifted more than 10 million of its citizens out of poverty and substantially lowered its rates of hunger and malnutrition (Chappell and LaValle 2011; Rocha 2009).

Figure 10.2. Deforestation and Cattle and Soybean Production in Brazil



Both cattle and soybean production have continued to increase steadily in Brazil in the past several years—even as deforestation rates have dropped to record-low levels.

Sources: FAS 2011; INPE 2010b.

This reduction in emissions was the result of many factors. Brazil has invested in enforcement and monitoring to stop illegal logging activities. It has greatly expanded protected areas and indigenous reserves in the Amazon region, and now over half of the Brazilian Amazon is legally protected land, including indigenous lands, strictly protected lands, and sustainable-use areas. These lands have been effectively protected and deforestation has been reduced (Figure 10.3) (Soares-Filho et al. 2010). For small and medium landholders in the Amazon, Brazil is regularizing and establishing land titles and then monitoring these areas so illegal deforestation does not take place (SECOM 2010).

In addition, Brazil has used funds from the Amazon Fund, which was set up to help reduce deforestation, and from its National Climate Fund for a range of activities that help contribute to its reduction in deforestation. Through these funds, Brazil is supporting sustainable forest management and development, conservation, restoration of degraded lands, and many other activities to help reduce deforestation. Norway has made a $1 billion commitment to the Amazon Fund that will be disbursed between 2008 and 2015 for reductions in deforestation emissions (SECOM 2010).

Brazil's citizens played a critical role in exerting pressure on government leaders and businesses that influence deforestation. The Zero Deforestation campaign, for example, which was launched in 2008 by a broad coalition of environmental, indigenous, rubber-tapper (traditional collectors of the sap of native rubber trees, which they sell for uses such as surgical gloves), human rights, and other NGOs, played an important role in pushing the federal government to act. In 2006 and 2009, Brazilian NGOs also conducted widely publicized exposés of the roles that the soybean (see Chapter 4) and beef (see Chapter 5) industries have played in deforesting the Amazon. The resulting publicity led to commitments from those industries to not sell products raised on deforested land (Amigos da Terra–Amazônia Brasileira 2009; Greenpeace International 2009). Research institutes in Brazil such as IPAM (the Amazon Environmental Research Institute) and IMAZON (the Amazon Institute of People and the Environment) have been important in monitoring progress and showing how ranchers, farmers, and loggers can increase their productivity in ways that make deforestation unnecessary.

Brazil has made great progress in reducing deforestation, but the drivers of deforestation must be continuously addressed. Government policies could be weakened, and increases in world soy and beef prices along with proposals to develop new roads and dams in the Amazon would create new pressure for deforestation. Thus, increased efforts are required to protect the progress made so far.

More Progress: Additional Countries Reducing Deforestation

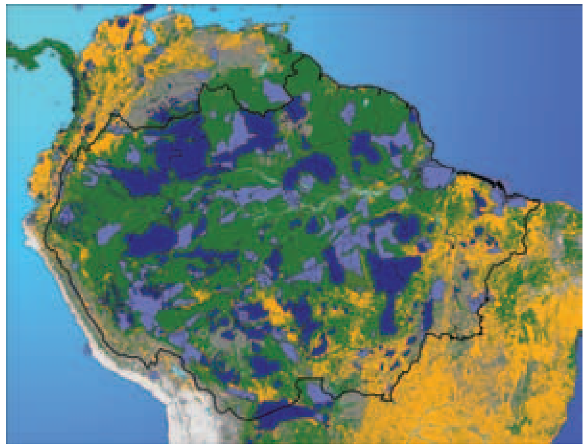
Other tropical countries besides Brazil have made progress in reducing deforestation. For example, Indonesia greatly reduced its deforestation rate from 2000 to 2005 compared with the 1990s. From 1990 to 2000, Indonesia averaged 1.78 million hectares per year of forest clearing, while from 2000 to 2005 the annual average was reduced to 0.71 million hectares per year. However, over the years from 2000 to 2005, the rate of forest clearing gradually increased, so it was unclear whether the downward trend in deforestation rates would continue (Hansen et al. 2009). But preliminary information suggests that deforestation peaked in 2006 and has been gradually declining each year up until 2010 (Hammer et al. 2010).

There are also a few tropical developing countries that have undergone a "forest transition," in which deforestation has slowed, reforestation is occurring, and on the whole the forest area in the country is increasing. In Vietnam, for example, forest area has grown from the early 1990s and continues to increase due to reforestation policies, better land management, and the intensification of small-farmer agriculture (Meyfroidt and Lambin 2009; Meyfroidt and Lambin 2008). Some of the deforestation that occurred in Vietnam was displaced to other countries since restrictions on wood extraction caused more wood imports from neighboring countries. However, more than half of the forest regrowth did not cause additional deforestation elsewhere, and thus Vietnam contributed a net gain to global forest cover (Meyfroidt and Lambin 2009). Other tropical countries that have undergone this transition include El Salvador, Gambia, Rwanda, and India (Meyfroidt, Rudel, and Lambin 2010). Mexico is another country in which a forest transition may be taking place (Klooster 2003).

