United States Department of Agriculture

Economic Research Service

Economic Research Report Number 229

April 2017

International Trade and Deforestation: Potential Policy Effects via a Global Economic Model

Jayson Beckman, Ronald D. Sands, Anne A. Riddle, Tani Lee, and Jacob M. Walloga

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Economic Research Service

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Recommended citation format for this publication:

Beckman, Jayson, Ronald D. Sands, Anne A. Riddle, Tani Lee, and Jacob M. Walloga. *International Trade and Deforestation: Potential Policy Effects via a Global Economic Model,* ERR-229, U.S. Department of Agriculture, Economic Research Service, April 2017.

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Abstract

Increasing global population and demand for food have led to rising agricultural production and demand for land; expanded agricultural land has often come from tropical deforestation. These forests support biodiverse ecosystems and further benefit the environment through carbon storage. This report analyzes patterns of deforestation in select countries to examine which commodities contribute most to "tropical" deforestation. ERS researchers use historical data on production and international trade patterns of four forest-risk commodities: palm oil, soybeans, beef, and forest products. Trade links for these commodities are quantified between the United States and six major exporting countries: Argentina, Brazil, Paraguay, Bolivia, Indonesia, and Malaysia. Deforestation in Argentina and Brazil is linked with production of beef and soybeans, while deforestation in Indonesia and Malaysia is linked with production of palm oil and timber. A global economic model is used to assess two potential policies that could affect tropical forest loss. Results indicate that removing tariffs on these forest-risk products could increase deforestation, while prohibiting exports of illegally logged wood could reduce deforestation.

Keywords: Deforestation, forest-risk products, palm oil, soybean, beef, wood products, Argentina, Brazil, Paraguay, Bolivia, Indonesia, Malaysia, tropical forest, selective logging

Acknowledgments

The authors would like to thank the following individuals for technical peer reviews: Elizabeth Marshall, U.S. Department of Agriculture (USDA), Economic Research Service (ERS); Denise McWilliams, Fahran Robb, and Caitrin Martin, USDA, Foreign Agricultural Service; Nelson Villoria, Kansas State University; Roger Sedjo, Resources for the Future; and two reviewers who requested anonymity. The author Jacob Walloga was an intern with ERS when this research was conducted. Thanks also to Maria Williams and Curtia Taylor, USDA, ERS, for editorial and design services.

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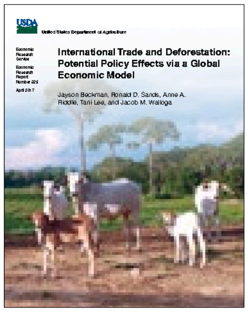

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International Trade and Deforestation: Potential Policy Effects via a Global Economic Model

Jayson Beckman, Ronald D. Sands, Anne A. Riddle, Tani Lee, and Jacob M. Walloga

What is the Issue?

An increasing world population and a shift in global diets toward vegetable oils and animal products increase the demand for agricultural commodities. To meet this demand, forestland is frequently converted into crop fields or pasture, especially in developing countries. South American and Southeast Asian countries have emerged as major exporters of "forest-risk" commodities (primarily beef, palm oil, soybeans, and forest products), often produced on newly deforested land. This land conversion not only threatens tropical forests but also raises concerns about biodiversity and carbon dioxide emissions from land-use change. Several factors influence production of forest-risk commodities, including consumption of these commodities in other countries and any barriers to international trade.

What Did the Study Find?

This report analyzes patterns of deforestation in major deforesting countries—Argentina, Bolivia, Brazil, Paraguay, Indonesia, and Malaysia. Deforestation in Argentina, Bolivia, Brazil, and Paraguay is linked with production of beef and soybeans, while deforestation in Indonesia and Malaysia is linked with production of palm oil and wood products. ERS researchers first track the history of production and international trade of forest-risk commodities from 1991 to 2013. The key findings are as follows:

- Although soybean production has increased substantially in Argentina and Brazil since 1991, the greatest post-conversion land-use change from agriculture in South America is due to beef production. In recent years, soybean production has mostly increased by expanding onto previously cleared cropland or pasture, rather than by contributing immediately to further deforestation.
- U.S. imports of palm oil are small relative to global production, and the United States has little influence on markets for palm oil. The United States is, however, a major producer and consumer of other forest-risk commodities (beef, soybeans, and wood products) and, by increasing production and exports of these commodities, can reduce incentives for their production in tropical countries.

ERS is a primary source of economic research and analysis from the U.S. Department of Agriculture, providing timely information on economic and policy issues related to agriculture, food, the environment, and rural America.

In addition to tracking historical land-use patterns, ERS researchers use an economic model of global markets to identify how potential international trade policies could affect tropical forest loss. Two policy options are examined: (1) removing tariffs on forest-risk commodities (tariffs are import taxes that restrict trade by raising imports' costs to consumers) and (2) prohibiting trade of forest products from countries that might be illegally logging.

- In a hypothetical baseline scenario of global economic expansion from 2014 to 2020 and no policy changes, global demand for agricultural products increases (including forest-risk products), which in turn leads to expansion of global cropland by 0.40 percent or 6.3 million hectares (Mha) and pasture by 0.29 percent (7.8 Mha), but a reduction in forest land of 0.88 percent (14.9 Mha). This pattern varies across world regions, with the greatest shares of forest lost in China and the European Union (EU).
- One effective route for reducing or avoiding deforestation involves increasing overall agricultural output by increasing the yield of land for all agricultural commodities. With greater agricultural productivity, less area will be needed for agriculture and more land becomes available for forests. ERS researchers constructed a scenario similar to the baseline, except with zero growth in agricultural productivity from 2014 to 2020. With agricultural productivity gains excluded, in 2020, cropland increases 10.1 Mha more than it increases in the baseline scenario. Likewise, in 2020, forest land declines 4.8 Mha more than it does in the baseline scenario.
- A hypothetical scenario in which tariffs (import taxes) on forest-risk commodities are completely removed leads to an increase in deforestation of 0.6 Mha relative to the baseline scenario in 2020. Because tariffs on imports into the United States are low compared with tariffs of other countries, the global removal of tariffs leads to increased domestic forest land loss in the United States, as U.S. agricultural exports outweigh its imports. On the other hand, because the EU has higher tariffs than other countries, the global removal of tariffs reduces the EU's rate of domestic forest loss as the EU increases its imports of agricultural products.
- The hypothetical scenario banning all trade of illegal forest products leads to a global increase of forest land compared to the baseline scenario of 0.9 Mha. In particular, South America and Southeast Asia—where forest-risk commodities have posed substantial threats—show gains in forest land. The increase in global forest land reduces land for crops (0.3 Mha) and pasture (0.6 Mha).

How Was the Study Conducted?

This study has three major sections: an assessment of recent deforestation trends; an analysis tracing consumption of forest-risk products from consumer back to country of origin; and an analysis of stylized international trade policies that can affect the amount of forest land. ERS surveys recent literature on tropical deforestation and reports the immediate post-conversion land-use change attributable, by remote sensing or other direct study, to forest-risk products. ERS then uses bilateral international trade data from the United Nations Food and Agriculture Organization, along with input-output methods, to trace the path from country of origin to region of consumption for forest-risk products. The MTED-GTAP global economic model with 14 world regions is then used to simulate world land use in 2020 for the baseline and policy scenarios.

International Trade and Deforestation: Potential Policy Effects via a Global Economic Model

Introduction

Agricultural production has risen over the past several decades through a combination of increased productivity and expansion of agricultural land, including expansion into tropical forests. Forest loss is directly connected with increased carbon dioxide emissions because carbon stored in trees is released to the atmosphere as carbon dioxide. Another concern is loss of biodiversity, especially from loss of tropical forests. Tropical deforestation rates have declined since the 1990s, but remain substantial today. In South America, deforestation rates have dropped from 4 million hectares per year in the early 2000s to about 2 million hectares per year in 2013. In Indonesia and Malaysia, deforestation rates have declined from 2 million hectares per year in the early 1990s to about 1 million hectares per year from the early 2000s to 2013.

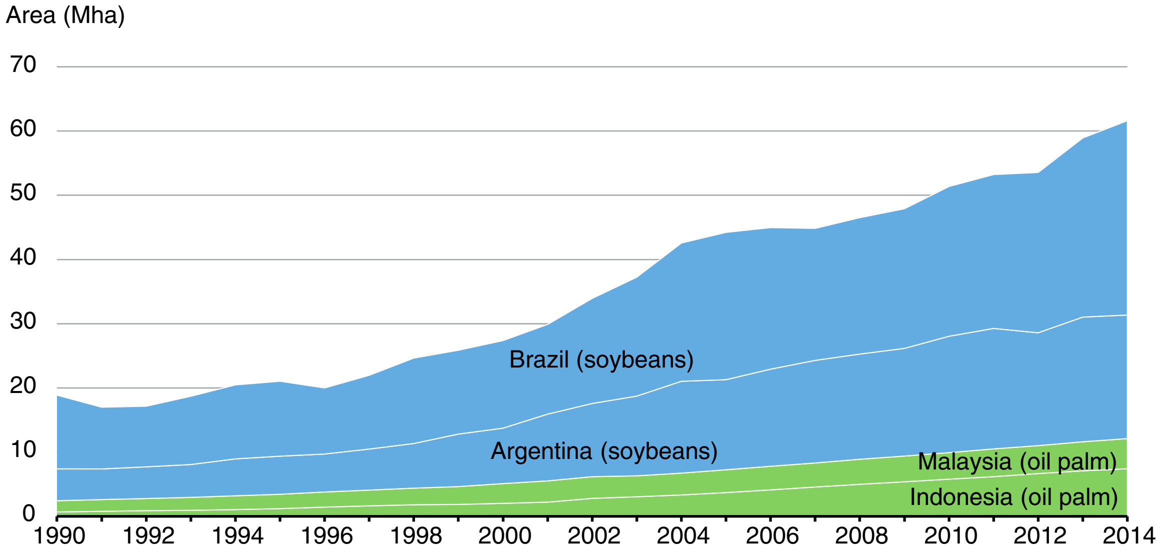
Forest-risk commodities are defined by Henders et al. (2015) as "products whose cultivation involves deforestation and vegetation clearing in the producing countries." From Henders et al. (2015), we adopt this definition, the same set of forest-risk commodities (beef, soybeans, palm oil, and wood products), and six of seven case countries with high deforestation rates (Argentina, Bolivia, Brazil, Paraguay, Indonesia, and Malaysia).[1] Deforestation in Brazil is linked most closely with production of beef and soybeans. Deforestation in Indonesia and Malaysia is linked with production of palm oil. Although not a tropical country, Argentina is included because it is a major deforesting country in South America and a major producer of soybeans.

Soybean production, in Argentina and Brazil, and palm oil production, in Indonesia and Malaysia, have increased rapidly in recent decades. The amount of land used to grow these commodities has increased as well (fig. 1), but not as quickly as production has grown, thereby forestalling some expansions of land used. Between 1990 and 2014, the average annual rate of yield increase for oil palm was 0.13 percent in Indonesia and 0.60 percent in Malaysia. Soybeans had higher average annual growth rates in yield: 1.05 percent in Argentina and 2.12 percent in Brazil. Ausubel et al. (2012) provide further examples of the influence of agricultural productivity growth on land use, describing production of wheat in India and maize in China, from 1960 through 2010. Increases in agricultural productivity over time allowed much higher production levels in 2010 with approximately the same amount of harvested land as in 1960. The authors describe efforts to increase agricultural productivity as "land-sparing" activities.

A large recent study of the effects of European Union (EU) consumption on tropical deforestation (European Commission, 2013a, 2013b, 2013c) places results in terms of commodities traded internationally to show "embodied deforestation." The calculation of embodied deforestation depends on estimates of deforestation rates in Southeast Asia and South America (Hansen et al., 2013) and

[1] Walker et al. (2013) include biofuels as a forest-risk commodity. Henders et al. (2015) include Papua New Guinea as a seventh case country.

Figure 1
Land use for soybeans and oil palm in select case countries



Note: Mha = million hectares.
Source: USDA, Economic Research Service calculations based on United Nations, Food and Agriculture Organization, FAOSTAT database.

simple assumptions to allocate deforested carbon to commodities traded internationally.[2] Our study differs from the EU study in the following ways: First, we extend analysis of deforestation and trade flows from 2008 through 2013. Second, we examine the connection between trade and forest loss from a U.S. perspective. Third, we view this issue not in terms of embodied deforestation,[3] but as land requirements in tropical countries for forest-risk commodities consumed elsewhere ("embodied land use").[4] An important commonality among our study, the EU study, and Henders et al. (2015) is that we all use the methodology of Kastner et al. (2011a) to trace consumption of forest-risk products to their country of origin. We consider this methodology state of the art for linking production in one country with consumption in another country. The primary source of data for these studies is the online agricultural database FAOSTAT, provided by the Food and Agriculture Organization (FAO) of the United Nations.[5]

[2] It is common for other studies to use terms such as "embodied deforestation" or "embodied land use" in products traded internationally.

[3] Embodied deforestation is a portion of change in forest area assigned to an agricultural product such as soybeans. This portion will vary over time along with forest area and could even change sign. This calculation is complicated by the method of attributing agricultural products to changes in forest area.

[4] Embodied land use is a straightforward economic concept: the area of land used per unit of output for an agricultural product such as soybeans. It varies slowly over time along with agricultural productivity and substitution among inputs as prices change.

[5] An alternative data source is the online Production, Supply, and Distribution (PSD) system from USDA's Foreign Agricultural Service (FAS). We used the FAO data for two reasons. First, we provide an update to the Henders et al. (2011a) paper through 2013. Their work uses FAO data, so to be consistent, we use the same. The second reason is the comparison between calendar and marketing years. As noted on the PSD website, "USDA makes projections on a marketing year basis (except for the livestock complex, the forest products complex, the fishery products complex, and tobacco (calendar year)). The Food and Agriculture Organization of the United Nations uses calendar years for all commodities."

While the EU study is strong on calculation of international trade of forest-risk commodities, it lacks an economic framework to project supply and demand of forest-risk commodities into the future. To identify how potential policies might affect future changes in forestry, we use a global economic model that tracks the complex international-trade links among agricultural commodities and records competition among these commodities for limited economic resources such as agricultural and forest land. Our primary interest is changes in production of forest-risk commodities (beef, soybeans, palm oil, and forest products) in countries where deforestation has occurred. To address how potential policies could affect forests, we first model a reference scenario of global economic change to 2020. Doing so provides a baseline with which to compare the effects of hypothetical scenarios. Two scenarios are then considered: (1) the removal of all global tariffs on forest-risk commodities and (2) changes in global forest policy that prohibit the trade of illegally logged forest products.

Overview of Tropical Deforestation As an Issue

An increasing global population—as well as a shift in global diets toward more vegetable oils and animal products—requires increased production of agricultural commodities. Improving yields is one way of increasing production, but often additional land is needed. On average, recent annual net forest loss was 5.2 million hectares in 2000-10 (FAO, 2010). Deforestation causes soil degradation, disruptions to ecosystem services such as water cycling and air filtration, and biodiversity loss (Foley et al., 2005). It is estimated to be the source of 7-14 percent of global anthropogenic carbon emissions over 2000-05 (Harris, 2012).

Deforestation has a diverse set of proximate causes. Historically, small-scale farmers were responsible for most deforestation in tropical Southeast Asia and Latin America (Rudel et al., 2009). Since the 1990s, mechanized agribusiness and forestry, producing for global markets rather than local markets or subsistence, have increasingly driven deforestation in developing countries (Rudel et al., 2009). Today, commercial agriculture at local and global scales is the most significant driver of deforestation worldwide (Hosonuma et al., 2012).

On average, the harvest of one-fifth of global cropland area was destined for export in the 2000s, and almost all growth in cropland area was for crops that are internationally traded (Kastner et al., 2014). The countries responsible for most global deforestation are also major suppliers of internationally traded commodities. Over 90 percent of the world's supply of palm oil originates in Indonesia and Malaysia. Argentina, Bolivia, Brazil, and Paraguay supply nearly all Latin America's soybean exports and over 80 percent of beef exports (FAOSTAT, 2016). Because demand for the final and intermediate products made with forest-risk commodities is global, production and associated land use change is geographically decoupled from associated demand (Henders et al., 2015). Kastner et al. (2011a) developed state-of-the-art methods to connect global consumption of forest-risk commodities (soybeans, beef, palm oil, wood) with production and land use in the countries of origin, and these methods were adopted by later studies (European Commission, 2013a,b,c; Henders et al., 2015).

Trends in Deforestation in Case Countries

This chapter reports deforestation rates since 1991 for all case countries, as reported in Henders et al. (2015). We calculate these by applying shares of deforestation directly attributable to each immediate post-conversion land use to the published deforestation rate. Henders et al. (2015) compiled these shares through an extensive review of the remote-sensing literature. In some cases, we have changed shares used in Henders et al. (2015) based on reviews of the literature, and we have updated them to 2013. See Appendix A for tables of deforestation rates and their sources, as well as a detailed description of the method.

Deforestation is an important issue throughout central South America, where large traded volumes of soy, beef, and timber products are viewed as contributing to deforestation. The Amazon Basin has perhaps received the most attention, internationally. Overall rates of deforestation in the Amazon Basin remain high, though they have decreased since the 1990s. Rates of deforestation in tropical dry forest ecosystems, such as the Brazilian Cerrado and the central Gran Chaco, have risen over the same period. Tropical dry forests experience dry and wet seasons, unlike the moist Amazon forests, but are also significant reserves of carbon and biodiversity, and produce important ecosystem services.

