The Root of the Problem
WHAT'S DRIVING TROPICAL DEFORESTATION TODAY?

Soybeans

Union of Concerned Scientists
Citizens and Scientists for Environmental Solutions
Soybean production has expanded into the Amazon.
Chapter 4: Soybeans

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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.

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
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.

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.

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
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 Itacoatiara 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.
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
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

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**BOX 4.1.**

**From the Amazon to Your Gas Pump**

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.
CHAPTER 4: SOYBEANS

Cleared land and soybean fields in Brazil

Soybean processing plant in Brazil

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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.
References


Deforestation and forest degradation have been occurring for thousands of years. Both are important sources of global warming pollution, as well as threats to biodiversity and 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 currently play a critical role in deforestation, as well as agents that have played a historical role in deforestation (to determine their role today).

**Background and Context**
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- Chapter 2: Population and Diet
- Chapter 3: Tropical Forest Regions

**Agents of Deforestation**
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- Chapter 7: Timber and Pulp
- Chapter 8: Wood for Fuel
- Chapter 9: Small-Scale Farming and Shifting Cultivation

**Solutions and Successes**
- Chapter 10: Successes
- Chapter 11: Development without Deforestation

The full report, executive summary, and chapters are available online (in PDF format) at [www.ucsusa.org/whatsdrivingdeforestation](http://www.ucsusa.org/whatsdrivingdeforestation).