Implications of Success

When efforts to counter the drivers of deforestation are successful, what will happen? How will deforestation change in terms of where it happens, who does it, how it is distributed, and what its causes are? How will the relative importance of deforestation versus forest degradation be altered, and where will new pressures develop?

Figure 10.3. Map of Amazon Indigenous Lands and the Protected Areas Network



This map of the Amazon basin (within the black line), shows indigenous reserves (dark blue) and other protected areas (light blue). Deforested areas are shown in yellow.

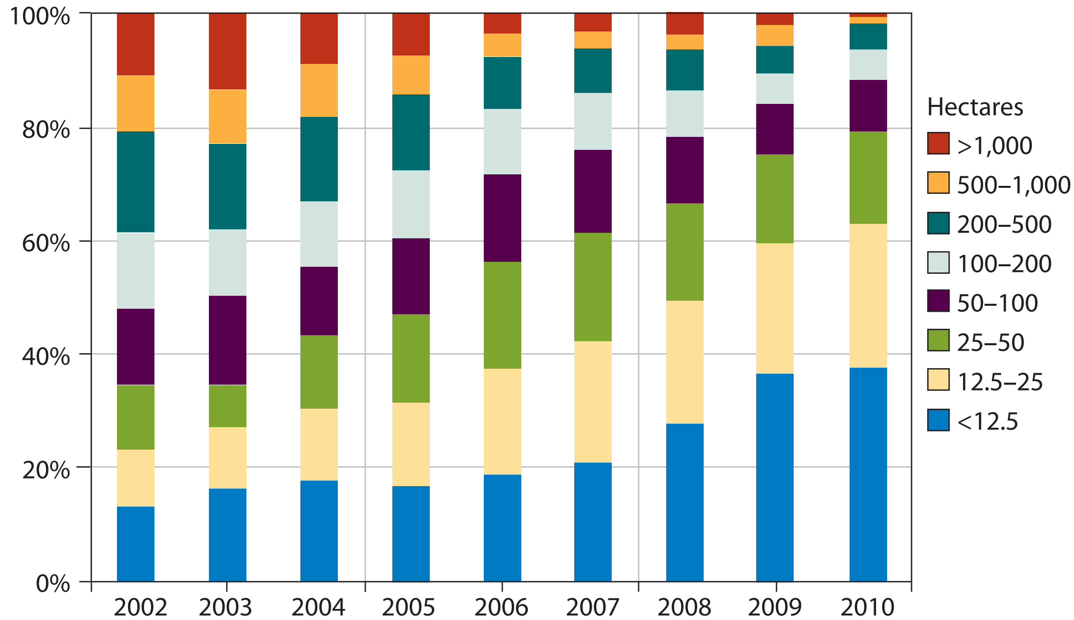
Source: Lefebvre 2011, Woods Hole Research Center.

Although we do not yet have models that allow us to answer these questions based on empirical data, there are some predictions that can be made and tested. We would expect that if efforts to counter the current drivers are successful, then future deforestation will:

- Be seen in smaller patches and on smaller farms and ranches. This is simply because as large deforesters are stopped, what remains is likely to consist more of smaller deforesters. The decreasing size of deforestation patches in Brazil since the early 2000s is a confirmation of this pattern (Figure 10.4, p. 98).
- Be due relatively more to forest degradation compared with deforestation. As deforestation decreases, more of the remaining emissions will be due to degradation.
- Produce a more mixed set of commodities, with less dominance regionally by single industries. Farms and ranches with a diversity of products and regions with a mix of producers are more likely to characterize where deforestation occurs, as large-scale industries such as soy or palm oil decline in importance as deforesters.

If these predictions are correct, then future reductions in deforestation will depend more on REDD+ programs and policies (reducing emissions from deforestation and forest degradation, plus related pro-forest activities) than in recent years. The large industrial drivers have not been compensated for their losses as they decreased deforestation, nor did they deserve to be.

Figure 10.4. Deforested Patches in the Brazilian Amazon by Size, 2002–2010



Deforested patches in the Brazilian Amazon have changed in size as the overall rate of deforestation has declined. In the early 2000s large areas of deforestation (over 50 hectares, or 125 acres) made up most of the deforested area, but by 2010 the majority of deforested areas were patches of 25 hectares or less; patches larger than 50 hectares comprised less than a fourth of the total.

Source: INPE 2010a.

Rather, countries have received compensation for lost tax income and the costs of sustainable development programs (e.g., Brazil through its REDD+ agreement with Norway). As the large enterprises diminish in importance, further progress will depend more on REDD+ support for smaller farmers, indigenous groups, and sustainable harvesters (e.g., rubber tappers).

As Drivers Are Displaced

Another prediction we can make with a good deal of confidence is that some of the drivers of deforestation will be displaced to other countries and continents. Leakage is not an accident; it is the inevitable result of economically driven deforestation in a globalized world. There is no way to prevent it from happening entirely; the point is to minimize it, restrict it, and guide it to places where it does the least environmental and social damage (Lambin and Meyfroidt 2011). It is difficult to generalize about the social effects of displacement, but in terms of climate change and biodiversity there are clearly better and worse places where deforestation can leak.