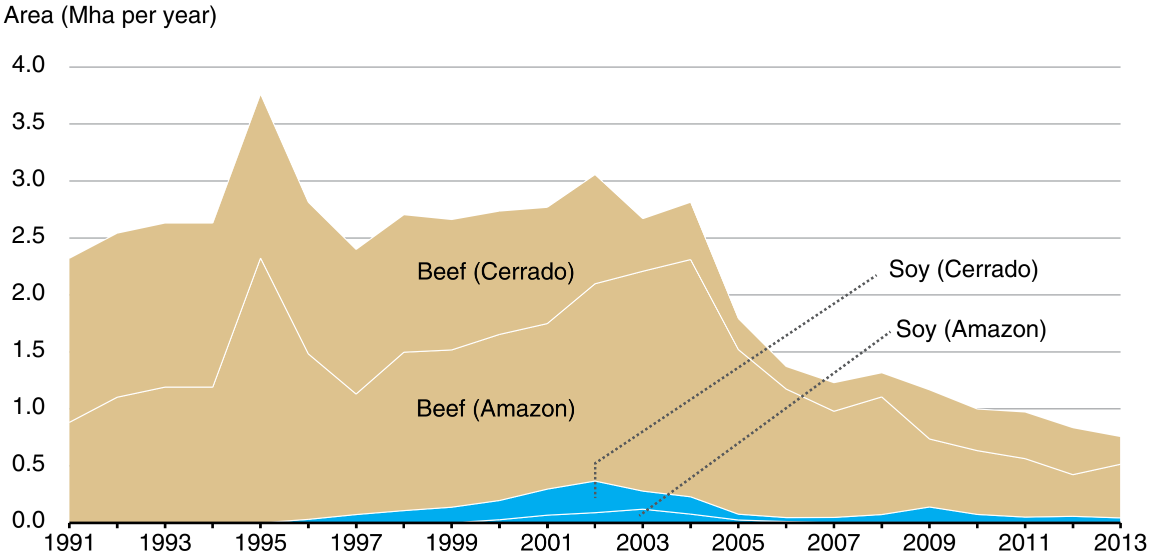
Hosonuma et al. (2012) provide a useful framework for understanding these results commonly used in deforestation literature. There, a distinction is commonly made between proximate or direct drivers and indirect or underlying causes. Proximate or direct drivers of deforestation are human activities directly affecting forest loss on the landscape and thus constituting measurable sources of change. For example, agricultural expansion, infrastructure expansion, or wood extraction all constitute drivers (Geist and Lambin, 2002). In contrast, indirect or underlying causes spring from underlying sociopolitical, economic, technological and cultural forces (Geist and Lambin, 2002). Of the two, only direct drivers may be measured on the landscape, and both are widely unknown at the national level (Hosonuma, et al. 2012).

For all commodities, we report the immediate post-conversion land use change, or drivers, attributable to each product by remote sensing or other direct study. These proximate drivers reflect the measurable economic decision made by the deforesting actor. Underlying, indirect causes cannot be measured in discrete quantities and time steps. For example, in Brazil, most increases in soybean production come not from new deforestation, but through expansion of soybeans onto previously cleared cropland or pastureland, including cattle pasture (Macedo et al., 2012; Graesser et al., 2015). Because of this, whether soy or beef production is more directly the driver of deforestation is difficult to disentangle; but remote sensing data clearly show that beef production is the more common next direct use in Brazil (fig 2). Our results show that gross deforestation for beef production has been declining since about 2004, and has also become more uniformly distributed across countries.

In addition, soybean yields in Brazil have risen over the study period, reducing deforestation pressure through intensification (Macedo et al., 2012). Declining rates of deforestation for beef production in Brazil may be due to improved enforcement and monitoring of deforestation by the Brazilian Government, voluntary moratoria on beef and soybean products by important exporters, or macroeconomic factors (Gollnow and Lakes, 2014; Gibbs et al., 2015).

While most deforestation in Brazil takes place in the Amazon basin, a significant amount also comes from the Cerrado region of southern Brazil, an area of tropical dry forest. Cattle is the major

Figure 2
Historical deforestation in Brazil



Note: Deforested area is categorized by its next immediate land use following deforestation (i.e., beef production or soy production). Mha = million hectares.
Sources: USDA, Economic Research Service calculations based primarily on Henders et al. (2015), Environmental Research Letters 10(12); and Hansen et al. (2013), University of Maryland, Google, U.S. Geological Survey, and National Aeronautics and Space Administration, www.globalforestwatch.org.

deforestation driver in both regions, historically responsible for over 80 percent of deforestation in the Amazon and up to 88 percent in the Cerrado (Klink and Moreira, 2002; Chomitz and Thomas, 2001; Macedo et al., 2012). While direct deforestation for soybean production in the Amazon has generally remained low, it has become increasingly common in the Cerrado (Gibbs et al., 2015). In the Amazon, logging is also important (Asner et al., 2006). (See box, "Selective Logging, Degradation, and Deforestation," on p. 7)

In contrast to Brazil, the dominant post-conversion land-use change in Argentina is to soybeans (fig. 3). Most deforestation in Bolivia is in the Amazon basin; there, expansion of soybean production has historically been most important (Muller et al., 2012), with increasing shares due to expanding cattle production since 1999 (fig. 4).

Deforestation has grown at an increasing rate in the dry Gran Chaco region, which extends into Argentina and Paraguay. Soybean and cattle production are the main deforestation drivers in this area, responsible for over 90 percent of deforestation (Clark et al., 2012), with some variation across countries. Although both are associated with deforestation in Argentina (fig. 3), most deforestation in Paraguay is because of beef production (fig. 5).

In Indonesia and Malaysia, palm oil and timber products have been linked with deforestation (figs. 6 and 7). In Indonesia, there are two principal drivers of direct forest loss: clear-cutting for timber and clearing to establish plantations, particularly oil palm (Henders et al., 2015). More recently, there has been increasing clearing to establish short-rotation tree plantations for the pulp and paper industries (Henders et al., 2015).

In Malaysia, most clearing is for timber or oil palm plantations (Henders et al., 2015). Both countries also have significant wood production from selective logging. Whereas Malaysia has more direct

Selective Logging, Degradation, and Deforestation

Wood products can originate from many complex sources. In our study areas, selective logging, plantation forests, and clear-cutting are all sources of forest products. Selective logging allows for multiple entries to the same land area, meaning the same parcel can be logged over many years. If little canopy area is damaged, effect on the forest is minimal (Asner et al., 2006). However, successive entries or removal of large amounts of canopy can lead to significant degradation, defined as thinning of the canopy and loss of carbon stocks (Hosonuma et al. 2012), or conversion to an intermediate land type like shrubland. Significant damage increases the chance the land will be finally cleared (Asner et al., 2006). In addition, logged land is more susceptible to fire in drought conditions (Cochrane, 2003), which can also result in forest loss.

In Indonesia, on average, only 4.1 percent of oil palm plantations originated from undisturbed forest land, while over 50 percent originated from degraded forest land (Gunarso et al., 2013). The largest single cause of historical forest loss in Indonesia is logging, followed by fire on the logged areas; these two drivers led to the conversion of large areas of forest into agroforest or shrubland (Gunarso et al., 2013). In a study of logged areas throughout the Amazon, 61-68 percent of logging operations had forest damage sufficient to leave the forest susceptible to fire in dry conditions (Asner et al., 2006), with an additional 8-17 percent having very serious damage, sufficient to remove over half the canopy. A logged area had a 16-percent chance of being deforested within 1 year of the initial selective logging, increasing by 5.4 percent each year afterward (Asner et al., 2006).

Complicating the picture, forest degradation results not only from commercial logging, but also from charcoal production, animal pasture, fire and drought pressures following logging, fuelwood-gathering for household use, and other factors (Hosonuma et al., 2012).

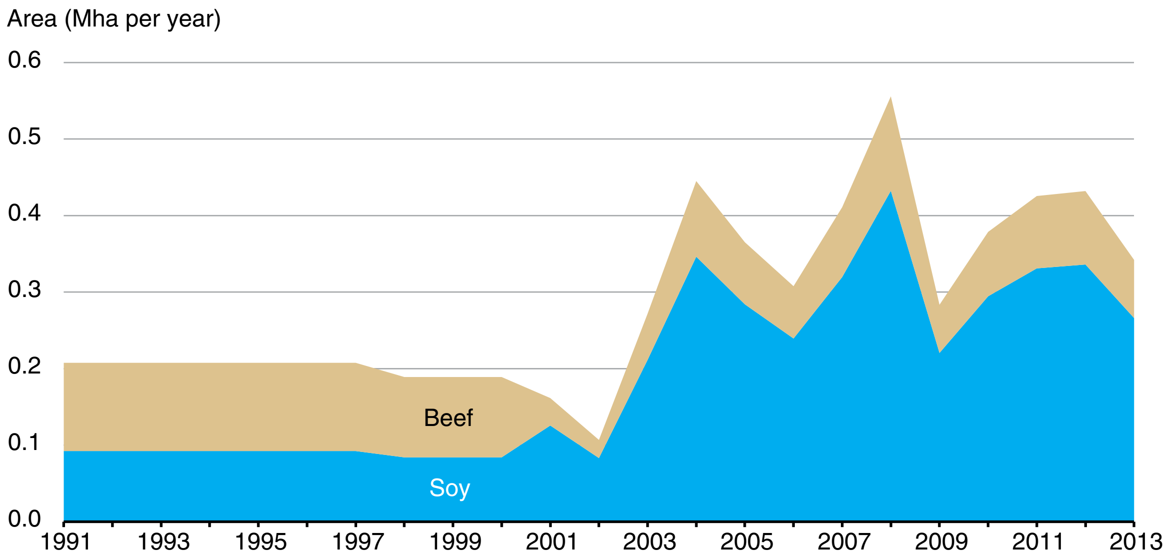
deforestation for oil palm, most palm plantations in Indonesia come from land that was previously degraded following unsustainable logging (Gunarso et al., 2013).

Planting of oil palms is the most frequently mentioned single cause of deforestation in Indonesia and Malaysia, and thus, our finding (figs. 6 and 7) that timber production has caused more deforestation than oil palm production may be surprising. (See Appendix A for a detailed discussion of our analysis approach.) However, other authors (Busch et al. 2015; Abood et al., 2015), too, have noted the strong effects of logging, particularly in Indonesia.

Our result stems from the decision to use a conservative rate of direct deforestation for oil palm of about 17 percent. This rate reflects the average of four studies (Abood et al., 2015; Lee et al., 2014; Busch et al., 2015; Gunarso et al., 2013), which covered wide geographic areas and multiple commodities. These authors, particularly Gunarso et al. (2013), show that palm production, like soy, typically expands onto seriously degraded forest or land that was previously cleared and in use for other crops. The authors state that the largest single cause of historical forest loss in Indonesia can be attributed to logging, followed by fire on the logged areas; the two factors led to conversion of large areas of forest into agroforest or shrubland, which in turn have been the primary land sources of oil palm plantations. Conversion of forest directly to oil palm plantations is more common in Malaysia (Gunarso et al., 2013).

Figure 3

Historical deforestation in Argentina

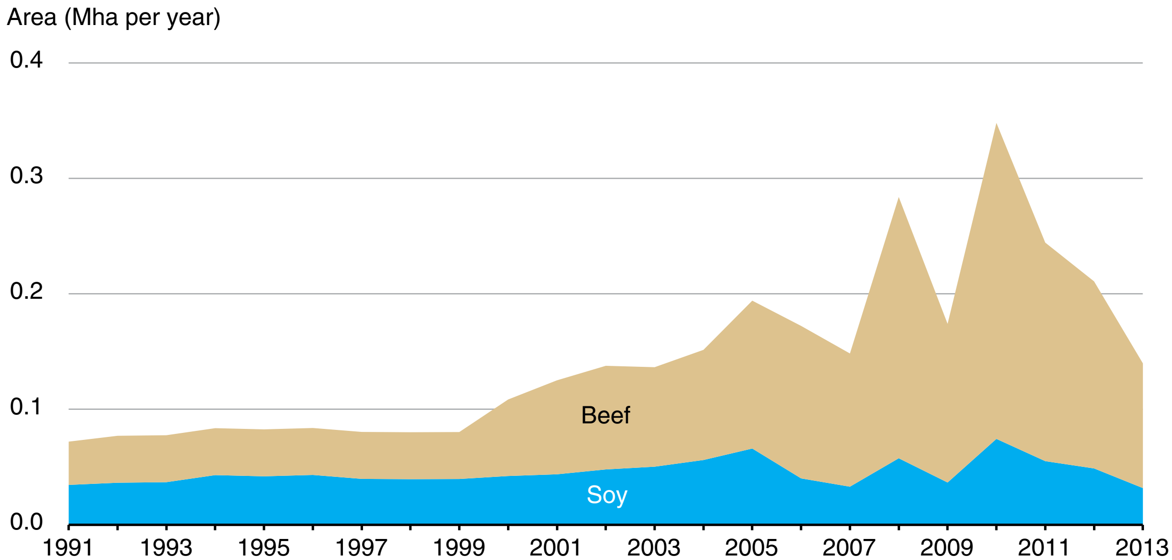


Note: Deforested area is categorized by its next immediate land use following deforestation (i.e., beef production or soy production). Mha = million hectares.

Sources: USDA, Economic Research Service calculations based primarily on Henders et al. (2015), Environmental Research Letters 10(12); and Hansen et al. (2013), University of Maryland, Google, U.S. Geological Survey, and National Aeronautics and Space Administration, www.globalforestwatch.org.

Figure 4

Historical deforestation in Bolivia

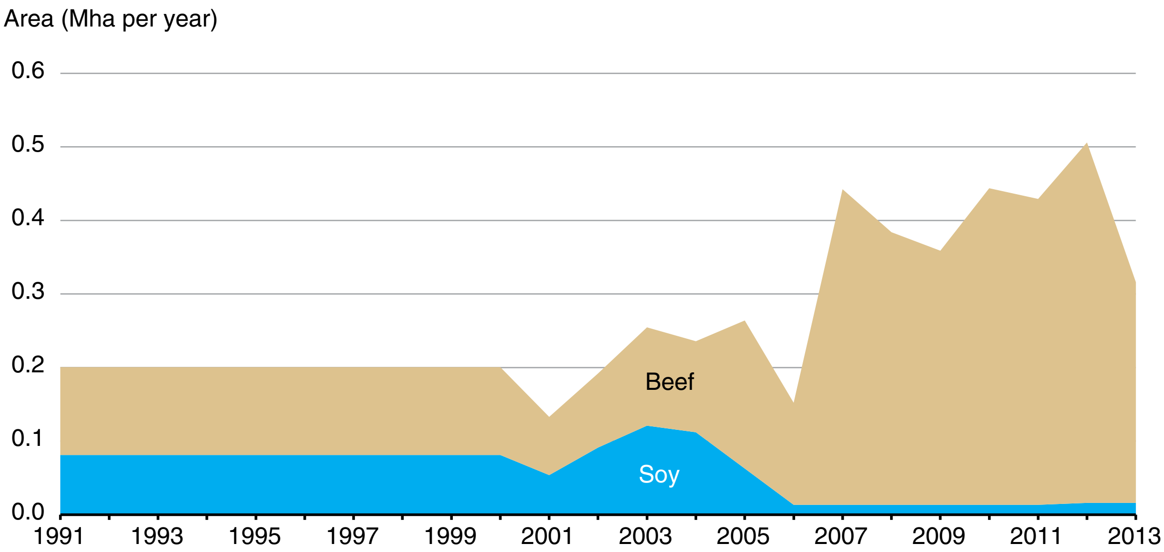


Note: Deforested area is categorized by its next immediate land use following deforestation (i.e., beef production or soy production). Mha = million hectares.

Sources: USDA, Economic Research Service calculations based primarily on Henders et al. (2015), Environmental Research Letters 10(12); and Hansen et al. (2013), University of Maryland, Google, U.S. Geological Survey, and National Aeronautics and Space Administration, www.globalforestwatch.org.

Figure 5

Historical deforestation in Paraguay



Note: Deforested area is categorized by its next immediate land use following deforestation (i.e., beef production or soy production). Mha = million hectares.
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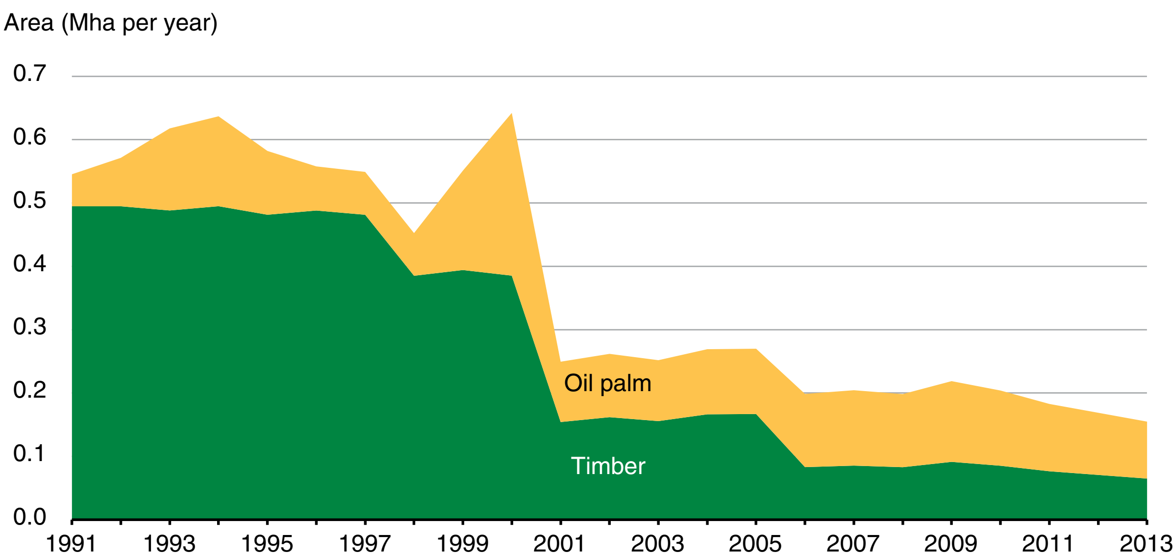
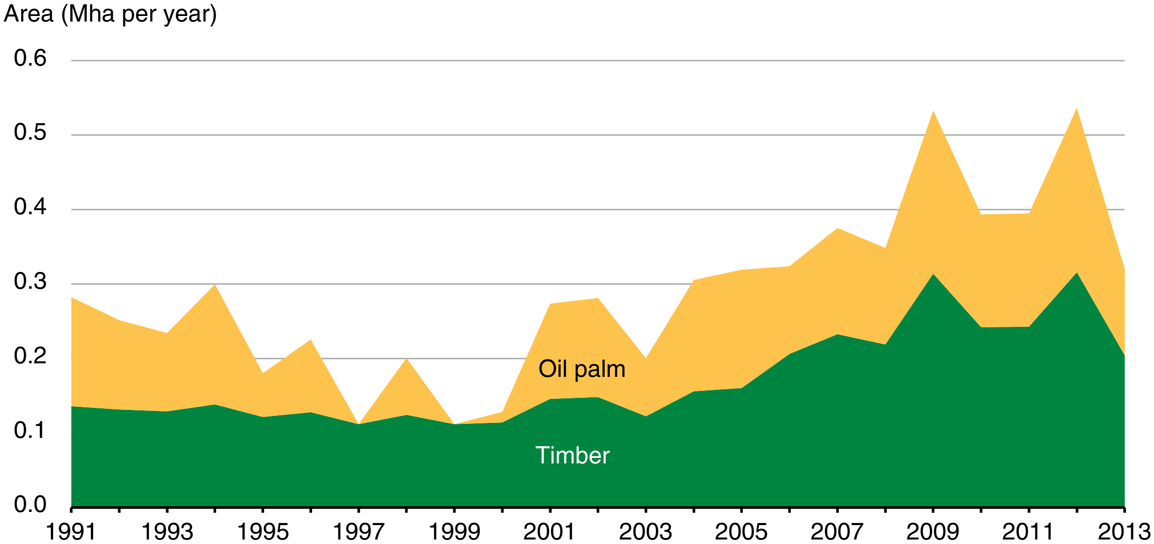
Figure 6

Historical deforestation in Indonesia



Note: Deforested area is categorized by its next immediate land use following deforestation (i.e., oil palm production or timber production). Mha = million hectares.
Sources: USDA, Economic Research Service calculations based primarily on Henders et al. (2015), Environmental Research Letters 10(12); and Hansen et al. (2013), University of Maryland, Google, U.S. Geological Survey, and National Aeronautics and Space Administration, www.globalforestwatch.org.