First, and most obvious, is that it is preferable for the displaced drivers to move into non-forested habitats. Forests, in the tropics and elsewhere, typically have the highest levels of both carbon and biodiversity in a region. While secondary and disturbed forests are likely to be lower in these factors than primary forests, they too can be important for wildlife and other species, and if allowed to restore themselves through natural succession will gain both carbon and biodiversity as time goes on. Thus it would be best to avoid forested areas entirely and have production moved to cleared lands.

But not all cleared lands are equal. Savannas and related biomes that occur naturally, such as the *cerrado* of Brazil, are often a mélange of ecosystems, some retaining high carbon and biodiversity and others quite degraded and dominated by a few, often exotic, species (see Chapter 3). The *cerradão* part of the *cerrado*, for example, is a highly diverse, carbon-rich vegetation type, while the *campo limpo* is a much lower-diversity grassland lacking trees and shrubs, often due to past overuse. Other things being equal, the second is preferable as a place for soybean production to move.

Looking at the tropics more broadly, cleared lands now dominated by grasses—particularly degraded ones with exotic grasses—are the logical places for agriculture to expand, at least from the biological and climate points of view. There are large areas of this kind in all three of the tropical forest continents—savannas in South America and especially in Africa, and grasslands dominated by cogon grass (alang-alang, *Imperata cylindrica*) derived from past clearing of forests in Southeast Asia. Social and economic questions, such as who owns or has traditionally used the land, should override purely scientific recommendations in specific areas, but overall the guidance should be: agriculture in grasslands, not forests.

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This shade-grown coffee in Mexico is an example of agroforestry, which offers a way for communities to develop without further deforestation

CHAPTER 11

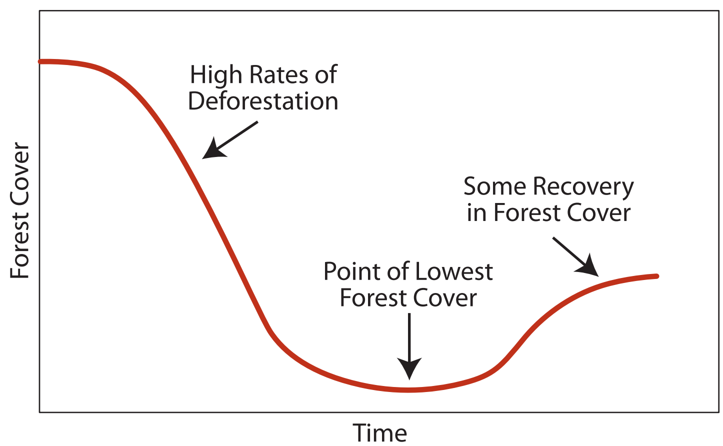
Development without Deforestation

Pipa Elias, Katherine Lininger, Calen May-Tobin, and Sarah Roquemore

TRADITIONALLY, ECONOMIC DEvelopment has occurred at the expense of a country's natural resources. In forested countries the trend is typically a high rate of deforestation during development, which eventually slows down and is ultimately reversed (Figure 11.1). This pattern, referred to as the **forest transition**, has already occurred in many developed nations and some developing ones. However, the path from net forest loss to net forest gain can be a long one. To help forested developing countries reverse deforestation more quickly, they must have the opportunity to develop economically without destroying their forests.

It is impossible to create policies, incentives, and systems for sustainable development and forest conservation without addressing the drivers of deforestation (Pfaff et al. 2010). Therefore, promoting development without deforestation will require reducing demand, moving agriculture and forestry onto non-forested land, or intensifying production on existing land. This chapter focuses on agricultural and forest management practices to promote development and economic productivity without increasing deforestation. These practices will need to occur in conjunction with other economic, social, and governance development strategies. Although of vital importance, these complementary policies will not be addressed in depth in this report.

Figure 11.1. The Forest Transition Curve



The forest transition curve along which forest cover decreases with development until it reaches a low point, after which it recovers somewhat.

Source: Meyfroidt, Rudel, and Lambin 2010.

Keeping Food Out of Forests

As tropical countries develop, they will need to produce increasing amounts of food and agricultural products in order to feed their populations and improve their health and welfare (see Chapter 2). To meet these demands, farmers often spread to new areas, a process known as extensification. In the 1980s and 1990s, forests were the major source of this new agricultural land in the tropics (Gibbs et al. 2010). Increasing agricultural yields instead of expanding onto new lands is generally referred to as intensification. This is also occurring in the tropics. For instance, from 2000 to 2005 agricultural production increased 3.3 to 3.4 percent annually while deforested land for agriculture only increased by 0.3 percent, so most of the increase in production must have come from intensification of current agriculture rather than from expansion of agricultural land (Angelsen 2010). This intensification over the last 30 years has already mitigated some global warming pollution by preventing emissions from deforestation (Burney, Davis, and Lobell 2010).

However, in order to meet future demand, agriculture in the tropics will have to intensify even more rather than clearing additional forest (Foresight 2011). With market pressure driving the demand for agricultural commodities, a combination of government policies, civil society pressure, and improved agricultural practices will be needed to decrease the demands on tropical forests.

John H. Vandermeer

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Conservation tillage, shown here in Mexico, leaves crop residues from the previous harvest on a field, which can reduce the loss of topsoil

When Intensification Promotes Deforestation

In the past, agricultural intensification has been encouraged through incentives that apply to all regions of a country. Since they are not specific to different landscapes, these "placeless" incentives often lead to increased deforestation even while encouraging increased intensification (Angelsen 2010). This may seem counterintuitive, but it in fact makes economic sense. If a farmer on the agricultural frontier increases his or her yield per hectare, then profits will rise as well. The smart economic choice is to reinvest those profits for future growth, and the best way to do that is by buying cheap forest land for crop expansion. However, this leads to further deforestation. For instance, a study of farmers in Tanzania showed that a 1 percent increase in output price leads to a 1 percent increase in agricultural land (Angelsen, Shitindi, and Aarrestad 1999).

While the agriculture/deforestation debate is often framed as "food versus forests," some agricultural goods are not food products (e.g., tobacco and cotton), and for most farmers their land is a business, not just a means of feeding their families. Therefore, farmers respond to local and global markets. Incentivizing agriculture uniformly will help it continue to expand onto new lands until it is no longer economical. This is usually well after most forests have been cleared.

To encourage intensification while conserving forests, agricultural incentives should be directed away from the agricultural frontier, and other incentives need to be devised to keep farmers at the frontier from expanding into forests.

Intensification to Conserve Forests

To encourage intensification while conserving forests, agricultural incentives should be directed away from the agricultural frontier, and other incentives need to be devised to keep farmers at the frontier from expanding into forests. Land use zoning can help direct these

BOX 11.1.

The Positive Effects of Land Ownership on Maintaining Forests

Ensuring land ownership rights and participation of local forest communities can be an effective way to maintain forests while improving the welfare of the poor—in particular, women—whose land rights are often neglected (Deininger 2003). Land ownership allows the poor to reap benefits from the land and owners to potentially get credit by using the land as collateral. This makes it possible to gain the capital necessary to invest in productive projects, including sustainable forestry, which will grow income and employment opportunities (Galiani 2009).

Land ownership does not necessarily mean clearing forests to earn a livelihood from the land. For example, in the Brazilian Amazon since 2002, the probability of deforestation has been 7 to 11 times lower in protected areas and on lands where indigenous populations have effective land ownership than in other regions (Ricketts et al. 2010).

A review of 80 forest commons (forests used by a substantial number of diverse people with legally enforceable property rights to forests and their benefits) across 10 countries found that those with a high degree of tenure security were more likely to conserve forests (Chhatre and Agrawal 2009). Secure land tenure can help communities look to the future and conserve forests for future sustainable use (Molnar et al. 2011; Chhatre and Agrawal 2009).

incentives to the right areas (Rudel 2009). Furthermore, policies to establish strong land tenure rights can also relieve pressure on forests (Box 11.1). Intensification should be encouraged in areas already cleared and in areas located away from forests, not at the agricultural frontier.

In existing agricultural areas and others already cleared of forest, there are a number of intensification practices that can decrease demand for forestlands. First, a number of practices can be undertaken to increase soil fertility. Crop residuals like mulch can add organic matter and nutrients to tropical soils that often have low fertility. Mineral fertilizers can also be used to add nutrients to soil. However, these fertilizers can have drawbacks. First, excessive fertilizer can produce nitrous oxide, which is a greenhouse gas. Second, mineral fertilizers are often expensive and have volatile prices, although this initial cost could be made up for by increased productivity and revenue. Legume cover crops (which add nitrogen to the soil, improve tree fallows, and lengthen rotation times to allow nutrients to be regenerated) are good alternatives to pricey fertilizers. Conservation tillage, which involves leaving crop residues from the previous harvest on a field, can also reduce the loss of topsoil, particularly in areas with heavy rain. These practices depend somewhat on population density. In high population densities mineral fertilizer and improved fallow systems are best for increasing soil fertility (Palm et al. 2010). However, all practices can be applied effectively in these areas.

Increasing research and development and agricultural capitalization can also help direct intensification. Research on tropical crops has long been neglected,

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Comparing agricultural techniques to increase crop yields in Mexico

resulting in low-yielding strains (Rudel 2009). Yields of tropical crops are consistently much lower than those in the temperate zone, and only part of the difference is due to climate and soils (West et al. 2010). New research and development is needed to breed higher-yielding varieties, and governments could develop policies (e.g., subsidized seeds and agricultural extension programs) to encourage their use.