Figure 7
Historical deforestation in Malaysia



Note: Deforested area is categorized by its next immediate land use following deforestation (i.e., oil palm production or timber production). Mha = million hectares.
Sources: USDA, Economic Research Service calculations based primarily on Henders et al. (2015), Environmental Research Letters 10(12); and Hansen et al. (2013), University of Maryland, Google, U.S. Geological Survey, and National Aeronautics and Space Administration, www.globalforestwatch.org.

Production and Exports of Forest-Risk Products

This chapter provides an overview of production and international trade in forest-risk products, along with the U.S. position in international trade in these products. Henders et al. (2015) identify four groups of forest-risk products: palm fruit products, soybean products, beef products, and wood products. In this chapter, we provide tables of production and exports of palm fruit products and soybean products for six case countries: Indonesia, Malaysia, Brazil, Argentina, Paraguay, and Bolivia. We also construct Sankey diagrams for three forest-risk products (palm fruit products, soybean products, and beef products), showing the source country and destination region.

Each group of products can be further divided into primary and processed products. For example, palm fruit is processed into palm oil, leaving palm kernels for further processing. Palm kernels are then processed into palm kernel oil and palm kernel cake. Most Indonesian and Malaysian palm fruit products were consumed elsewhere, as more than three-quarters of palm oil produced in Indonesia and nearly four-fifths of palm oil produced in Malaysia were exported (table 1).[6]

The next step is to match producers with consumers of forest-risk products. This step is important for palm oil, as production of palm oil requires land that could instead be tropical forest. Export data from table 1 are available from FAO by country of destination, so we can construct a data table for each exported commodity with each row containing source country, target country, and quantity traded (in tons). In the case of palm fruit products, there are three exported commodities: palm oil, palm kernel cake, and palm kernel oil. Exports of these commodities are then converted to common units, palm fruit equivalent, using weights in table 2. With all products in primary equivalent, they can be summed.

There is no unique method to weight the various products derived from oil palm fruit. Some studies use dry weight equivalent (Henders et al., 2015), which preserves mass balance. Kastner et al. (2011a) use calorie density to construct weights, which preserves calorie balance. Another possibility

Table 1
Palm fruit products, production and exports, 2013

	Palm fruit	Palm oil	Palm kernels	Palm kernel cake	Palm kernel oil
			Million tons		
Production					
Indonesia	120.0	26.9	6.9	-	3.1
Malaysia	95.7	19.2	4.9	-	2.3
Exports					
Indonesia	-	20.6	-	3.6	1.6
Malaysia	-	15.2	-	2.5	0.8

Note: Blank cells represent no data in the FAOSTAT database. FAOSTAT contains a limited amount of production data on processed crops, and production of palm kernel cake is not reported. Exports of palm fruit and palm kernels are small and not reported in FAOSTAT. Oil palm fruit is perishable and is processed quickly to extract the palm oil and palm kernel.
Source: United Nations, Food and Agriculture Organization, FAOSTAT database.

[6] All tons in this report are metric tons.

Table 2
Weights applied to commodity exports

Commodity	kcal/100 g	Weight[1]	Equivalent
Oil palm fruit	158	1.00	Oil palm fruit
Palm kernel cake	240	1.52	
Palm oil	884	5.59	
Palm kernel oil	884	5.59	
Soybeans	335	1.00	Soybeans
Soybean oil	884	2.64	
Soybean cake	261	0.78	
Meat, cattle (carcass weight)	107	1.00	Meat, cattle
Meat, beef and veal sausages	313	2.93	
Meat, beef, preparations	233	2.18	
Meat, cattle, boneless (beef and veal)	150	1.40	

Note: kcal = kilocalorie. g = gram.
[1]The weights convert secondary products to primary equivalent based on kcal per 100 g. For example, soybean oil has 884 kcal/100 g; soybeans have 335 kcal/100 g; the weight for soybean oil is the ratio 884/335 = 2.64. Primary products have a weight of 1.
Source: FAO (2001) *Food Balance Sheets: A Handbook*.

is to weight products by price per kilogram, which preserves expenditure balance. These are all options to avoid double counting, and make it possible to sum palm fruit products for presentation in a chart. We use the method of Kastner et al. (2011a) to weight products by caloric content, as it is the most common unit for food.

The primary product determines the amount of land required. Each primary product in table 2 (oil palm fruit, soybeans, and cattle meat) has a weight equal to 1. Processed products can have a weight less than or greater than 1, depending on the calorie density (kcal/100 g). Oils have a high density of 884 kcal/100 g (FAO, 2001). For example, 1 ton of palm oil has 5.6 times the calories as 1 ton of oil palm fruit. These weights allow exports to be expressed as palm fruit equivalent, which provides a better indication of land embodied in each export commodity.

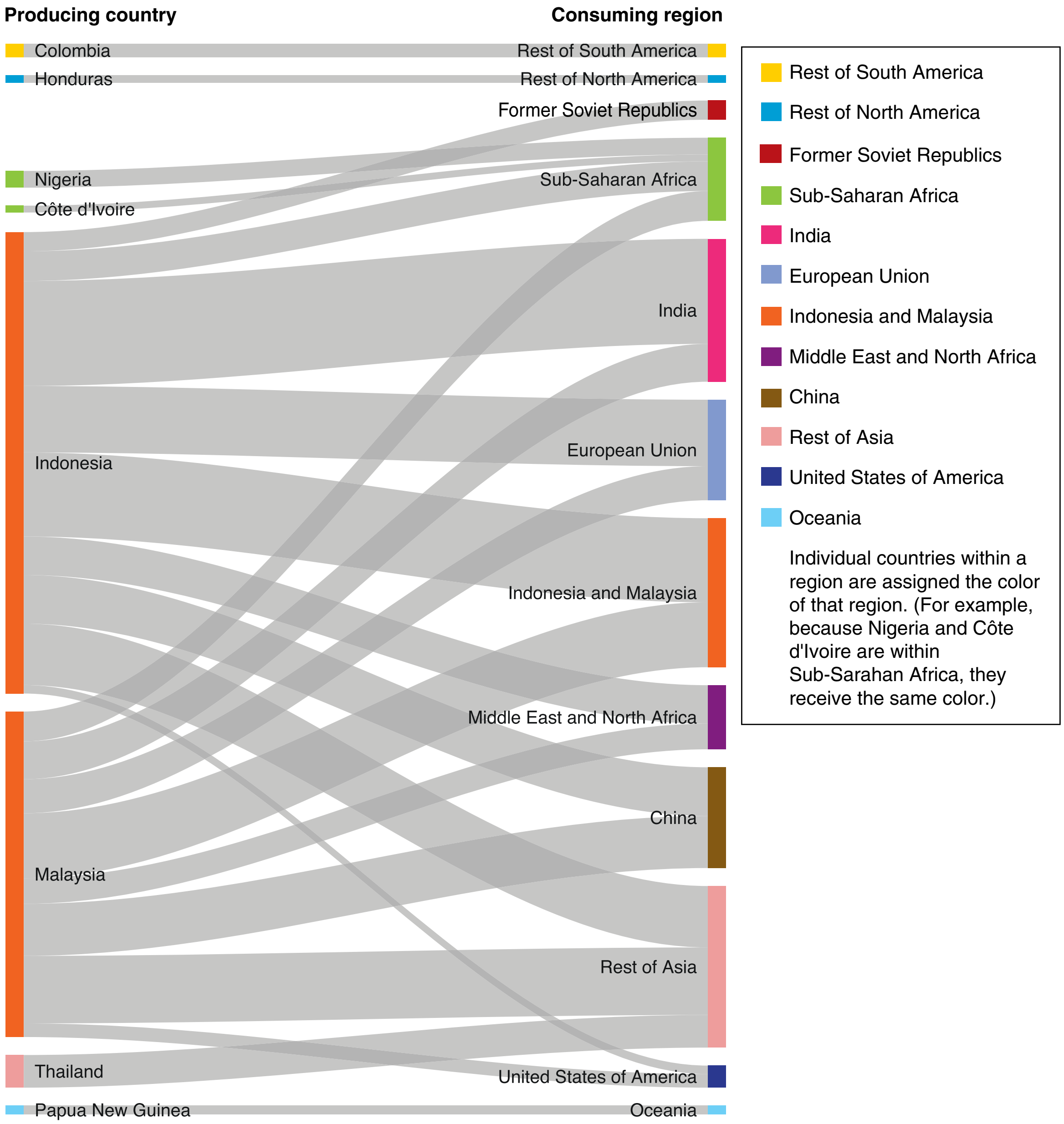
In the Sankey diagrams (figs. 8-10), domestic production of the primary commodity is split into the portion consumed and the portion exported. Exports may consist of the primary product and various secondary products. The weights in table 2 allow exports to be converted to primary equivalent and summed. The width of each band in the Sankey diagrams is proportional to calories consumed domestically or exported, and is an indicator of land requirements in the exporting country.

With exports of palm fruit products expressed in common units of palm fruit equivalent, they can be summed across products to provide data for the Sankey diagram (fig. 8). Calorie flows for palm fruit products from Indonesia and Malaysia and other smaller producers are shown in this figure. Source countries are on the left, and target regions on the right. We partition the world into 14 regions,[7] as listed in appendix table B.1, to better visualize where forest-risk products are consumed. For example, the European Union appears as a major consumer of palm oil but individual European

[7] Because shares for the "Rest of Europe" region are too small to appear in figures 8-10, these charts show only 13 regions.

Figure 8

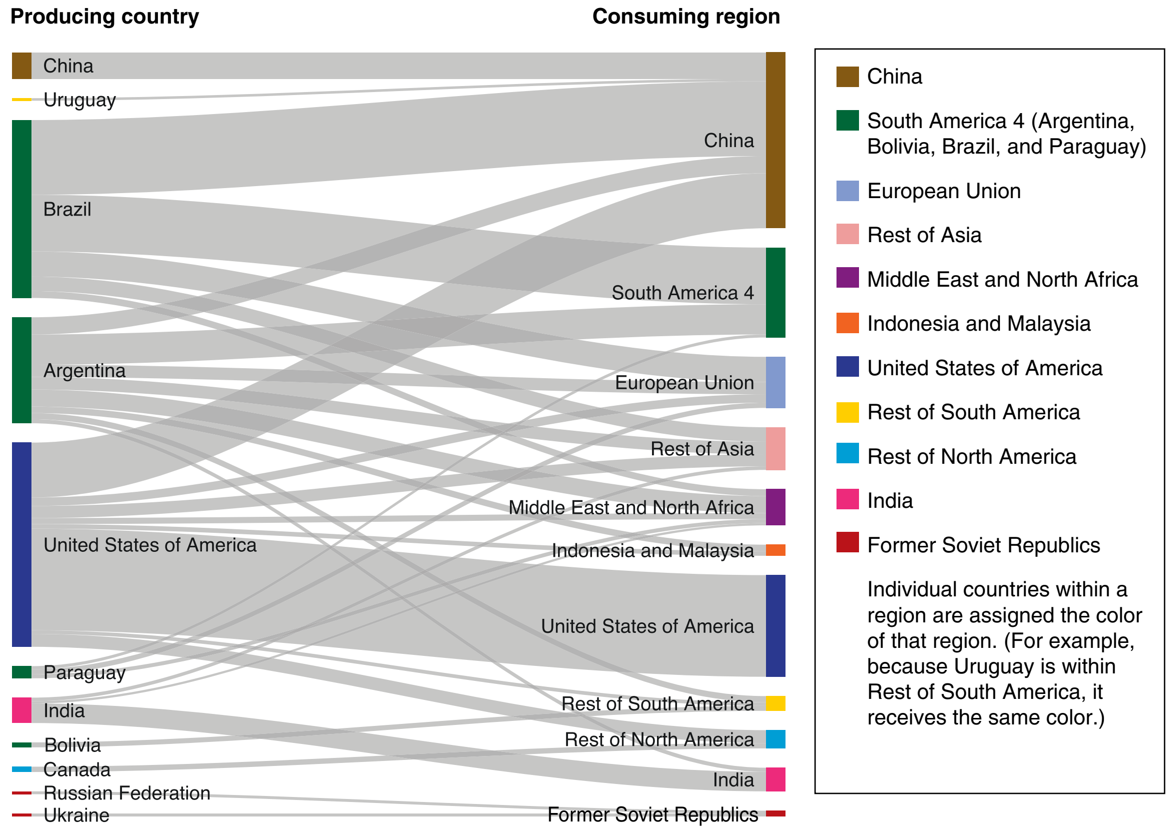
Calorie flows for palm fruit products (production and consumption, 2013)



Notes: Gray bands indicate the trajectory of palm fruit products from production to consumption (whether consumed domestically or exported). The width of each band is proportional to calories produced (on left) and then consumed or exported (on right). Exports are a weighted sum of palm oil, palm kernel oil, and palm kernel cake. The weights convert exports into calories of palm fruit equivalent. This diagram excludes bands with less than 1 million metric tons of palm fruit equivalent. “Oceania” is Australia, New Zealand, and Pacific island nations.

Source: USDA, Economic Research Service calculations based on United Nations, Food and Agriculture Organization, FAOSTAT database.

Figure 9
Calorie flows for soy products (production and consumption, 2013)



Notes: Gray bands indicate the trajectory of soy products from production to consumption (whether consumed domestically or exported). The width of each band is proportional to calories produced (on left) and then consumed or exported (on right). Exports are a weighted sum of soybeans, soybean oil, and soybean cake. The weights convert exports into calories of soybean equivalent. This diagram excludes bands with less than 1 million metric tons of soybean equivalent.
Source: USDA, Economic Research Service calculations based on United Nations, Food and Agriculture Organization, FAOSTAT database.

countries would be small consumers. Three of these regions are large countries: the United States, China, and India.

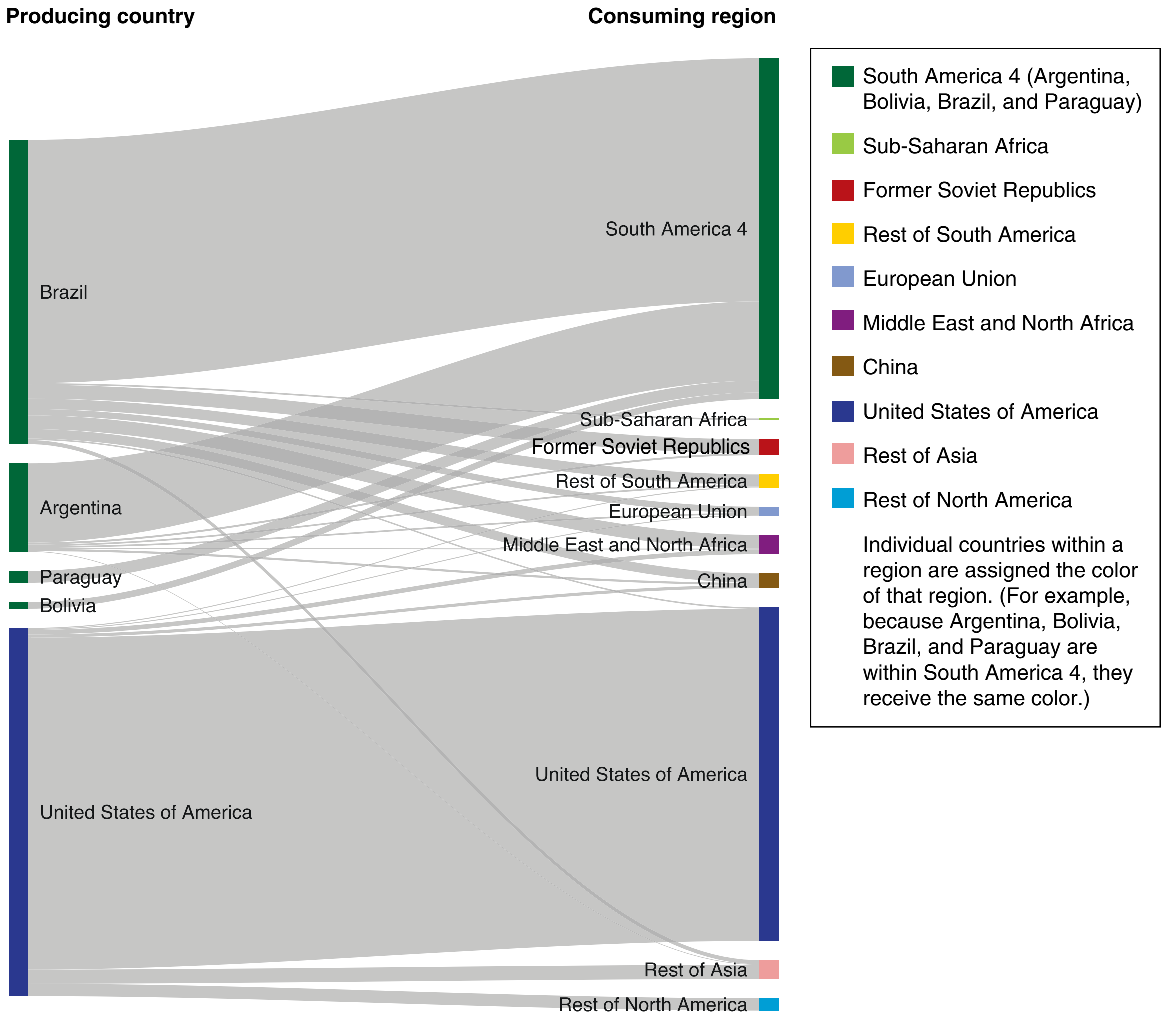
India, China, the European Union, and Sub-Saharan Africa are all large importers of palm fruit products, but the United States is a small consumer. The width of each band in figure 8 is proportional to quantity of palm fruit equivalent. Exports are a weighted sum of palm oi1, palm kernel oil, and palm kernel cake.[8]

Data that appear in figure 8 have gone through one final processing step. Rather than use trade flow data directly, which do not account for re-exports, we further adjust for pass-through trade to better distinguish the consuming country of palm fruit products. We use input-output methods of

[8] The primary product always has a weight of 1. This allows domestic production to be split into the portion exported and the portion consumed domestically, all with common units. It is necessary to sum all exported products with common units, whether primary or processed.