Improving infrastructure is a very effective way to combat poverty and spur economic development (Calderon and Servén 2004). If done in areas where forests have already been cleared, it can also reduce pressure on forests. Although building new roads is often considered a major agent driving deforestation, improving roads in existing agricultural areas can actually help reduce it (Angelsen 2010). Improved roads allow farmers to get their crops to market more quickly and easily. Crops are less likely to be damaged or spoiled in transit, and transportation costs to farmers decrease. Better roads also allow for direct farmer-to-consumer markets, increasing profits for farmers. In addition, better roads make it easier for labor, equipment, and inputs to get to the farmer, further lowering costs. Better roads also allow for improvements of other infrastructure, such as irrigation systems. As seen in a case study in the Philippines, increased irrigation in lowlands allowed for more crops to be produced and relieved stresses on upland forests. This not only conserved the forests, but also led to an increase in employment and an economic benefit for the area (Shively 2001).

In addition to intensifying agriculture on currently productive land, restoring abandoned agricultural land can help increase production without expanding into forests.

While most of these policies should be used to incentivize agriculture away from forests, there are some practices and policies that can be used at the forest margin, where food insecurity is high and much agriculture is subsistence. Conservation tillage, mulching and composting, and improved manure use and pastures can all be effective in intensifying the use of land on a small scale. Additionally, policies that encourage migration to forest areas and base land tenure on land clearing should be phased out, and large-scale agriculture at the forest margin should not be encouraged. Theoretically, at the agricultural frontier the value of the forest (and its carbon) should outweigh the value of crops. This can be achieved by policies and practices that encourage agriculture away from the forest frontier and incentivize forest management near it.

Recalled to Life: Increasing Productivity on Abandoned Lands

In addition to intensifying agriculture on currently productive land, restoring abandoned agricultural land can help increase production without expanding into forests. Such lands can be low in soil fertility and may have been colonized by invasive species. Clearing these lands and restoring soil fertility can bring them back

BOX 11.2.

Bioenergy: A Potential New Driver or a Potential Source of Income from Degraded Lands?

Bioenergy development in tropical forest regions could change the drivers of deforestation in a fundamental way. No longer would deforestation and agricultural expansion be linked to the demand for food for humans and livestock, which are likely to level off in the twenty-first century (see Chapter 2). Rather, they would be driven by our hunger for energy, creating an appetite for land much less likely to be satiated anytime soon.

However, without knowing what will happen to the prices of fossil fuels in coming decades—and how governments will respond to these changes—it is difficult to say whether bioenergy will develop to become an important driver of tropical deforestation or remain a minor one (see Chapter 4). If the former, palm oil is likely to be the biggest bioenergy-driven threat to tropical forests. By using abandoned and degraded lands to produce bioenergy, its direct and indirect threats to forests could be reduced.

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Sustainable land-use practices are beneficial to both the environment and the lives of farmers like these in Cameroon

into production and alleviate stresses on forests (Rudel 2009). One example of this is the cassava industry in West Africa, which could expand onto abandoned land overgrown by invasive *Imperata* grass, thus utilizing the overrun, degraded land to grow a crop with economic value (Doreo Partners 2010). There are an estimated 385 million to 472 million hectares of abandoned agricultural land globally, with 97 million to 129 million hectares of it in the tropics, though not all of this is suitable for intensified agriculture (Campbell et al. 2008). Furthermore, abandoned land where forests have re-grown could be used for bioenergy (Box 11.2) or agroforestry crops.

Abandoned agricultural land is often so degraded, either through erosion, nutrient runoff, or invasive weeds, that converting it back to productive agricultural land is prohibitively expensive. Further, even natural re-growth can be significantly hindered on such marginal lands. However, through deliberate management techniques, landowners may be able to restore forests that provide economic benefits and allow the community to set aside natural forests for conservation rather than production.

Often the goal of forest restoration is to mimic the structure and species composition of a naturally regenerating forest. This helps avoid permanent degradation, encourages propagation of desired species, and promotes quicker restoration (Ashton et al. 2001). Landholders can use techniques such as reducing fire risk and planting desired species to help forests regenerate more quickly, mixing and matching them as appropriate. Planting fruit trees and high-value timber species on highly degraded sites can provide sources of income from degraded land as they are restored.

In some cases, rather than simply recreating a natural forest, landowners may want to establish a managed forest on their marginal land. Managed forests are those from which products—usually timber—can be removed for many decades to come. Planting managed forests on degraded lands may allow natural forests to

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A young boy prepares to plant a cacao seedling in Belize

remain protected as no-use areas, while still providing the community with a source of income. Managed forests need not be large, single-species monoculture; landholders can plant diverse and complex forests (Elias and Lininger 2010).

Agroforestry: Combining Forests with Food

Agroforestry, the practice of growing traditional crops and trees on the same plot, allows communities to use degraded lands to produce both agricultural and forest goods. Crop production is usually the main goal, so farmers typically plant a few widely spaced trees to reduce interference with agriculture. The most famous example of agroforestry is planting cacao or coffee under shade trees (e.g., Duguma, Gockowski, and Bakala 2008; Beer et al. 1998). These mixed-use, multi-species systems provide a variety of benefits. Thinning of trees produces fuelwood for use or sale, and provides timber for crating other products, such as fruit and nuts. Trees planted on pastures provide shade for livestock and can produce income when farmers sell the timber at the end of the rotation. Tree root systems can also move nutrients up from deeper in the soil, helping with restoration of degraded land.

Making Tropical Forests Pay

In addition to intensifying agriculture and reclaiming abandoned land, payments for sustainable management or conservation of forests may help promote development without deforestation. Internationally recognized policies such as reducing emissions from deforestation and forest degradation, plus related pro-forest activities (REDD+) and payment for environmental services (PES) programs provide economic value to standing forests so communities can be paid for conservation work and avoid deforestation. Furthermore, to reduce pressure on primary forests, certification systems can add value to products from sustainably managed forests. Applying some or a combination of these policies and programs to forests in tropical countries may help support economic development without deforestation.

Making Green from REDD+

Over the past few years the international community has discussed the need to create global incentives to conserve tropical forests. This conversation has led to a policy known as REDD+. The idea behind REDD+ is that payments should go toward forest conservation and management that reduce the amount of heat-trapping emissions coming from tropical forests. At a 2010 meeting of the UN Framework Convention on Climate Change (UNFCCC), over 190 countries decided on basic activities for REDD+: reducing emissions from deforestation, reducing emissions from forest degradation, conservation of forests, sustainable management of forests, and increasing carbon sequestration in forests. Additionally, countries agreed that REDD+ would ultimately provide a system through which developing countries can be paid for taking these actions, thereby promoting development but reducing deforestation. In the past, international policy efforts to reduce deforestation that do not address the drivers of deforestation have generally been ineffective (Pfaff et al. 2010). However, the agreement on REDD+ specifically asked all countries to find ways to address the drivers of deforestation.

Countries agreed that REDD+ programs should consider how tropical countries will need to adapt to climate change and promote sustainable development and poverty reduction. REDD+ can promote local sustainable development by paying communities that preserve their forests, or by providing supplementary payments to communities and families who garner other income, goods, and services from local forests. REDD+ should include the full participation of indigenous peoples and local communities, and it should also ensure their rights, including their traditional land tenure (RRI 2011).

REDD+ is an important opportunity because it will provide an international venue for addressing and financing reductions in deforestation. Furthermore, REDD+ should provide an opportunity to incorporate forest conservation efforts across all necessary scales, *"Absent any global governance regime for forests, land-use transitions are shaped by national land-use policies, the free-trade regime, and decisions by traders. Local-level policies to control deforestation, although necessary, will not be sufficient to slow the destruction of forests on a global scale. There are policy options to increase forest cover in a country without exporting deforestation elsewhere. International policies, such as those under the UNFCCC's Kyoto Protocol or REDD+, aimed at rewarding countries that engage in reforestation/afforestation and reduce deforestation, could monitor the displacement of land use via international trade."*

— Meyfroidt, Rudel, and Lambin (2010)

from local to global. Indeed, without international-level policies the movement of deforestation from one country to another is difficult to avoid (Meyfroidt, Rudel, and Lambin 2010; Pfaff and Walker 2010).

Valuing Nature: Payments for Environmental Services

Many of the major benefits of forests, such as clean air and water, wildlife habitat, and carbon sequestration, are consistently undervalued in economic analyses. Payment for environmental services (PES) programs are designed to make these environmental services, which previously were abundant but are becoming more scarce, economically valuable. This scarcity has created a more concrete and direct demand for these services. However, most people who benefit from environmental services are not the same people who live on, own, or manage the land. PES programs are a way to connect demand (buyers) with supply (sellers of environmental services or owners and managers of land that provides those services). There are many ways to implement PES programs, and some include (Wunder 2007):

- Government payments for services that benefit entire regions, such as clean water
- Premiums on "greener" products, such as those that do not use fertilizers or pesticides
- Natural-asset-building payments for environmental restoration of degraded land
- Use-restriction programs that generate payment for direct conservation of forests and soils

While previous conservation efforts that did not link conservation and development at a large scale have not always been successful, lessons learned from these experiences can be applied to PES programs to ensure they are efficient and effective (Blom, Sunderland, and Murdiyarso 2010). Strong PES programs must ensure that payments are made once the service, which would not have occurred without payment, has been

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Many of the major benefits of forests—clean air and water, wildlife habitat, carbon sequestration—are consistently undervalued in economic analyses

provided over the long term (Wunder 2007). Social and economic principles are also critical for ensuring the success of PES programs. These include community engagement at all steps in the process and setting prices to allow for broad participation of buyers and strong financial incentives for producers. In addition to providing financial incentives, successful PES programs can provide landowners and managers with the technical assistance needed to employ some conservation techniques (Cole 2010). PES programs can make forest conservation valuable, therefore reducing the risk that deforestation is seen as the only development pathway to local communities.