Figure 10

Calorie flows for beef products (production and consumption, 2013)
Production in Brazil, Argentina, Paraguay, Bolivia, and United States



Note: Gray bands indicate the trajectory of beef products from production to consumption (whether consumed domestically or exported). The width of each band is proportional to calories produced (on left) and then consumed or exported (on right). This diagram excludes bands with less than 10,000 metric tons of cattle meat equivalent. To limit the complexity of the diagram, the producing countries on the left were limited to those shown.
Source: USDA, Economic Research Service calculations based on United Nations, Food and Agriculture Organization, FAOSTAT database.

Kastner et al. (2011a) to better match consumption patterns with the country of origin.[9] The authors provide an example of soybeans shipped from Brazil to the Netherlands, which are processed into soybean oil and then shipped to Austria for consumption. Three types of data are needed for these calculations: (1) production data for the primary product (tons); (2) bilateral trade data for the primary product and secondary products derived from it (tons); and (3) conversion factors to convert secondary products into primary equivalents. Kastner et al. (2011a) provide the matrix algebra for these calculations.

[9] An input-output framework allows analysis of the interdependence of industries, usually within an economy, but can also be applied to international trade. Kastner et al. (2011a) derive a clever way to adjust trade data for pass-through trade, adapted from standard input-out methods. Miller and Blair (2009) provide a thorough coverage of input-output techniques.

For production and export of soybeans, the deforesting countries of interest are Argentina, Bolivia, Brazil, and Paraguay (table 3). Exports of soy products include soybeans, soybean oil, and soybean cake. The pattern of exports varies by country: Brazil exports mostly soybeans, but Argentina exports more processed soy products. Figure 9 shows the origination of consumed soybean flows from major world producers. Brazil, Argentina, and the United States supply large quantities of soybeans consumed in China and other parts of Asia as well as in the EU. Exports are a weighted sum of soybeans, soybean oil, and soybean cake, converted to soybean equivalent.[10]

Boneless beef and veal constitute the largest category of trade in beef products. Production and exports of beef products from South American case countries and the United States are shown in figure 10. In 2013, Brazil exported 1.87 million tons (Mt) of beef, out of 9.68 Mt produced.

Other countries besides those shown in figure 10 also produce and export large quantities of beef, but this figure would have been too complex if all large producing countries were included. To clearly show export patterns from the four South American case countries, it was necessary to limit the number of countries on the left side of the figure to those shown.

These diagrams do not capture the full amount of land embodied in exports. For example, soybean meal is fed to livestock and livestock products are exported. Table 4 provides an example for Brazilian animal products including eggs and milk.

This level of production in 2013 was supported by 86.0 Mt of feed, including 14.3 Mt of soybean meal and 0.6 Mt of soybeans. Maize is the largest component of feed at 40.5 Mt. To calculate the full amount of cropland embodied in exports of poultry, pork, and beef, we would need to estimate

Table 3

Soy products, production and exports, 2013

	Soybeans	Soybean oil	Soybean cake
		Million tons	
Production			
Argentina	49.3	6.4	-
Bolivia	3.0	0.4	-
Brazil	81.7	7.1	27.6
Paraguay	9.1	0.6	2.3
Exports			
Argentina	7.8	4.7	22.0
Bolivia	0.6	0.3	1.4
Brazil	42.8	1.4	13.3
Paraguay	5.1	0.5	1.9

Note: Blank cells represent no data in the United Nations (UN), Food and Agriculture Organization (FAO), FAOSTAT database. FAOSTAT contains a limited amount of production data on processed crops, and production of soybean cake is not reported for some countries.
Source: United Nations, Food and Agriculture Organization, FAOSTAT database.

[10] The logic here is the same as that of palm fruit products. Here, the primary product is soybeans with a weight of 1.

Table 4
Animal products, production and exports in Brazil, 2013

Commodity	Production in 2013	Exports in 2013	Share exported
	Million tons		*Percent*
Poultry	12.92	3.90	30.2
Eggs	2.29	0.02	0.9
Pork	3.28	0.76	23.1
Beef	9.68	1.87	19.3
Milk	32.65	0.12	0.4

Note: Mt = million tons.
Source: United Nations, Food and Agriculture Organization, FAOSTAT database.

the quantity of each type of feed used to produce each type of animal product.[11] Further progress in this area is reported by Herrero et al. (2013), by allocating feed to 8 livestock production systems in 28 world regions.

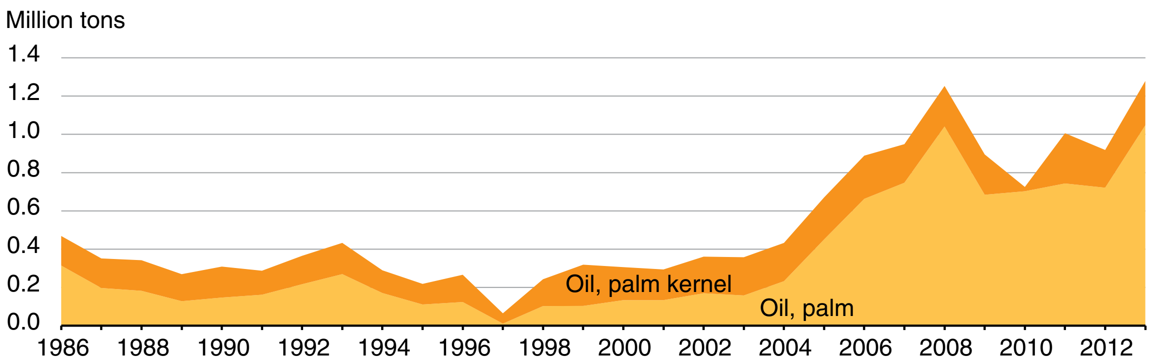
[11] Kastner (2011a) notes that data on feed shares by animal product are not readily available, but a good starting point is feed baskets for pigs and chicken in Steinfeld et al. (2006).

U.S. Imports of Forest-Risk Products

U.S. imports of forest-risk products, as well as the source country, have varied over time. Imports of palm oil and palm kernel oil since 2005 have been much higher than previously (fig. 11). Nearly all U.S. imports of these products are from Malaysia and Indonesia.

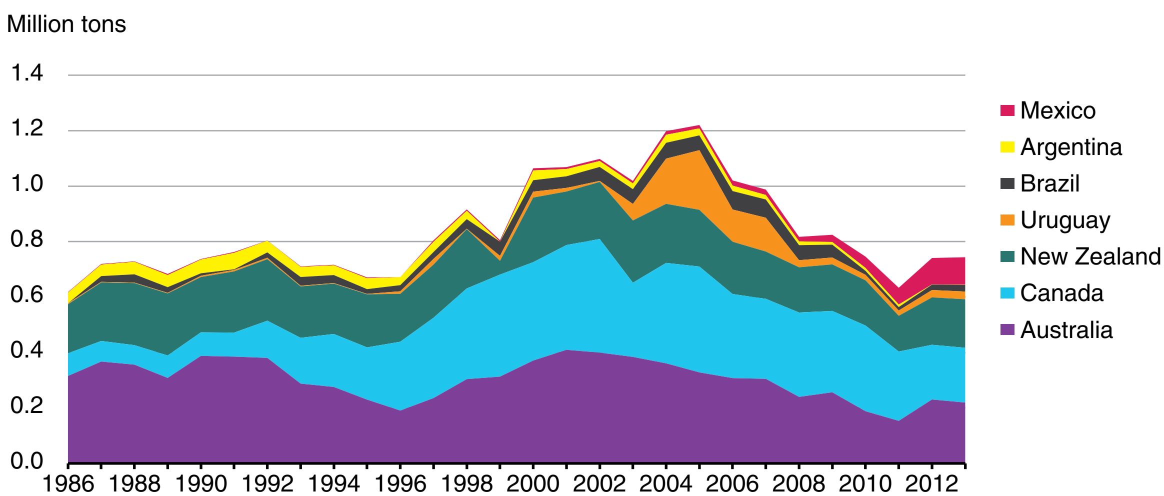
Most U.S. beef imports are from the seven countries in figure 12.[12] Beef imports to the United States peaked around 2005, and they are now at about the same level as in the 1990s. Imports from tropical South America (Argentina, Brazil, and Uruguay) are small relative to those from the other source countries.

Figure 11
U.S. imports of palm oil and palm kernel oil from Indonesia and Malaysia



Source: USDA, Economic Research Service calculations based on United Nations, Food and Agriculture Organization, FAOSTAT database.

Figure 12
U.S. imports of beef products



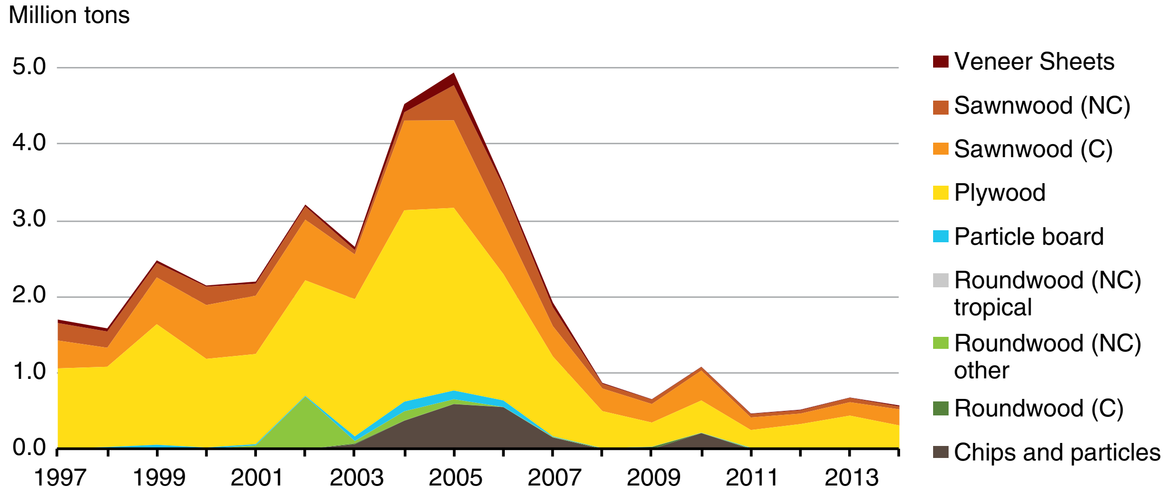
Source: USDA, Economic Research Service calculations based on United Nations, Food and Agriculture Organization, FAOSTAT database.

[12] Note that imports represent about 7 percent of U.S. beef supply based on calculations from http://www.ers.usda.gov/data-products/livestock-meat-domestic-data.aspx#26091

U.S. imports of wood products from tropical countries consist mainly of plywood and coniferous sawnwood (fig. 13). Imports have fallen dramatically since 2005, corresponding to a downturn in the overall U.S. wood-products and construction sectors (Woodall et al., 2011). These amounts, less than 1 Mt in 2014, are small compared to U.S. wood imports from Canada, about 28 Mt in 2014.

Figure 13

U.S. wood product imports from tropical case countries: Argentina, Bolivia, Brazil, Paraguay, Indonesia, Malaysia



Note: C = coniferous; NC = non-coniferous

Source: USDA, Economic Research Service calculations based on United Nations, Food and Agriculture Organization, FAOSTAT database.

Global Economic Modeling

Given the complex links and interactions between the agricultural and forest sectors, competition among these sectors for limited economic resources, as well as interactions among production, consumption, and trade, an economy-wide computable general equilibrium (CGE) modeling approach provides an appropriate framework to analyze the effects of policies on forest loss. The value of using a CGE model to evaluate policies on deforestation has been shown in Rose et al. (2013) and Villoria et al. (2014).

For both the CGE data and model, we rely on resources from the Global Trade Analysis Project (GTAP) modified by the Economic Research Service (ERS). The model and associated data development are discussed in Appendix B. With the data and model in place, we first specify a reference scenario that tracks economic changes to 2020. This business-as-usual scenario provides a point of comparison to the alternative scenarios. The alternative scenarios are motivated by policies which might induce land-use competition between forest and other land types. In the first alternative scenario, tariffs on forest-risk commodities are completely removed. In the second alternative scenario global forest policy is changed to prohibit exports of wood products from regions that have been logged illegally.

Reference Scenario—Increasing Demand for Agricultural Products

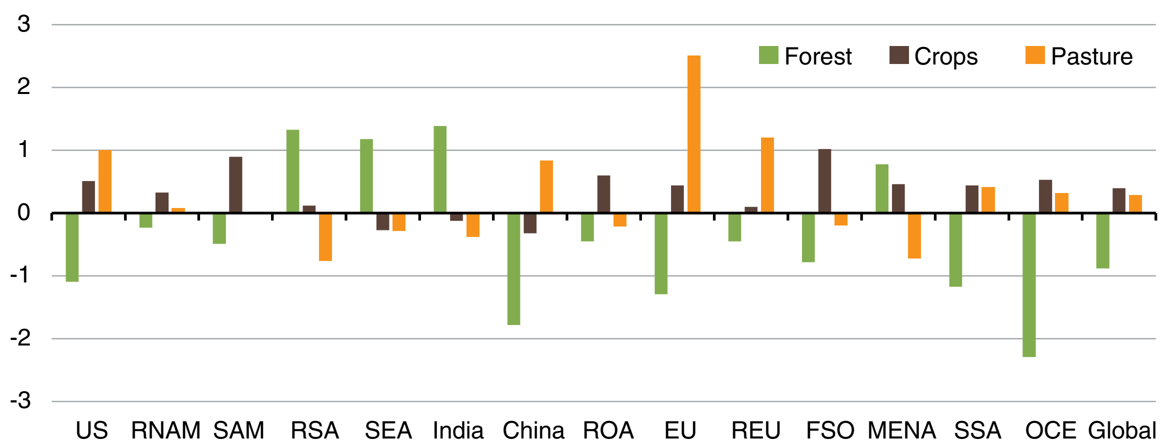
We first construct a business-as-usual scenario that provides a dynamic context with which to consider alternative scenarios. This scenario considers changes in key economic variables that project changes in the global economy over 2014-20. In particular, this scenario simulates projected growth in GDP, increased supplies of capital and labor, changes in population, and changes in agricultural productivity (see Appendix B for details).[13] The increases in population and GDP will increase the demand for agricultural commodities. The subsequent changes in labor, capital, and productivity will determine whether or not agricultural production can meet this increase. Alternative scenarios are then built upon this reference scenario. The difference in economic effects between the reference scenario and an alternative scenario will be the effect from the policy change.

Land Use

The results presented here and in the subsequent chapters cover forest-risk commodities (see Appendix C for detailed commodity level results). Figure 14 presents the land-use effects from the reference scenario (in percentage changes), detailing the changes to forest, crop, and pasture land due to the update from 2014-20. The results show increases in cropland in most regions (to meet growing food demand); globally, there is a 0.40-percent (6.3 Mha) increase in land used for crops. In addition, there is an increase in land for pasture of 0.29 percent (7.8 Mha). The entire increase in

Figure 14
Land-use effects in the reference scenario (percent change)

Percent change in land-use



Note: US = United States. RNAM = Rest of North America. SAM = South America (Argentina, Bolivia, Brazil, and Paraguay). RSA = Rest of South America. SEA = Indonesia and Malaysia. ROA = Rest of Asia. EU = European Union. REU = Rest of Europe. FSO = Former Soviet Republics. MENA = Middle East and North Africa. SSA = Sub-Saharan Africa. OCE = Oceania.
Source: USDA, Economic Research Service using the Markets and Trade Economic Division/Global Trade Analysis Project model.

[13] The growth rates are based on authors' calculations from Fouré et al. (2013). Their work gathers information for their projections from many sources, but does not consider specific policies for individual countries. Their projections do not provide a strong level of detail to individual countries; however, it is the most complete set of projections available for our data. Agricultural productivity growth rates were applied to all crops, but productivity for forests is unchanged.

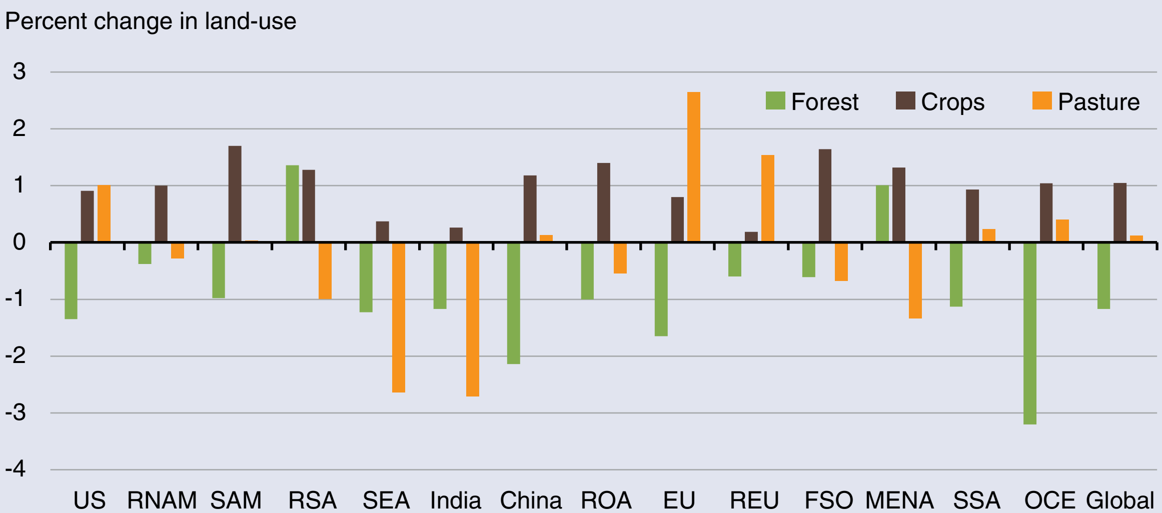
land for crops and pasture comes from forest land; globally, there is a 0.88-percent (14.9 Mha) reduction in forest land.[14] The reduction in forest land occurs mainly in those countries that are large agricultural exporters (e.g., the United States). The United States and EU have large increases in both crop and pasture land. China has a large reduction in forest land, as it allocates more land to pasture to respond to its growing population and richer economy. Oceania (OCE) also has a large decrease in forest land, as it produces more crops and livestock. Note that the increase in population and incomes is increasing the demand for agricultural products; technological progress in agricultural production is the primary means with which to increase supply. (See box, "The Role of Agricultural Productivity.")