Payments for forest protection can create additional value to communities by protecting biodiversity, directly contributing to poverty alleviation (Koziell and McNeill 2002). In Laos, for example, deforestation, overfishing, and decreased use of indigenous species in agriculture threaten the biodiversity that rural communities depend on for wild sources of rice, meat, fish, medicine, and building materials. In fact, wild resources contribute 50 to 60 percent of the livelihoods of the poorest people in Laos. Therefore, direct development investment in biodiversity should help alleviate poverty in a sustainable way (Emerton 2009).

Seal of Approval

Through years of research, forest managers now know many factors that contribute to sustainably managed forests (Imai et al. 2009; Lindenmayer, Margules, and Botkin 2000; Keenan et al. 1999). In order to make sustainable management of forests more widely practiced it must become more profitable than historically non-sustainable forestry (Richards 2000). This can be done through appropriate incentives and disincentives (Pearce, Putz, and Vanclay 2003). Disincentives could include fees for unsustainable practices that cause pollution, or regulations such as the U.S. Lacey Act, which prevents the import of illegal timber (see Chapter 7). Incentives for sustainable management could include direct payment for practices, indirect payment from markets (e.g., from carbon markets for fewer emissions or increased sequestration, or from a water-protection market), and certification of sustainable practices.

In the voluntary market—that is, one where producers and consumers are not required to create or use sustainable products—certification is one of the most popular ways to provide incentives for sustainable management of tropical forests (Table 11.1). The most commonly used label is from the Forest Stewardship Council (FSC). FSC's Principles and Criteria describe

Table 11.1. Current Timber Certification Programs in the Tropics

Logo	Name	Abbreviation	Scope
	Forest Stewardship Council	FSC	International
	Programme for the Endorsement of Forest Certification	PEFC	International
	Programa Brasileiro de Certificaçáo Forestal	Cerflor	National
	Lembaga Ekolabel Indonesia	LEI	National
	Malaysian Timber Certification Council	MTCC	National

Source: Purbawiyatna and Simula 2008.

how forest management can meet social, economic, ecological, cultural, and spiritual needs over time. The organization has developed specific criteria for tropical forests.

Despite a variety of certifiers, certification is not widely used in either tropical forests or community-managed forests. As of 2008 only 0.6 percent of forests in Africa, 1.2 percent in Latin America, and 1.4 percent in Asia were certified. Additionally only 14 percent of certified tropical forests were community-owned or managed (Purbawiyatna and Simula 2008). Within the FSC system, only 12.6 percent of certified forests are in the tropics (Forest Stewardship Council 2011). Certification programs have had varying success throughout the tropics, and evidence suggests that these

Certification of forest products is one of the most popular ways to provide incentives for sustainable management of tropical forests. Increased consumer demand for certified tropical products may be needed to increase participation in these programs and help support forest owners who pursue sustainable choices.

programs must be flexible enough to adapt to local circumstances to be beneficial and accepted by the community (Humphries and Kainer 2006). Furthermore, increased consumer demand for certified tropical products, as well as funding for undergoing the certification process, may be needed to increase participation in these programs and help support forest owners who pursue sustainable choices.

Additionally, non-timber forest products can be an important component of rural livelihoods, and can also be certified for sustainable practices (Shanley et al. 2008). These products can include medicinal products, spices, nuts, fruits, resins, latex, oils, fungi, raw materials for fragrances, and wood for crafts. In Brazil, an innovative training system has been developed to integrate sustainable forestry, providing information about certification programs as well as the market value and ecology of non-timber forest products. Brazil is essentially training foresters to inventory both timber and non-timber forest products and to consider the value

Patrick Meyfroidt

Hmong villagers in Vietnam identify areas of forest regrowth

of the forest to the local community. In some cases, on the forest frontiers, this training is being combined with education and literacy programs for foresters (Shanley et al. 2008).

It Takes a Village to Raise a Forest

One additional opportunity for successful forest management is to do so locally. Community forestry is a governance and forest management practice with three basic features (Charnley and Poe 2007):

- Government gives communities formal responsibility for managing forests
- Communities take responsibility for practicing ecologically sustainable forestry
- Local social and economic benefits are central goals

These features allow for local economic development while protecting forests. For example, in Mexico governance structures promoting community forestry have enabled communities to sell timber and non-timber products while also protecting forests and local environments (Bray, Antinori, and Torresrojo 2006). Because this management strategy provides a variety of benefits, community forestry can actually be more effective in reducing deforestation than giving forests legal "no-touch" status (Ellis and Porter-Bolland 2008). Instead of shutting local people out, community forests that designate different areas for different activities can provide multiple benefits. For example, both timber removal and reforestation of former cattle pastures

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Involving local people in community forestry can provide multiple benefits to the community and the environment

are elements of a community forest program on the Yucatan Peninsula (Ellis and Porter-Bolland 2008). Outside of Mexico, community forestry has also been successfully implemented in Bolivia, India, Nepal, and the Philippines.

A recent analysis of more than 80 sites in East Africa and South Asia showed that forest systems where local forest users were part of the decision-making process were more likely to be sustainable in terms of both local livelihoods and biodiversity. Conversely, forests where local users were not part of the process were more likely to be unsustainable (Persha, Agrawal, and Chhatre 2011).