The Role of Agricultural Productivity

To show the importance of agricultural productivity in our analysis, we simulate land-use effects in the reference scenario with agricultural productivity unchanged. Globally, with agricultural productivity constant over time, forest land falls by 1.17 percent (19.7 Mha), which is a quarter of a percent larger than forest loss with agricultural productivity included. The reason for this decrease in forest land when productivity does not increase is that more land is then needed for crops (1.05 percent versus 0.40 percent in the reference scenario). Pasture land also decreases relative to the reference scenario, with some pasture changed to cropland. In this scenario of unchanged agricultural productivity, forest land increases only in Rest of South America (RSA) and Middle East and North Africa (MENA). For those two regions, there is a large decline in pasture land that is reallocated for crops.

Box figure

Land-use effects in the reference scenario with no change in agricultural productivity



Note: US = United States. RNAM = Rest of North America. SAM = South America (Argentina, Bolivia, Brazil, and Paraguay). RSA = Rest of South America. SEA = Indonesia and Malaysia. ROA = Rest of Asia. EU = European Union. REU = Rest of Europe. FSO = Former Soviet Republics. MENA = Middle East and North Africa. SSA = Sub-Saharan Africa. OCE = Oceania.
Source: USDA, Economic Research Service using the Markets and Trade Economic Division/Global Trade Analysis Project model.

[14] Percent changes are calculated using the GTAP land use data base for 2011 (Peña-Lévano et al., 2015). In 2011, global accessible forest land covered 1,686 Mha, global cropland was 1,562 Mha, and global pasture was 2,704 Mha. One hectare (ha) equals 2.47 acres.

Production, Prices, and Trade

The land-use effects are driven by production changes necessary to fulfill demand from growing economies and populations that are projected under the reference scenario. The United States shows a decrease in forest land (fig. 14), the result of rising production of almost every agriculture commodity (Appendix table C.1). There is a decrease in production of soybean-based vegetable oil; however, total oilseed production rises as a result of a large increase in soybean production (table 5). The United States also has an increase in beef production. Most other regions show similar large increases in agricultural production; however, because the United States is one of the world's largest producers of most agricultural products, its large changes result in land being converted from forest to crops and pasture. The EU, another major agricultural producer, also has large increases in production for most products, which also lead to land being converted from forest to crops and pasture. The increases in cropland are largest for South America (SAM), due to oilseed production, and Former Soviet Republics (FSO), due to grain production. Production of forest products rises in most countries. Globally, production of all three forest-risk products increase.

Oilseed prices rise in all regions due to the increase in demand under the reference scenario (table 5). On the other hand, prices for forest products rise in most regions while beef prices are mixed. Table 5 also presents changes in trade (exports and imports) in these forest-risk commodities. Table

Table 5

Production, prices, and trade changes in the reference scenario (percent change)

	Production			Prices			Exports			Imports		
	Forest	Oilseeds	Beef	Forest	Oilseeds	Beef	Forest	Oilseeds	Beef	Forest	Oilseeds	Beef
US	11.65	7.66	4.34	-1.01	37.66	-2.65	30.89	15.46	24.04	-0.51	8.61	-5.30
RNAM	-7.23	22.54	13.99	23.98	17.90	-4.27	-18.31	29.37	38.83	25.59	11.09	7.26
SAM	4.88	20.49	5.93	19.71	32.67	1.99	-20.16	27.15	-3.79	30.89	59.87	12.07
RSA	7.07	8.80	7.26	36.26	12.29	1.53	-8.60	9.60	-1.07	20.57	9.86	15.85
SEA	-4.88	9.71	-15.48	46.14	22.25	23.28	-35.70	11.68	-79.46	40.41	26.03	83.28
India	13.45	2.63	58.87	20.59	29.67	-6.61	4.71	0.75	77.65	16.74	23.14	-5.51
China	2.33	5.41	13.45	19.77	24.47	4.56	-42.02	20.15	-22.09	83.15	19.43	30.42
ROA	56.02	4.33	8.84	-5.33	12.67	-4.01	131.39	5.07	41.19	-15.76	3.06	-1.63
EU	2.94	1.17	12.55	2.46	14.43	-2.96	3.97	1.85	30.54	9.63	0.08	-12.26
REU	-1.03	14.06	3.04	18.55	16.19	-1.52	-17.83	56.77	15.45	24.90	2.22	15.05
FSO	-19.26	24.54	4.70	73.98	13.91	1.84	-48.19	49.49	-5.98	65.07	15.00	19.31
MENA	36.78	16.13	9.15	-4.36	15.98	-0.42	69.36	49.17	4.57	5.59	13.55	24.03
SSA	11.82	7.79	17.96	68.56	33.73	-7.93	5.07	-10.61	82.05	28.58	16.07	3.13
OCE	-5.01	-3.02	-12.12	44.53	24.61	7.87	-23.18	-2.09	-39.29	50.11	2.67	22.16
Global	11.43	9.99	8.09	11.11	25.10	-0.87	14.05	18.81	17.25	16.57	12.52	5.09

Note: Forest includes the sectors *frs* and *woodp*; oilseeds includes *soy*, *palm*, *othosd*, *soyoil*, *palmoil*, and *othvol*. US = United States. RNAM = Rest of North America. SAM = South America (Argentina, Bolivia, Brazil, and Paraguay). RSA = Rest of South America. SEA = Indonesia and Malaysia. ROA = Rest of Asia. REU = Rest of Europe. FSO = Former Soviet Republics. MENA = Middle East and North Africa. SSA = Sub-Saharan Africa. OCE = Oceania.

Source: USDA, Economic Research Service (ERS) using the USDA, ERS, Market and Trade Economic Division/Global Trade Analysis Project model.

5 shows large gains in U.S. exports in all three forest-risk commodities, while U.S. imports fall for two of the three products (forest products and beef). China and India are the world's largest importers of oilseed products; their imports increase under the reference scenario. The percentage change in oilseed imports is largest for SAM and Southeast Asia (SEA); however, their base imports are small. Exports of forest products fall for 8 of the 14 regions.

Tariffs Removed on Forest-Risk Products

This alternative scenario considers the complete global removal of tariffs on forest-risk products (see Appendix C for the rates). Tariff removal could have competing effects on land use. As noted in European Commission (2013b), the removal of tariffs could lead to increased consumption of these commodities and possibly more deforestation. In addition, tariff removal could increase land rents in land-abundant countries leading to greater deforestation. Alternatively, tariff removal could lead to a reallocation of production to the most efficient producers, leading to less deforestation.

Land Use

Figure 15 presents the land-use effects from the tariff removal scenario (in percentage changes), detailing the changes to forest, crop, and pasture land.[15] Under this scenario, there is a 0.03 percent (0.6 Mha) increase in global forest loss compared to the reference scenario. But, the change in land use is mixed across regions. Crucially, in the forest-risk areas of Rest of South America (RSA), Indonesia and Malaysia (SEA) and South America (SAM), there is a reduction in forest land compared to the reference scenario. There is also a reduction in forest land in several other regions (United States, China, India, and OCE). Among the regions showing an increase in forest land compared to the reference scenario, the EU, Rest of Europe (REU), Former Soviet Republics (FSO), and Middle East and North Africa (MENA) experience the greatest changes. The increase in EU forest land and reduction in land for pasture results from the elimination of the large tariffs on beef. Removal of the tariffs leads to an increase in EU beef imports and a decrease in domestic production. U.S. beef exports rise under this scenario; thus there is an increase in the amount of land moving out of U.S. forests into pasture relative to the reference scenario.

Production, Prices, and Trade

Tariff removal leads to changes in production of forest-risk products relative to the reference scenario (table 6). The largest changes relative to the reference scenario are in the production of oilseeds and beef (disaggregated results are in appendix table C.5). Oilseed production in the United States falls by a quarter of a percent relative to the reference scenario, although the United States is a major global producer. This occurs because production of beef in the United States increases by 4 percent relative to the reference scenario, leading to less resources for other agricultural uses. The land conversion results shown in figure 15 are a result of the switching between oilseed and beef production. U.S. beef production increases due to the removal of tariffs on beef—in particular, the removal of tariffs in the EU. As noted in Beckman and Arita (2016), the EU has high protectionist barriers on beef imports; much of the increase in U.S. beef production is exported to the EU.

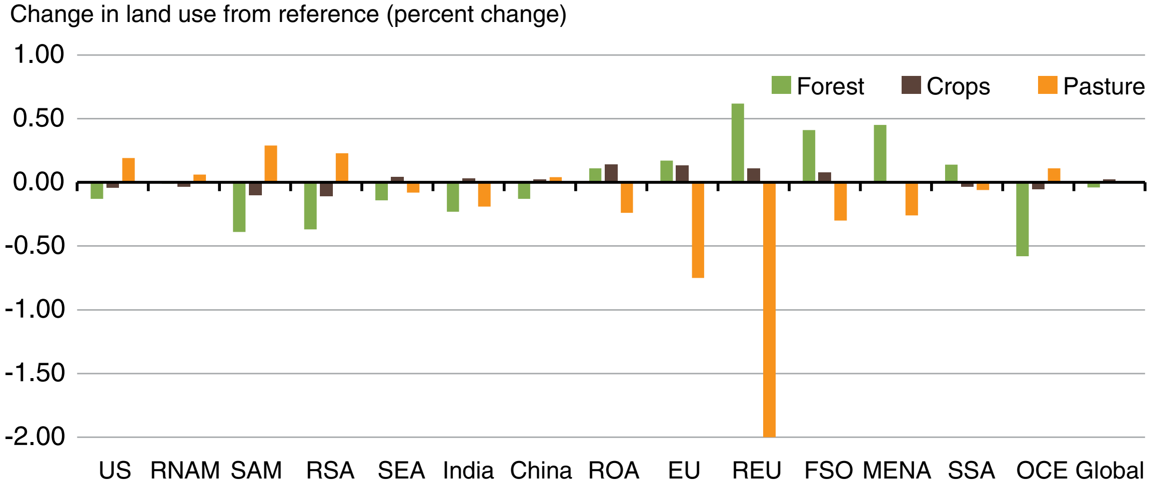
The increase in imports into the EU leads to a large reduction in beef production relative to the reference scenario. Beef production also rises in SAM and RSA, two major beef producers identified as deforestation regions earlier in the report. There are decreases in the production of forest products, mainly because the increase in beef production draws resources away from that activity.[16] Apart from the United States, the other major global oilseed producers have mixed results; although there

[15] For each alternative scenario, the reported change equals the percent change in the alternative scenario minus the percent change in the reference scenario.

[16] Note that in 11 of the 14 regions, forest products decrease and beef increases (or vice-versa).

Figure 15

Land-use effects from tariff removal scenario relative to reference scenario (percent change)



Note: US = United States. RNAM = Rest of North America. SAM = South America (Argentina, Bolivia, Brazil, and Paraguay). RSA = Rest of South America. SEA = Indonesia and Malaysia. ROA = Rest of Asia. EU = European Union. REU = Rest of Europe. FSO = Former Soviet Republics. MENA = Middle East and North Africa. SSA = Sub-Saharan Africa. OCE = Oceania.
Source: USDA, Economic Research Service using the Markets and Trade Economic Division/Global Trade Analysis Project model.

Table 6

Production, price, and trade changes from tariff removal scenario relative to reference scenario (percent change)

	Production			Prices			Exports			Imports		
	Forest	Oilseeds	Beef	Forest	Oilseeds	Beef	Forest	Oilseeds	Beef	Forest	Oilseeds	Beef
US	-3.06	-0.25	4.33	-0.28	1.00	0.64	-4.35	1.65	79.76	11.60	7.62	6.27
RNAM	-7.73	1.83	2.44	-1.33	0.49	0.17	-8.09	4.33	19.35	17.86	4.43	1.37
SAM	-10.12	0.77	7.13	-5.15	1.06	1.28	-11.87	0.97	55.74	90.87	-1.18	4.27
RSA	-7.86	0.00	7.79	-3.61	0.30	1.57	-15.68	0.31	111.87	30.42	-0.04	8.10
SEA	2.06	1.13	-0.97	-0.12	1.76	0.75	20.00	3.13	-8.71	34.69	2.29	3.37
India	2.93	1.67	-27.21	-0.27	0.41	0.16	25.67	16.04	-38.70	65.63	2.41	53.50
China	3.96	-0.61	-3.16	-0.17	0.54	-0.22	30.01	-0.89	-34.21	74.80	1.12	18.19
ROA	22.40	-1.10	-22.13	0.54	0.45	-1.44	67.27	10.33	-47.99	17.60	1.16	65.01
EU	-1.89	-0.26	-50.18	-0.33	-0.07	-0.92	1.32	2.04	-46.77	12.06	0.42	180.08
REU	2.49	-8.14	-72.58	-0.81	-1.63	-7.83	11.97	36.85	-35.67	1.42	30.13	550.91
FSO	-14.82	3.49	-7.62	-4.20	-0.20	-1.81	-4.22	9.46	-47.07	43.05	4.21	89.74
MENA	-8.65	3.58	-14.65	-0.54	-0.58	-0.73	-5.21	43.95	-49.21	22.72	6.00	85.56
SSA	-16.63	-0.34	0.84	-2.90	-0.46	-0.36	-11.35	5.57	205.10	48.43	0.83	49.68
OCE	-10.55	-0.07	10.31	-1.12	0.45	1.96	-2.52	-0.16	25.11	38.54	-0.35	3.80
Global	1.28	0.50	-8.50	-0.52	0.71	-0.14	15.86	3.42	4.62	23.76	2.15	95.77

Note: US = United States. RNAM = Rest of North America. SAM = South America (Argentina, Bolivia, Brazil, and Paraguay). RSA = Rest of South America. SEA = Indonesia and Malaysia. ROA = Rest of Asia. REU = Rest of Europe. FSO = Former Soviet Republics. MENA = Middle East and North Africa. SSA = Sub-Saharan Africa. OCE = Oceania.
Source: USDA, Economic Research Service using the Markets and Trade Economic Division/Global Trade Analysis Project model.

are increases in the forest-risk regions of SAM and SEA. Globally, there is an increase in forest-product and oilseed production, but a decrease in beef production.

Almost all regions experience a decrease in the price of forest products relative to the reference scenario as production and demand falls. These price changes are, however, smaller than those for oilseeds and beef. The global price of forest products decreases from 9.56 percent in the reference scenario to 9.21 percent in this trade scenario; the change for oilseeds is from 22.75 to 23.43 percent, while beef changes from -1.36 to -0.36 percent. Individually, prices for oilseeds increase the most compared to the reference scenario for SAM and SEA (two of the regions with the largest production increases), while price changes for beef are mixed.

As expected, the tariff removal scenario generates changes in trade (table 6). The United States has an increase in both exports and imports of oilseeds; overall, there is an increase in net exports (exports minus imports) because the United States exports much more oilseeds than it imports. Almost all regions have an increase in oilseed exports and imports. The largest gains in net exports are to Rest of North America (RNAM), SAM, and FSO. There are increases in imports of forest products and beef in every sector, but export changes are mixed. The United States, RSA, and Sub-Saharan Africa (SSA) have large increases in exports of beef, although SSA has relatively small base exports compared to the other two.

Under this scenario, there are large changes in net exports of forest products. Net exports decrease in many countries, due to a reduction in exports. This change occurs despite the fact that current tariffs are higher for these products than for oilseeds. Since oilseeds are necessary for consumption, the removal of tariffs and the reallocation of resources leads to a stronger demand for oilseeds than for forest. This reduction in exports leads to the decline in production, which factors into the reduction in forest land (fig. 15).

Prohibiting Exports of Illegally Produced Forest Products

The second alternative scenario considers changes due to global forest policy, such as the through the Lacey Act in the United States (see box, "Background on the Lacey Act"), which prohibits exports of forest products produced illegally in their country of origin.[17] Using the work of Li et al. (2008), we construct a measure of illegally produced forest products in each region. Exports of forest products are then reduced by that percentage through a tax on exports. Note that the estimates of illegal logging for each region (fig. 16) consider the upper bound of illegally logged forest products from Li et al. (2008)[18], and thus, they should be considered an upper bound of potential effects. The Lacey Act is used as an example of a policy currently in place, but the regions noted for illegal logging in figure 16 do not necessarily reflect the current state of the Lacey Act or any other policy. Again, note that this scenario considers a reduction in global exports of these regions.

Land Use

Under a scenario that prohibits the exports of products from illegally logged wood, there is a decrease in global deforestation relative to the reference scenario (fig. 17). Compared to the reference scenario, land allocated to forest increases by 0.06 percent (0.9 Mha), this is at the expense of both cropland (-0.02 percent or -0.3 Mha) and pasture land (-0.02 percent or -0.6 Mha). In addition, in figure 17, there is a decrease in deforestation in many of the regions that show up as illegal loggers in figure 16. Thus, illegal deforestation has likely decreased. The largest increases in forest land relative to the reference scenario are generally to those countries with the highest share of forest products illegally logged; the main exception is in ROA. That is, the amount of land used for forest increases the most relative to the reference scenario, although ROA has only the fifth largest share of illegally

Background on the Lacey Act

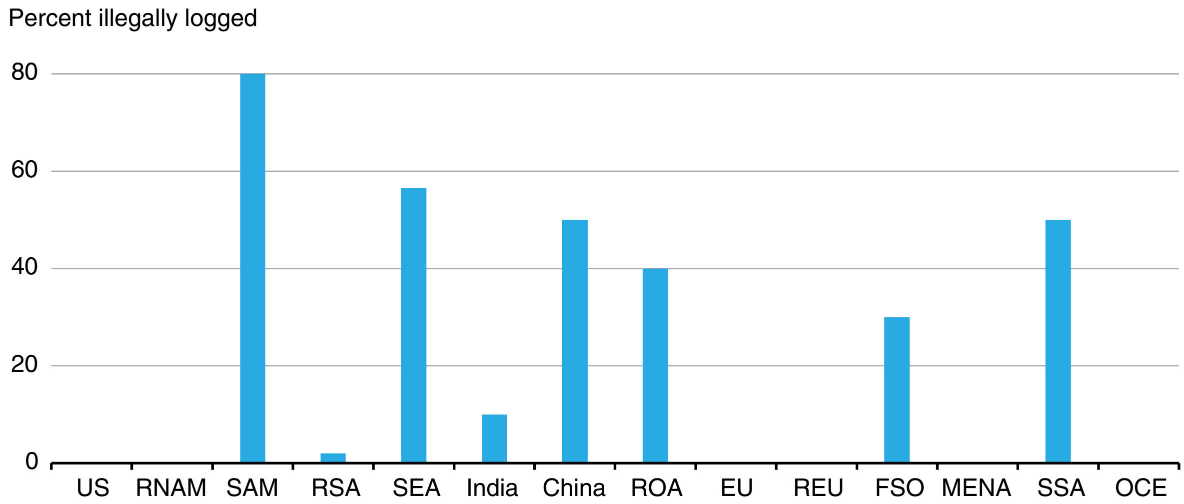
The U.S. Lacey Act of 1900 requires that plant and animal products imported into the United States be produced and obtained legally (Prestemon, 2015). Since 2008, it has also required that imported forest products be produced and traded legally throughout their supply chain, including in the country of origin (Prestemon, 2015). Rates of illegal logging vary between countries, but for some important deforesting nations, up to 80 percent of wood production may be illegal (Ruhong et al., 2008). Stopping imports of these products is a potential tool for reducing deforestation and forest degradation. Research has shown that import quantities have declined and prices increased for tropical hardwoods originating from some countries where illegal logging is known to exist (Prestemon, 2015). However, previous research has not linked import reductions in the United States, and the associated global trade adjustments, with land use change in source countries. The scenario here represents perfect Lacey Act enforcement, such that no illegally sourced wood may be imported to the United States, to model that effect.

[17] In addition, several other countries have similar policies, e.g., Australia and the EU.

[18] Li et al. (2008) provide high and low estimates of the share of illegally logged products from sawlogs and pulpwood. We use the sawlogs estimates since data from the FAOSTAT database indicate that the majority of wood products are produced from sawlogs.

Figure 16

Share of forest products illegally logged

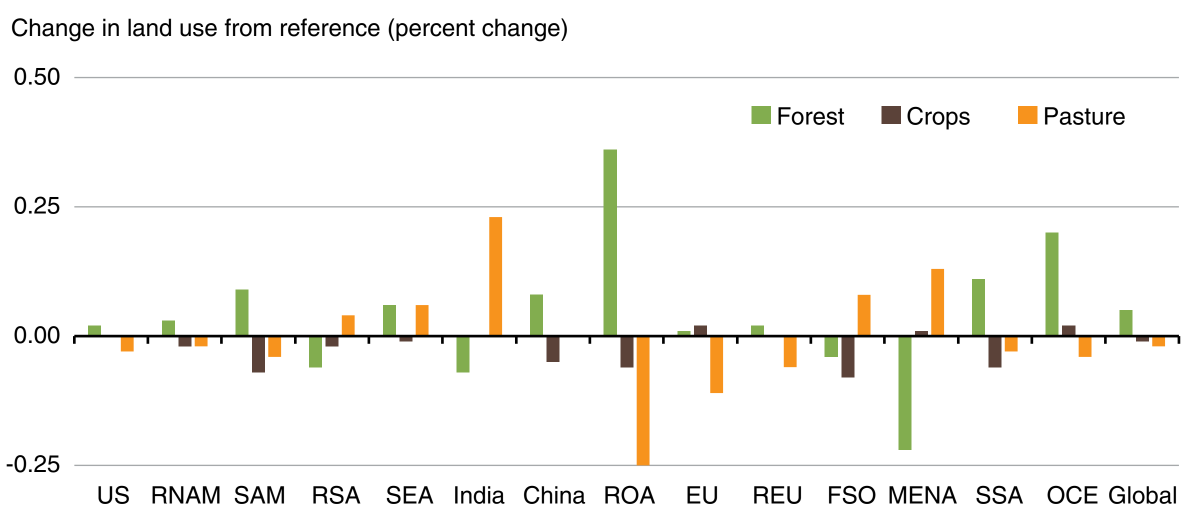


Note: We use the largest producer of sawnwood for each region as the representative point, except for SEA, which is an average of Indonesia and Malaysia. US = United States. RNAM = Rest of North America. SAM = South America (Argentina, Bolivia, Brazil, and Paraguay). RSA = Rest of South America. SEA = Indonesia and Malaysia. ROA = Rest of Asia. EU = European Union. REU = Rest of Europe. FSO = Former Soviet Republics. MENA = Middle East and North Africa. SSA = Sub-Saharan Africa. OCE = Oceania.

Source: USDA, Economic Research Service calculations based on Li et al. (2008), Forest Policy and Economics 10:480-490.

Figure 17

Land-use effects from forest policy scenario relative to reference scenario (percent change)



Note: US = United States. RNAM = Rest of North America. SAM = South America (Argentina, Bolivia, Brazil, and Paraguay). RSA = Rest of South America. SEA = Indonesia and Malaysia. ROA = Rest of Asia. EU = European Union. REU = Rest of Europe. FSO = Former Soviet Republics. MENA = Middle East and North Africa. SSA = Sub-Saharan Africa. OCE = Oceania.

Source: USDA, Economic Research Service using the Markets and Trade Economic Division/Global Trade Analysis Project model.

produced forest products. The United States has an increase in forest land of 0.02 percent relative to the reference scenario, although U.S. forest-product exports are not restricted.

Production, Prices, and Trade

The forest policy scenario leads to decreases in production of forest for most of the countries with reductions in forest-product exports (table 7).[19] Globally, production of forest products increases by 0.41 percent over the reference scenario and is due to the rise in EU and U.S. production of 18.05 and 12.14 percent, respectively. The EU and United States also show the largest increases in terms of quantity of forest products produced. Most regions have an increase in oilseed production compared to the reference scenario, with the exceptions being SAM and India. Production of beef compared to the reference scenario is mixed; although globally, there is a 0.12-percent reduction. Forest-product prices rise in 8 of the 14 regions compared to the reference scenario; however, many of the countries are limited in how much can be exported, which affects production. Therefore, more land is available for conversion to oilseeds and beef, and these prices fall compared to the reference scenario.[20]

Table 7
Production, price, and trade changes from forest policy scenario relative to the reference scenario (percent change)

	Production			Prices			Trade					
							Exports			Imports		
	Forest	Oilseeds	Beef	Forest	Oilseeds	Beef	Forest	Oilseeds	Beef	Forest	Oilseeds	Beef
US	12.14	2.30	-0.09	6.08	-5.79	-2.79	47.62	-0.25	-5.04	-21.38	-0.38	1.50
RNAM	-0.19	0.84	-0.16	21.79	-4.48	-2.84	3.21	-1.20	-2.70	-3.14	0.07	-0.36
SAM	-3.78	-0.15	0.35	-3.18	-5.24	-3.60	-59.84	-0.32	3.03	-41.69	-0.10	-0.79
RSA	1.65	3.57	0.08	26.02	-3.99	-3.23	6.60	-0.18	0.12	-13.43	0.01	0.86
SEA	-0.38	0.22	0.74	-5.05	-4.68	-4.55	-20.80	-0.19	0.60	-49.85	-0.37	-1.66
India	-1.16	-0.08	-4.31	-1.95	-4.71	-2.75	-14.71	-1.51	-6.16	-36.44	0.12	1.66
China	-1.49	6.23	0.09	16.31	-6.54	-5.32	-7.98	4.38	11.52	-35.75	-1.94	-4.86
ROA	-57.81	4.72	1.02	-1.12	-4.93	-5.34	-171.39	2.44	27.07	-35.26	-0.24	-7.20
EU	18.05	1.13	-1.04	8.89	-4.00	-2.74	32.86	-0.77	-3.36	-17.22	0.31	2.04
REU	1.87	4.19	-0.39	20.57	-3.98	-2.61	11.99	-4.30	-4.41	-2.81	0.10	0.48
FSO	19.41	1.27	-0.12	-34.08	-3.87	-2.86	18.19	-3.07	-2.26	-36.07	-0.52	1.57
MENA	27.98	0.76	0.03	5.25	-3.83	-2.79	83.99	-3.84	-3.00	-16.53	0.46	2.15
SSA	8.02	0.71	-0.19	-44.11	-4.75	-2.63	-55.07	-1.42	-3.31	-43.20	0.02	1.18
OCE	8.28	1.28	0.85	34.13	-4.40	-4.10	10.19	-0.41	1.35	-27.16	0.63	-0.57
Global	0.41	1.96	-0.12	7.48	-5.14	-3.21	-8.51	-0.54	-1.84	-22.74	-0.54	-0.46

Note: US = United States. RNAM = Rest of North America. SAM = South America (Argentina, Bolivia, Brazil, and Paraguay). RSA = Rest of South America. SEA = Indonesia and Malaysia. ROA = Rest of Asia. REU = Rest of Europe. FSO = Former Soviet Republics. MENA = Middle East and North Africa. SSA = Sub-Saharan Africa. OCE = Oceania.
Source: USDA, Economic Research Service using the Markets and Trade Economic Division/Global Trade Analysis Project model.

[19] Note that only some of the forest land in the land-use figures is used to produce *forest* products; the rest is simply left alone. Hence, results could differ in land use and *forest* products.

[20] Note that the relationship between land used to illegally log wood products and land used for crop/beef production is the same as the relationship between all forest land and crop/livestock production. That is, there is no specification for land that has been illegally logged in our data.

Among the forest-risk commodity producers (SAM, SEA, and RSA), forest-product production declines in two of the three regions. In particular, there are large changes relative to the reference scenario for SAM and SEA, where there is a 60-percent and 21-percent reduction in forest-product exports. Because the share of forest products illegally logged in the other region (RSA) is very small, forest production and land allocated to forest is only slightly affected. Beef production rises in all three regions, while oilseed production increases in RSA and SEA. Note that of the three, only RSA experiences an increase in production of forest products relative to the reference scenario.

For the United States, the forest policy scenario leads to a large increase in exports of forest products, at the expense of oilseed and beef exports. Imports of oilseeds fall; however, there is an increase in beef imports relative to the reference scenario.

Conclusions

In recent decades, global agricultural production has increased as a result of rising agricultural productivity, but also because of expanding agricultural land area, including expansion into tropical forests. This expansion into tropical forests has raised concerns about loss of biodiversity and carbon dioxide emissions from forest loss. Projected increases in future population and per-capita income will bring rising demand and further increases in agricultural production.

Land used for production of soybeans and palm oil, both forest-risk commodities, has expanded rapidly in tropical countries. The increase in land area since 1990 for soybeans and oil palm is less than, but nearly equal to, area deforested over the same period. However, the immediate post-conversion land use is not necessarily the same as the most rapidly expanding land use. In Brazil, land for soybeans is expanding, but beef is the dominant land use immediately after deforestation.

Oil palms are grown in tropical countries, and there is little opportunity to increase production of palm oil elsewhere. However, other oilseed products are available as substitutes for palm oil used in cooking or as a biodiesel feedstock. World demand for soybeans is growing along with world demand for animal products. The United States is a large supplier of soybeans to world markets, along with Argentina and Brazil. Future increases in soybean yield in these three countries, along with world soybean demand, will determine the amount of land required for soybeans. Depending on changes in future agricultural productivity, the amount of land used to grow soybeans could either increase or decrease.

A global economic model was used to identify potential effects of policies on forest loss relative to a reference scenario. The global economic model simulated global land use for 14 world regions from 2014 to 2020. In the reference scenario, without additional policies, global cropland increases by 6.1 Mha, while forest area declines by 14.8 Mha. Two alternative policies were considered: removal of tariffs on all forest-risk products, and a prohibition of exports of illegally produced forest products. In the tariff removal scenario, the amount of deforestation increases as countries produce more oilseeds and beef. Crucially, forest land is reduced in the forest-risk regions, by 0.39 percent (Argentina, Bolivia, Brazil, and Paraguay), 0.37 percent (rest of South America), and 0.17 percent (Indonesia and Malaysia). In the scenario in which illegally traded forest products are eliminated, there is an increase in forest land compared to the reference scenario of 0.8 Mha.

It is important to note the role agricultural productivity plays in reducing the amount of land necessary for crops and pasture to meet the increase in food demand from increasing population and income in the reference scenario. Without the agricultural productivity increases noted in appendix table B.3, the amount of land necessary for conversion from forest land would be much greater as cropland would be less productive. Note that recent work by Ausubel et al. (2012) concludes that agricultural productivity increases could be of such a magnitude as to take pressure off the need for expanding agricultural lands.

This study considers two alternative scenarios that could affect forest loss, but does not consider their probability of implementation. In addition, the results from this study depend heavily on assumptions used to update the reference scenario and then to project it forward. Also important is the role of parameters in the computable general equilibrium model that is used for the global economic analysis. In particular, the parameter that governs the substitutability among land-use types is critical. For this work, we relied on those used by the California Air Resources Board in their indirect land-use assessment of various biofuels.[21] Some of the parameters have received scrutiny from the academic community. Thus, any further work should closely examine these, especially the rate of land-use change among activities.

This work considers how current and future consumption of food and wood products affect deforestation. Without limits to consumption, production will increase to meet demand. Our analysis indicates that agricultural productivity can partly help to meet this demand; however, additional land is likely required. At least for food products, increased consumption is unavoidable. Substitutions can be made within groups of food products—e.g., other vegetable oils for palm oil or chicken for beef—but even this strategy may require more land (or increased productivity). Forest products can likely be substituted more easily than food products. A long-term model with a time horizon of 2050 or beyond could address this potential for substitution and the degree to which it could affect consumption.

[21] More information can be found at: https://www.arb.ca.gov/fuels/lcfs/iluc_assessment/iluc_assessment.htm

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Appendix A. Methods and Data

We adhered to the methods and data sources compiled in Henders et al. (2015), except where noted. All primary production data and bilateral trade data (in the form of exports from the reporter country) were obtained from FAOSTAT (2016). We converted all secondary agricultural products into tons of primary product-equivalent using methods reported in Kastner et al. (2011a).

We used the deforestation rates compiled by Henders et al. (2015) to the year 2011, and allocation of those deforestation rates to commodities, unless noted otherwise. We extended deforestation data to 2013 using Hansen et al. (2013) and updated shares of deforestation for each commodity if the literature supports a change; if not, the shares from 2011 have been extended.

Deforestation data for the Brazilian Amazon were extended using the INPE PRODES project of the Brazilian government (INPE, 2016). Deforestation data for the Brazilian Cerrado were updated from 2008-2011 using the data produced by the Brazilian PMDBBS project (IBAMA, 2016); 2011-2013 data were taken from Spera et al. (2016). Extended data on shares of clearing for soy in the Brazilian Cerrado were taken from Gibbs et al. (2015).

Claims as to the proximate causes of deforestation in Indonesia have differed widely across studies (Henders et al., 2015). These claims have been complicated by differing standards of reporting results, remote sensing practices, and study areas. Some differences stem from the study region chosen: palm production is highly geographically concentrated, particularly in Kalimantan and Sumatra, and reported rates tend to be higher in studies limited to these regions. Other differences stem from the categorization of forest land in remote sensing data. Some authors distinguish intact primary and secondary forest from scrubland, agroforestry, and seriously degraded forest land, while others use coarser definitions of forest cover. Some authors may separate plantation forests for fiber while others do not (Busch et al., 2015).

In addition, while some authors report the fate of deforested land (which are the data needed here), others report the origin of land converted to palm plantations. These statistics are not equivalent: see the entry for Gunarso et al. (2013) in appendix table A.1 for an example of how they can differ. As a trivial example, consider a situation where 2 hectares of forest are cleared, resulting in 1 hectare of palm plantation and 1 hectare of fiber plantation. While the origin of the palm plantation is 100-percent forest, the converted fate of the forest is 50-percent palm plantation and 50-percent fiber plantation. Because some authors report the former statistic, some studies (Carlson et al., 2012; Koh and Wilcove, 2008) could not be used for our purposes. (See appendix table A.1. for a synopsis.)

Due to the weaknesses inherent in the existing studies, we elected to use an average over two time periods, 2000-2004 and 2005-2013, of four studies (Abood et al., 2015; Gunarso et al., 2013; Lee et al., 2014; Busch et al., 2015). This rate is conservative compared with some other studies—notably, Henders et al. (2015), which relies on calculations of deforestation from national production statistics.

In Indonesia and Malaysia, primary production data for palm kernels and palm fruits downloaded from FAOSTAT indicate that these commodities are traded in very small volumes. This is because palm fruit is perishable and thus both the fruit and its seed, the kernels, are pressed immediately after harvest. Thus, we do not report trade for palm kernels or palm fruit. In addition, long-term aggregate trade data for wood products from these countries do not match more recent bilateral trade

Appendix table A.1
Shares of direct deforestation for forest-risk commodities in Indonesia

Source	Crop	Year	Location	Information type*	Share
Abood et al. (2015)	Fiber	2000-2010	All/most	Converted fate of forests	12.8
	Logging	2000-2010		Converted fate of forests	12.5
	Palm	2000-2010		Converted fate of forests	11.0
Busch et al. (2015)	Palm	2000-2010	All/most	Converted fate of forests	19.9
	Fiber	2000-2010		Converted fate of forests	12.6
	Logging	2000-2010		Converted fate of forests	5.2
Lee et al. (2013)	Palm	2000-2010	Sumatra	Converted fate of forests	19.3
Gunarso et al. (2013)	Palm	2000-2005	All	Converted fate of forests	7.7
		2005-2010	All	Converted fate of forests	27.0
		2000-2010	All	Origin of palm plantations	36.5
Koh and Wilcove (2008)	Palm	1990-2005	All	Origin of palm plantations	56.0

*The information type given here represents the type of data presented by the authors. For the "converted fate of forests," the share represents the share of cleared forest whose next use is oil palm plantations. For the "origin of palm plantations," the share represents the share of palm plantations whose previous land use was forest. These data are not interchangeable: see Gunarso et al. (2013) as an example of the difference.
Source: USDA, Economic Research Service calculations, using United Nations, Food and Agriculture Organization FAOSTAT data, 2016.

data, which imply larger traded volumes than the aggregate data. We used bilateral data for the years 1997 onward, and aggregated data for earlier years.