Dealing with Global Drivers as a Global Community

The fact that businesses, many of them large, are the principal drivers of deforestation does not make them invincible. Indeed, like the biblical giant Goliath, their very size creates vulnerabilities.

The most prominent of these is what economists refer to as "reputational risk." Companies selling branded products internationally, including in markets where consumers are concerned about social and environmental issues, need to avoid associating their brands with deforestation. The risk of unpopular associations can apply not only to the brand itself but all along the supply chain, exerting pressure on their suppliers, investors, distributors, and retailers as well.

This risk makes it possible for civil society, organized in NGOs, unions, religious organizations, and indigenous peoples' groups as well as coalitions, to change the behavior of businesses by revealing their links to deforestation. The clearest example of success using this approach is the soy moratorium in Brazil, where a Greenpeace report in 2006 quickly led to a negotiated agreement under which the country's largest processors and exporters agreed not to buy soybeans from land that had been deforested (see Chapter 4). A similar result came about in the beef industry three years later (see Chapter 5), and NGOs are now working to apply the same kind of pressure to the palm oil industry (see Chapter 6).

These accounts were not based on consumer boycotts, but were resolved by negotiation. The products involved were not sold to consumers at all; only a small fraction of the world's soybean harvest is even eaten by humans (see Chapter 4). Organized efforts of civil society, rather than the spending decisions of individual consumers, led to change.

Thus, globalization has not only internationalized the drivers of deforestation, but also the means to deal with them. In a globalized world, links around the world connect not only the economic actors but also those who work to change their actions. Civil society groups, working together in coalitions and across national boundaries, can mobilize the strength needed to be effective (Shandra 2007).

The fact that businesses, many of them large, are the principal drivers of deforestation does not make them invincible. Civil society groups, working together in coalitions and across national boundaries, can mobilize the strength needed to be effective.

Meeting Demand without Demanding More Land

The successes of recent years, the trends in population and diet that will eventually diminish the demand for land, and the prospect of redirecting agriculture into non-forested lands, are all reasons to hope that deforestation can be eliminated in our lifetime. Indeed, while a commonly discussed goal in international climate talks has been to cut emissions from deforestation 50 percent by 2020, it was already cut more than 30 percent by 2010 (see Chapter 10, Figure 10.1). Greater ambition—and greater REDD+ funding to make that ambition a reality—are clearly necessary. However, the demand for the commodities that drive deforestation will continue to increase as currently developed countries seek more resources to meet their inefficient lifestyles and as less-developed countries demand more to meet the needs of their increasingly urban populations. Under business-as-usual circumstances, it is expected that more land will be cleared and more forests cut down. But it does not need to be this way. Demand for goods does not have to mean demand for forestland.

First, although intensification may reduce some demand for land it may still be necessary to expand agricultural production onto other lands to meet future demand. When this happens, the first choice should be already cleared land. This abandoned land can be revitalized to grow crops, and can also be reforested to provide sustainably managed forest products.

Second, increasing crop and timber products are not the only avenue for tropical countries to develop. Programs like REDD+ and PES provide economic incentives to tropical countries to conserve their forests. With these programs in place, developing countries need not destroy forests in the same way that currently developed countries did; instead, they can develop without deforestation.

Finally, in the long run, the solution to deforestation is not just to move the drivers elsewhere, like nonforested lands, but to reduce them. Diminishing demand for paper by recycling, reducing demand for timber by building more durable and long-lasting houses that use wood more efficiently, and shifting diets to more land-efficient sources of meat (see Chapter 2) are examples that can be applied to many other products as well. Clearly, the ultimate answer to the deforestation challenge is to reduce waste at all stages of production, distribution, and consumption so that agriculture and forestry truly meet human needs rather than simply consumer desires.

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Reducing deforestation is not only beneficial in reducing global warming pollution, but also in preserving biodiversity and the quality of people's lives around the globe

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Deforestation and forest degradation have been occurring for thousands of years. But why? And what are the causes of these changes—the "drivers" of deforestation? In this report, the Union of Concerned Scientists explains these drivers and shows that they have changed fundamentally in the twenty-first century.

For many years, tropical deforestation was attributed to expanding populations of subsistence farmers cutting down the forest for small-scale agriculture and firewood. But many recent scientific studies show that large, commercial agriculture and timber enterprises are the principal agents of tropical deforestation, which is responsible for about 15 percent of global warming pollution worldwide. The drivers of deforestation differ by region: soy and cattle are key in South America while timber, paper, and palm oil are more important in Southeast Asia.

The demand for these products is global and originates primarily in urban areas. Recent actions to deal with some of the drivers of deforestation, such as pressure to change the soybean industry in Brazil, have proven successful, showing how deforestation can be slowed—and even stopped—in the next few decades.

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The Union of Concerned Scientists is the leading science-based nonprofit working for a healthy environment and a safer world. The full report, executive summary, and chapters are available online (in PDF format) at *www.ucsusa.org/whatsdrivingdeforestation*.

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