In South America, double-cropping presents a special issue. In commercial systems, soy is often intercropped with wheat, sunflower, corn, or a second crop of soy, either by planting a winter and summer crop or by alternating crops in rotation. To attribute deforestation between these crops requires understanding the importance of each crop in the deforesting agent's decisionmaking process, an issue we can only understand at the broadest level in this context.

In Bolivia, wheat and sunflower are the principal crops grown with soy. Analysis of revenue per hectare shows that revenues from each crop are very similar. Furthermore, detailed analysis by Redo and Millington (2011) shows that, from 1994 to 2008, land was converted to double- rather than single-cropping in Bolivian regions at similar or higher rates than to single-cropping, and with much larger absolute areas lost to double-cropping. However, we are unable to determine what crops are double-cropped with soybeans in these systems, and farmers often produce two crops of soy rather than a second commodity. Despite similar revenues per acre for each crop, comparing total production of soy, wheat, and sunflower over the study period shows that much more soy is produced in Bolivia. Thus, we used relative proportions of each crop to allocate deforestation between crops. This also reflects historical perspectives on the system showing that wheat and sunflower have decreased in importance over time.

In Brazil, absolute production of corn and soy are roughly on par with each other through the study period. From FAOSTAT data, revenues per hectare have generally favored soy, with the ratio of corn to soy returns varying between 60 percent and 90 percent of those of soy. Area planted early in the study period favored corn (at its most, a ratio of 1.4 hectares of corn to soy), declining steadily through the study period to about 0.5 hectares of corn to soy. Together, these provide a relatively complete picture. Corn yields more per acre than soy does, and yields for both have increased as better varieties are introduced, explaining the steady total production ratios while planted area has decreased. We use the product of area planted and returns per acre to determine the allocation of land use change (LUC) between corn and soy, which reflects corn's greater initial returns early in the study period and decreasing planted area more recently. Based on production maps, we have allocated all this LUC to the Cerrado, as little appreciable corn production takes place in the Amazon.

Indonesia, Malaysia, and Brazil are significant sources of traded wood products; while some wood products may originate from clear-cutting or plantation forestry, some originate from selective logging or opportunistic logging in advance of clearing for soy, palm or pasture. In these cases, logging is not the final use of the land after conversion, but a contributing factor to the economic rationale determining whether the land is cleared or not (see box, "Selective Logging, Degradation and Deforestation"). Thus, we allocate a very conservative amount of LUC from these agricultural commodities to selectively logged wood products, using the implied gap size and yield estimates published by Pearson et al. (2014). We also calculate deforestation based on the size of logged areas in Asner et al. (2006) and Gunarso (2013), assuming no re-entry and distributing logging over the entire study period (Appendix equation A.1). In Indonesia and Malaysia, yields for clear cutting are from Griscom et al. (2014) and total logged area is from Gunarso (2013). Appendix tables A.2 – A.8 describe deforestation rates by case countries and deforestation shares by country and commodity.

Trade Data for Economic Modeling

The most recent Global Trade Analysis Project (GTAP) database uses a base year of 2011 and products are highly aggregated. This model's data are updated to 2014 using the method described in this report's computable general equilibrium (CGE) model and further disaggregated using 2014 trade data. Since this study focuses on global forest loss most affected by food and commodities, key sectors such as oilseeds and oilseed oils needed further disaggregation using import data from the Global Trade Atlas[22] (GTA) database to study the impact of the sectors more closely. The GTA contains trade data reported by more than 85 countries that account for over 90 percent global

Appendix equation A.1

Equation describing calculation of total deforestation attributable to commercial timber

Total deforestation attributable to commercial timber

= (Deforestation for agriculture×share previously logged

× Canopy loss due to selective logging)

+ (Total degraded land

× canopy loss due to selective logging)

+ (Total deforestation for clear-cut logging)

Source: USDA, Economic Research Service equation.

[22] http://www.gtis.com/gta/

Appendix table A.2

Deforestation rates (million hectares) per year for case countries

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012 [1]	2013
Henders et al. (2015)														
Argentina	0.21	0.18	0.12	0.3	0.49	0.41	0.34	0.46	0.62	0.31	0.42	0.47	-	-
Bolivia	0.15	0.18	0.2	0.2	0.22	0.26	0.22	0.19	0.38	0.23	0.46	0.32	-	-
Brazil (Amazon)	1.82	1.82	2.17	2.54	2.78	1.90	1.43	1.17	1.29	0.75	0.70	0.64	-	-
Brazil (Cerrado)	1.59	1.59	1.59	0.82	0.89	0.48	0.35	0.44	0.38	0.3	0.37	0.74	-	-
Paraguay (Chaco)	0.12	0.08	0.1	0.13	0.12	0.20	0.14	0.43	0.37	0.35	0.43	0.42	-	-
Paraguay (Atlantic Forest)	0.14	0.09	0.11	0.15	0.14	0.08	0.02	0.02	0.02	0.02	0.02	0.02	-	-
Indonesia	1.43	0.57	0.60	0.57	0.61	0.62	0.69	0.71	0.69	0.76	0.71	0.64	-	-
Malaysia	0.02	0.30	0.32	0.19	0.36	0.38	0.34	0.41	0.37	0.62	0.43	0.43	-	-
This study (2017)														
Argentina	0.21	0.18	0.12	0.30	0.49	0.41	0.34	0.46	0.62	0.31	0.42	0.47	0.48	0.38
Bolivia	0.15	0.18	0.20	0.20	0.22	0.26	0.22	0.19	0.38	0.23	0.46	0.32	0.27	0.18
Brazil (Amazon)	1.82	1.82	2.17	2.54	2.78	1.90	1.43	1.17	1.29	0.75	0.70	0.64	0.46 [2]	0.59
Brazil (Cerrado)	1.59	1.59	1.59	0.82	0.89	0.48	0.35	0.44	0.38	0.76 [3]	0.65	0.72	0.73 [4]	0.43
Paraguay (Chaco)	0.12	0.08	0.10	0.13	0.12	0.2	0.14	0.43	0.37	0.35	0.43	0.42	0.49	0.30
Paraguay (Atlantic Forest)	0.14	0.09	0.11	0.15	0.14	0.08	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Indonesia	1.43	0.57	0.60	0.57	0.61	0.62	0.69	0.71	0.69	0.76	0.71	0.64	0.59	0.54
Malaysia	0.02	0.30	0.32	0.19	0.36	0.38	0.34	0.41	0.37	0.62	0.43	0.43	0.63	0.33

Note: Cells in Henders et al. (2015) section are blank for 2012 and 2013 because that study ended with 2011.

[1] All deforestation rates have been extended using Hansen et al. (2013) unless otherwise noted.

[2] Deforestation rates for the Brazilian Amazon were updated using data from the INPE PRODES (2016) project of the Brazilian Government.

[3] Deforestation rates for the Brazilian Cerrado for the years 2009-11 have been changed from Henders et al. (2015) using data produced by IBAMA/PMDBBS (2016).

[4] Deforestation rates for the Brazilian Cerrado for the years 2012 and 2013 are from Spera et al. (2016).

Source: USDA, Economic Research Service calculations, using United Nations, Food and Agriculture Organization FAOSTAT data, 2016.

Appendix table A.3

Shares of deforestation attributable to beef production

Henders et al. (2015)														
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Argentina	0.50	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	-	-
Bolivia	0.44	0.44	0.44	0.44	0.44	0.50	0.60	0.60	0.60	0.60	0.60	0.60	-	-
Brazil (Amazon)	0.80	0.80	0.80	0.76	0.75	0.76	0.79	0.80	0.80	0.80	0.80	0.80	-	-
Brazil (Cerrado)	0.68	0.64	0.60	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	-	-
Paraguay	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	-
This study (2017)														
Argentina	0.50	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20 [1]	0.20
Bolivia	0.44	0.44	0.44	0.44	0.44	0.50	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Brazil (Amazon)	0.80	0.80	0.80	0.76	0.75	0.76	0.79	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Brazil (Cerrado)	0.68	0.64	0.60	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
Paraguay	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Note: Cells in Henders et al. (2015) section are blank for 2012 and 2013 because that study ended with 2011.

[1]Shares are extended from Henders et al. (2015) as no literature was found supporting a change.

Source: USDA, Economic Research Service calculations, using United Nations, Food and Agriculture Organization FAOSTAT data, 2016.

Appendix table A.4

Shares of deforestation attributable to palm production

Henders et al. (2015)														
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Indonesia	0.18	0.61	0.5	0.53	0.62	0.65	0.58	0.32	0.5	0.54	0.53	0.52	-	-
Malaysia	0.83	0.42	0.42	0.42	0.42	0.42	0.35	0.35	0.35	0.35	0.35	0.35	-	-
This study (2017)														
Indonesia	0.14 [1]	0.14	0.14	0.14	0.14	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19 [2]	0.19
Malaysia	0.83	0.42	0.42	0.42	0.42	0.42	0.35	0.35	0.35	0.35	0.35	0.35	0.35 [3]	0.35

Note: Cells in Henders et al. (2015) section are blank for 2012 and 2013 because that study ended with 2011.

[1] Shares of deforestation for palm in Indonesia were taken as averages of shares reported in Abood et al. (2015), Busch et al. (2015), Gunarso et al. (2013) and Lee et al. (2014).

[2] Gunarso et al. (2013) report rates from 2000-2004 and from 2005-2010 separately, allowing for different averages over these time periods.

[3] Shares in Malaysia were extended from 2011 as no literature was found to support a change.

Source: USDA, Economic Research Service calculations, using United Nations, Food and Agriculture Organization FAOSTAT data, 2016.

Appendix table A.5

Shares of deforestation attributable to single- and double-cropped soy in Brazil

Henders et al. (2015)	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012 [1]	2013
Brazil (Amazon)	0.01	0.04	0.04	0.05	0.03	0.01	0.01	0.00	0.00	0.00	0.01	0.01	-	-
Brazil (Cerrado)	0.18	0.22	0.25	0.29	0.24	0.15	0.15	0.15	0.28	0.25	0.15	0.09	-	-
This study (2017)														
Soy (Amazon)	0.01	0.04	0.04	0.05	0.03	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.01 [1]	0.01
Soy (single- and double-cropped, Cerrado)	0.18	0.22	0.25	0.29	0.24	0.15	0.15	0.15	0.28	0.25	0.15	0.09	0.11 [2]	0.13
Soy Alone (Cerrado) [3]	0.11	0.14	0.17	0.19	0.17	0.11	0.10	0.10	0.18	0.18	0.11	0.06	0.07	0.09
Corn (Cerrado)	0.06	0.07	0.07	0.08	0.09	0.07	0.04	0.05	0.06	0.10	0.07	0.04	0.03	0.04

Note: Cells in Henders et al. (2015) section are blank for 2012 and 2013 because that study ended with 2011.

[1] Rates were extended using Henders et al. (2015), as no literature was found to support a change.

[2] Rates were extended using Gibbs et al. (2015).

[3] The allocation of land-use change for double-cropped soy was created using the product of planted area and returns per acre (FAOSTAT). These figures have no direct comparison to Henders et al. (2015), as the authors did not allocate land use change between crops as part of their study. See page 39 for a more detailed discussion.

Source: USDA, Economic Research Service calculations, using United Nations, Food and Agriculture.

Appendix table A.6

Shares of deforestation attributable to single- and double-cropped soy in Bolivia

Henders et al. (2015)	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012 [1]	2013
Soy (single- and double-cropped)	0.00	0.00	0.11	0.24	0.55	0.54	0.04	0.04	0.00	0.51	0.40	0.29	-	-
This study (2017)														
Soy (single- and double-cropped) [1]	0.33	0.29	0.29	0.29	0.29	0.29	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Soy [2]	0.28	0.24	0.23	0.26	0.26	0.26	0.18	0.17	0.15	0.16	0.16	0.17	0.18	0.18
Corn	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01
Wheat	0.03	0.03	0.03	0.01	0.01	0.01	0.01	0.02	0.03	0.03	0.02	0.02	0.02	0.02

Note: Cells in Henders et al. (2015) section are blank for 2012 and 2013 because that study ended with 2011.

[1] These rates are taken from Henders et al. (2015) for all double and single-cropped soy in the study period. The authors elect to use another method to calculate land use change in their study.

[2] Relative rates for corn, soy, and wheat were created using the ratio of total production of corn, soy and wheat in each period. They cannot be directly compared to Henders et al. (2015) as the authors did not directly calculate land use change for each crop. See page 39 for a more detailed discussion.

Source: USDA, Economic Research Service calculations.

Appendix table A.7

Shares of deforestation attributable to clear-cut logging

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012 [1]	2013
Henders et al. (2015)														
Indonesia	0.27	0.27	0.27	0.27	0.27	0.27	0.12	0.12	0.12	0.12	0.12	0.12	-	-
Malaysia	0.14	0.20	0.20	0.20	0.20	0.20	0.37	0.37	0.37	0.37	0.37	0.37	-	-
This study (2017)														
Indonesia	0.27	0.27	0.27	0.27	0.27	0.27	0.12	0.12	0.12	0.12	0.12	0.12	0.12 [1]	0.12
Malaysia	0.14	0.20	0.20	0.20	0.20	0.20	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37

Note: Cells in Henders et al. (2015) section are blank for 2012 and 2013 because that study ended with 2011.

[1] Rates were extended from Henders et al. (2015), as the literature did not support a change.

Source: USDA, Economic Research Service calculations, using United Nations, Food and Agriculture Organization FAOSTAT data, 2016.

Appendix table A.8

Statistics used to determine total deforestation attributable to timber

	Share of deforested area logged prior to deforestation [1]	Share of canopy lost to selective logging [2]	Total degraded land
Brazil (Amazon)	0.23	0.0017	79,713 [3]
Indonesia (Palm oil)	0.80	0.0017	1,010,130 [4]
Indonesia (Fiber plantations)	0.00	0.0017	1,010,130
Malaysia (Palm)	0.80	0.0017	734,826.1

Source: USDA, Economic Research Service calculations, using United Nations, Food and Agriculture Organization FAOSTAT data, 2016.

[1] From Henders et al. (2015).

[2] From implied gap size and yield estimates published by Pearson et al. (2014) on selective logging.

[3] Statistics for Brazil are from Asner et al. (2008) and reflect total selectively logged land as detected by remote sensing.

[4] Statistics for Indonesia and Malaysia are from Gunarso et al. (2013) and reflect the total degraded land in each country throughout the study period. Statistics on selectively logged acreage were not available for these countries. Degraded land has forest canopy cover but shows significant canopy gaps. We assume degraded land is entered and the share of canopy removed yearly.

trade.[23] Each country's reported import data include all countries that they import from: the dataset includes 264 economies grouped into the country groupings specified in previous chapters.

The primary oilseeds/oilseed oils traded globally include soybeans, soybean oil, and palm oil. Although many other oilseed products are produced, these products were grouped into "other oilseeds" and "other oilseed oils" categories. Product groupings were created using the Harmonized Commodity and Coding System developed by the World Customs Organization. This system, also known as the Harmonized System of tariff nomenclature (HS code), provides a uniform 6-digit numerical method of classifying products traded around the world (Appendix table A.9).

The United States and Brazil are major producers and exporters of soybeans while China and the European Union (EU) are major importers. Palm nuts and kernels (HS 120710) are traded on a much smaller scale than palm oil is. Total world imports of palm nuts and kernels reached roughly $29.5 million in 2014, while palm oil imports reached $24.1 billion in the same year. Leading exporters include Costa Rica and Thailand, while leading importers include Malaysia, the EU, and Costa

[23] Data source: http://www.gtis.com/gta/secure/help/index.html, click on "Data Availability, Source, Valuation"

Appendix table A.9

Harmonized System (HS) codes for product groups

Product group	HS Code
Soybeans	120110, 120190
Palm kernel	120710
Other oilseeds	120200, 120300, 120400, 120510, 120590, 120600, 120721, 120729, 120730, 120740, 120750, 120760, 120770, 120791, 120799
Soybean oil	150710, 150790
Palm oil	151110, 151190
Other oilseed oils	150810, 150890, 150910, 150990, 151000, 151211, 151219, 151221, 151229, 151311, 151319, 151411, 151419, 151491, 151499, 151511, 151519, 151521, 151529, 151530, 151550, 151590, 151790

Source: Compiled from the Global Trade Atlas.

Rica. The largest exporters of other oilseeds include Canada (mostly rapeseed) and India (mostly, sesame seeds and peanuts), and the largest importers of other oilseeds include the EU (rapeseed and peanuts) and China (rapeseed and sesame seeds). Argentina and Brazil are the leading exporters of soybean oil, while India and China are major importers. For palm oil, Indonesia and Malaysia are major producers and exporters, and the EU, China, and India are major importers.

Appendix B. The Computable General Equilibrium Model

In the standard static Global Trade Analysis Project (GTAP) model, producers are described as perfectly competitive cost-minimizers, with technology defined as a nested production function. Producers' demand for intermediate inputs responds to prices for inputs and outputs, subject to a Leontief intermediates production function. A Constant Elasticity of Substitution (CES) production function over value-added allows producers to substitute among primary factors as their relative prices change. Consumer demand is described by a Constant Difference of Elasticity (CDE) demand system, a non-homogeneous function that allows income growth to affect consumer preferences. Cobb-Douglas functions describe government and investment demand, which imply constant budget shares in total expenditure. Import demand is described by nested Armington functions, in which demand is first allocated between the domestic good and the composite import, and then among national sourcing of the composite import. Countries (or regions) are linked through their bilateral trade flows, which explicitly account for transportation and marketing costs in moving goods from port to port. Factors are assumed to be fixed in national supply, fully employed, and mobile across commodities except for land, which is assumed to have limited substitutability across crops.

We use a version of the GTAP model built by Beckman et al. (2015) (known as MTED-GTAP), which encompasses all the standard features mentioned above, along with some critical updates for our sectors of interest. In particular, the model incorporates biofuels and biofuel co-products into a GTAP-E model (Beckman et al., 2011), and also incorporates the livestock/feed nesting structure from Keeney and Hertel (2009). In addition, the model uses the detailed land-use module (GTAP-AEZ), which captures heterogeneous land quality and allows a more realistic representation of agricultural production. GTAP-AEZ disaggregates land into 18 agro-ecological zones (AEZs) that share common climate, precipitation, and moisture conditions (Hertel et al., 2008). Alternative agricultural and forestry land uses then compete for lands with heterogeneous quality. In the GTAP database, land that is considered forest is land managed and assessable, so the model does not account for shifts between unmanaged forests. Land-use competition is modeled in the AEZ module with a nested constant-elasticity-of-transformation (CET) function. By imposing homothetic separability on the revenue function, the land allocation decision can be split into two sequential stages. In the first stage, the landowner decides on land cover, whether a given parcel of land will be in crops, forestry, or pasture. In the second stage, cropland is allocated across different uses.

While the model used in Beckman et al. (2015) provides detailed information on land-use impacts from trade policies, here we specify a different database that is appropriate for modeling users of forest land. Our regional aggregation, presented in appendix table B.1, is based on information gathered in the literature review corresponding to the source and users of forest-based products[24]. We use the most recent GTAP database for our experiments, v. 9, which has a base year of 2011.

Our sector aggregation scheme is heavily weighted toward agricultural, biofuel, and forest-based commodities (appendix table B.2). To that end, we keep any GTAP data corresponding to these activities (e.g., beef) disaggregated. Unfortunately, there are some important commodities that are not explicitly aggregated; thus, we use the SplitCom utility to create those commodities of interest. As a result, our final aggregation is 22 agricultural, biofuel, and forest commodities, with 31 total sectors.

[24] The disaggregated GTAP base data contain over 130 regions and 57 sectors; researchers often aggregate these to make the results easier to comprehend and interpret.

Appendix table B.1
Regional aggregation

Country/region	Included GTAP country/regions
United States (U.S.)	United States of America
Rest of North America (RNAM)	Canada, Mexico, Rest of North America, Costa Rica, Guatemala, Honduras, Nicaragua, Panama, El Salvador, Rest of Cental America, Dominican Republic, Jamaica, Puerto Rico, Trinidad and Tobago, Rest of Caribbean
South America 4 (SAM)	Argentina, Bolivia, Brazil, Paraguay
Rest of South America (RSA)	Chile, Columbia, Ecuador, Peru, Uruguay, Venezuela, Rest of South America
South East Asia (SEA)	Indonesia, Malaysia
India	India
China	China, Hong Kong
Rest of Asia (ROA)	Bangladesh, Brunei Darussalam, Cambodia, Laos, Japan, Singapore, Thailand, Vietnam, South Korea, Mongolia, Taiwan, Rest of East Asia, Rest of Southeast Asia, Nepal, Pakistan, Sri Lanka, Rest of South Asia
European Union (EU)	Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, United Kingdom, Croatia, Bulgaria, Romania
Rest of Europe (REU)	Switzerland, Norway, Rest of Euro Free Trade Zone, Albania, Rest of Europe
Former Soviet Republics (FSO)	Russia, Ukraine, Rest of Eastern Europe, Kazakhstan, Kyrgyzstan, Rest of Soviet Union, Armenia, Azerbaijan, Georgia
Middle East and North Africa (MENA)	Bahrain, Iran, Israel, Jordan, Kuwait, Oman, Qatar, Saudi Arabia, Turkey, United Arab Emirates, Rest of Western Asia, Egypt, Morocco, Tunisia, Rest of North Africa
Subsaharan Africa (SSA)	Benin, Burkina Faso, Cameroon, Cote d'Ivoire, Ghana, Guinea, Nigeria, Senegal, Togo, Rest of Western Africa, Central Africa, South Central Africa, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Rwanda, Tanzania, Uganda, Zambia, Zimbabwe, Rest of Eastern Africa, Botswana, Namibia, South Africa, Rest of South African Customs Union
Oceania (OCE)	Australia, New Zealand, Rest of Oceania, Rest of the World

Source: USDA, Economic Research Service aggregation based on the Global Trade Analysis Project: https://www.gtap.agecon.purdue.edu/databases/regions.asp?Version=9.211.

Appendix table B.2

Sectoral aggregation

No.	Name	Description	GTAP sector code
1	Grains	Rice, wheat	pdr, wht, pcr
2	Coarse grains	Barley, corn, oats, sorghum	gro
3	v_f	Fruits, vegetables, and nuts	v_f
4	Soybeans*	Raw soybeans	osd
5	Palmk*	Palm kernel	osd
6	Other oilseeds	All other oilseeds	osd
7	Othag	Sugar, other crops	c_b, sgr, pfb, ocr
8	Cattle	Cattle, sheep, goats	ctl
9	Livestock	Hogs, poultry, wool, raw milk, fish	oap, rmk, wol
10	frs	Forestry	frs
11	NatRes	Fishing and other mining	fsh, omn
12	Coal	Coal	coa
13	Oil	Oil	oil
14	Gas	Natural gas	gas, gdt
15	Beef	Beef	cmt
16	Othm_dairy	Pork, poultry, dairy products	omt, mil
17	Soyoil*	Soybean oil	vol
18	Palmoil*	Palm oil	vol
19	Othvol*	Other vegetable oils	vol
20	Feed*	Animal feed	ofd
21	ofd	Other food, beverages and tobacco	ofd, b_t
22	p_c	Petroleum, coal products	p_c
23	woodp	Products made from wood	lum, ppp
24	L_Mfg	Labor-intensive manufacturing	tex, wap, lea, fmp, mvh, otn, omf
25	Ethanol1*	Corn-based ethanol	p_c
26	Ethanol2*	Sugar-based ethanol	crp
27	H_Mfg	Capital-intensive manufacturing	crp, nmm, i_s, nfm, ele, ome
28	Ely	Electricity	ely
29	Other services	All other services	wtr, cns, trd, otp, wtp, atp, cmn, ofi, isr, obs, ros, osg, dwe
30	DDGS*	Dried distillers' grains with solubles	ofd
31	Biodiesel*	Biodiesel	crp

Note: * represents a commodity split using SplitCom.
Source: Authors' aggregation based on the Global Trade Analysis Project (GTAP), https://www.gtap.agecon.purdue.edu/databases/v9/v9_sectors.asp.

Disaggregating the GTAP data

We completely disaggregate two of the GTAP-defined commodities using the SplitCom utility developed by Horridge (2008). In addition, we break individual biofuels from their previous aggregate commodity. For example, ethanol from grains (*Ethanol1*) is split from the commodity petroleum and coal products (*p_c*), but the *p_c* commodity remains. SplitCom is a matrix balancing program that allows the user to subdivide the rows and columns of a commodity from a balanced social accounting matrix (SAM). The user provides data to disaggregate a GTAP sector's input demands, uses in intermediate and final demand/trade, and tax/tariff payments. SplitCom then uses methods similar to maximum entropy to balance the disaggregated SAM and to satisfy accounting identities. The utility manipulates only the disaggregated sectors, which can be re-aggregated to restore the original values in the GTAP SAM. We ultimately use SplitCom to disaggregate oilseed, oilseed oil, feed, and biofuel subcommodities. Those with an asterisk in appendix table B.2 are split; the original aggregated commodity is represented in the fourth column. For example, the original GTAP database has a commodity referred to as *osd*. This commodity is split into three components: soybeans, palm kernel, and other oilseeds.

Data for the SplitCom procedure are drawn from multiple sources. Bilateral trade and tariff data are disaggregated using TASTE (Tariff Analytical and Simulation Tool for Economists), a software developed by Horridge and Laborde (2010) and based on the Market Access Maps (MAcMap) HS-6 trade and tariff database (Guimbard et al., 2012). TASTE disaggregates the GTAP sectors into HS-6 data for trade and tariffs. These disaggregated data are then re-aggregated into the sectors defined in the MTED-GTAP model, using the HS2002 concordance developed by Hutcheson (2006). Data for the disaggregation of subsectors' inputs and demands for their output are drawn from multiple sources, including FAOSTAT; USDA's Production, Supply and Distribution (PS&D) Database; USDA's Global Agricultural Information Network (GAIN) reports; and Energy Information Administration energy statistics, and national statistics.

Updating the database

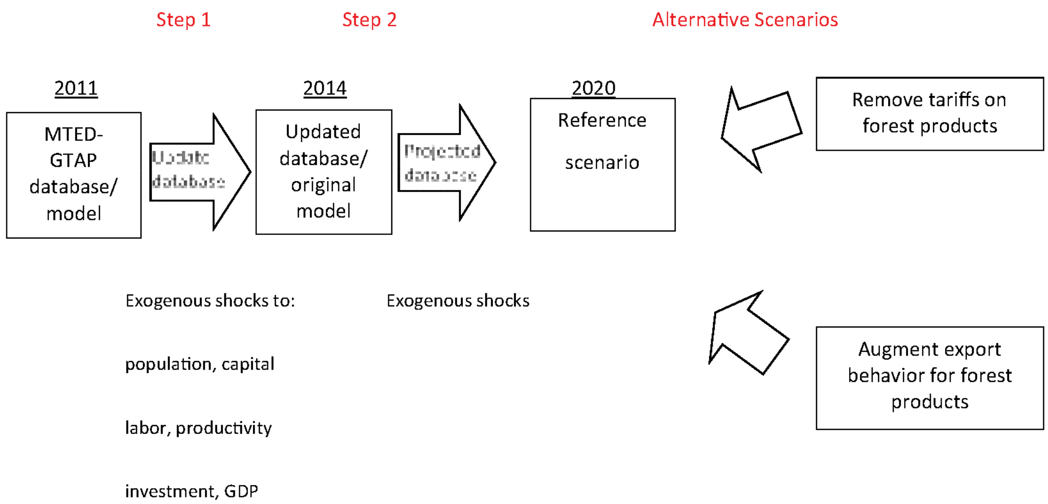
The latest GTAP database is set to 2011; we conducted an updating procedure to bring the model to 2014 (appendix figure B.1). We follow the approach by Beckman et al. (2011), who show that by shocking population, labor supply, capital, investment, and agricultural productivity, the resulting equilibrium offers a reasonable approximation to key features of the more recent economy. Agricultural productivity growth was applied to all crops, but productivity for forests was left unchanged. This is the first step in appendix figure B.1; the shocks are given in the first set of columns in appendix table B.3. The second step conducts the necessary experiment to provide the reference scenario; these shocks are the second set of columns in appendix table B.3. As an example, China's GDP will be increased by 38.2 percent in the 2011-14 updating. Then, when we conduct the reference scenario, their GDP will increase by another 49.8 percent (2014-20). Finally, the alternative scenarios build on the reference scenario by including policy changes that could impact forest land use.

Tariffs

We use external data from multiple sources and ERS expert reviews to validate the oilseed and vegetable oil tariff rates and to estimate a tariff rate for commodities that were disaggregated using SplitCom. Note that the SplitCom program will allocate the original tariff value to all newly split

Appendix figure B.1

Steps to model policies used in computational general equilibrium model



Source: USDA, Economic Research Service equation.

Appendix table B.3

Exogenous changes (percent) needed to update the Global Trade Analysis Project model data to 2014 and reference scenario

	GDP		TFP		Capital		Labor		Investment		Population	
	2011-2014	2014-2020	2011-2014	2014-2020	2011-2014	2014-2020	2011-2014	2014-2020	2011-2014	2014-2020	2011-2014	2014-2020
China	38.20	49.80	15.14	33.79	34.01	57.73	2.44	-0.21	18.20	55.87	1.50	2.80
EU	1.04	11.05	3.23	11.65	3.95	12.29	-0.84	-1.66	4.18	21.30	0.48	0.95
FSO	0.19	27.68	4.67	27.83	8.82	24.55	0.46	-1.12	24.54	49.55	1.51	1.22
India	11.59	38.06	6.21	20.56	20.35	35.59	6.55	10.46	-3.34	32.11	3.84	6.78
MENA	12.22	22.84	1.27	7.10	15.00	28.68	7.28	9.96	2.20	16.74	6.28	8.41
OCE	6.34	19.81	5.16	9.80	8.96	18.52	2.38	7.12	5.95	32.88	4.70	8.47
REU	0.52	14.78	3.26	8.28	4.96	16.52	1.24	2.77	7.54	31.99	1.29	4.11
RNAM	4.12	19.77	2.63	11.14	10.04	21.11	4.12	9.14	10.77	19.96	1.29	7.20
ROA	-10.20	14.28	4.81	10.18	6.03	15.76	4.26	7.65	25.17	17.40	3.53	5.91
RSA	12.75	18.07	3.98	5.40	15.23	24.87	3.64	9.51	5.27	6.24	3.37	7.24
SAM	-6.54	18.18	1.72	7.14	10.96	23.17	2.87	7.00	-6.82	15.79	2.95	4.91
SEA	3.00	21.60	5.47	10.40	20.73	29.45	5.48	10.48	1.38	-0.19	4.01	6.81
SSA	15.54	31.61	2.69	9.89	15.07	32.28	8.83	18.79	7.20	25.42	8.50	16.43
U.S.	12.25	11.92	3.15	5.64	6.41	15.51	2.23	2.96	32.56	8.49	2.29	4.77

Note: Total factor productivity (TFP) is an indicator of technological progress. TFP growth was applied to all crops in the reference scenario. Productivity for forests was not changed. US = United States. RNAM = Rest of North America. SAM = South America (Argentina, Bolivia, Brazil, and Paraguay). RSA = Rest of South America. SEA = Indonesia and Malaysia. ROA = Rest of Asia. REU = Rest of Europe. FSO = Former Soviet Republics. MENA = Middle East and North Africa. SSA = Sub-Saharan Africa. OCE = Oceania.

Source: USDA, Economic Research Service calculations based on Fouré et al. (2013). Changes in gross domestic product (GDP) from 2011-14 are validated with data from the World Bank (2016).

commodities—e.g., if the tariff for the oilseed commodity is 20 percent, the new soybean, palm, and other oilseed commodities will all have a tariff of 20 percent. The World Trade Organization (WTO) database on tariffs provides a Most Favored Nation (MFN) rate for each of our new commodities; ERS experts provided input into the validity of these values. Finally, we use GTAP's Altertax utility to update the model to redefine tariffs on split commodities and to correct or update various tariff rates (appendix table B.4).

Appendix table B.4

Most Favored Nation rates for new oilseed and oil commodities (percents)

	Soybeans	Palm kernel	Soy Oil	Palm Oil
United States (U.S.)	0.00	0.00	14.33	0.00
Rest of North America (RNAM)	0.00	0.00	4.63	4.84
South America (SAM)	0.00	0.00	0.00	0.00
Rest of South America (RSA)	0.00	0.00	0.00	0.00
South East Asia (SEA)	2.50	0.00	5.00	0.50
India	0.00	0.00	11.50	11.50
China	2.40	0.00	9.00	8.84
Rest of Asia (ROA)	0.00	0.00	11.00	3.25
European Union (EU)	0.00	0.00	7.35	5.75
Rest of Europe (REU)	9.38	0.00	66.89	77.52
Former Soviet Replublics (FSO)	0.00	0.00	15.00	0.60
Middle East and North Africa (MENA)	4.00	0.00	22.98	19.28
Subsaharan Africa (SSA)	8.00	0.00	25.00	10.00
Oceania (OCE)	0.00	0.00	0.00	0.00

Note: US = United States. RNAM = Rest of North America. SAM = South America (Argentina, Bolivia, Brazil, and Paraguay). RSA = Rest of South America. SEA = Indonesia and Malaysia. ROA = Rest of Asia. REU = Rest of Europe. FSO = Former Soviet Republics. MENA = Middle East and North Africa. SSA = Sub-Saharan Africa. OCE = Oceania.
Source: USDA, Economic Research Service (ERS) calculations based on World Trade Organization and ERS data.

Appendix C. Detailed Global Model Results

Reference Scenario

Production and Prices

At the more detailed commodity level, the United States has a double-digit increase in soybeans, livestock, feed, and forest products (appendix table C.1) and decreases only for soy oil and biodiesel. Most other regions have similar large increases in agricultural production; however, as one of the world's foremost producer of most agricultural products, the large changes in the United States result in land being converted from forest to crops and pasture.

Agricultural prices increase for many commodities due to the increase in demand from the reference scenario (appendix table C.2). Most of these increases are in the double digits; however, other food and beverages (ofd) is the commodity consumed most as a food source across all regions. For this commodity, prices actually decline for some of the regions; however, prices rise in China and India. Because ofd consists of processed products, this makes sense, since Chinese and Indian incomes continue to grow and spur demand for more consumer-oriented products.

Trade

The shocks used in the reference scenario indicate an increase in GDP and population for all regions, as such the increase in agricultural production for most products is not surprising. Appendix table C.3 indicates that the United States has large gains in exports for most agricultural commodities occurring in the reference scenario, as well as an increase in imports for most commodities (appendix table C.4). However, the U.S. export gains generally outweigh imports (except for fruits and vegetables (v_f), palm oil, and biodiesel). U.S. exports increase for most agricultural commodities; for most of these exports rise by more than $1 billion. Exports do decrease, however, for vegetable oils, ethanol, and biodiesel.

Trade is mixed for other regions; the EU has a large increase in beef exports (as does Rest of North America (RNAM) and Sub-Saharan Africa (SSA)). The increase in U.S. exports of soybeans leads to a decrease in net trade for their biggest competitor (South America (SAM)). China and India exhibit large increases in imports of most commodities.

Alternative Scenario: Tariffs Removed on Forest-Risk Products

Production and Prices

Changes in production are presented as changes from the reference scenario (appendix table C.5). Even though global tariffs on soybeans are low, removing the barriers does lead to an increase in production for the United States. This increase draws resources away from other agricultural uses, in particular, there is a decrease in *grains* production. Most agricultural prices increase relative to the reference scenario (appendix table C.6). For the United States, forestry products are the only category whose price is lower than the reference scenario's.

Appendix table C.1

Production changes from reference scenario (percent change)

	US	RNAM	SAM	RSA	SEA	India	China	ROA	EU	REU	FSO	MENA	SSA	OCE
Grains	6.71	6.05	-2.35	4.53	2.61	5.52	7.75	4.07	7.60	5.37	9.23	0.59	-2.77	7.17
Coarse grains	3.64	4.35	0.43	7.23	7.17	4.57	11.98	3.26	5.86	3.83	4.71	6.99	9.20	6.97
V_f	4.81	6.93	0.07	6.29	4.47	4.55	8.51	5.61	6.25	2.89	4.27	7.29	8.23	7.79
Soybeans	12.10	22.96	1.06	10.49	15.75	8.82	12.43	15.02	16.51	14.26	11.76	15.96	10.16	18.54
Palmk	-	-	35.93	9.90	9.01	9.63	11.26	5.69	-	-	-	15.14	11.13	4.14
Other oilseeds	6.53	14.67	55.18	5.54	7.07	1.97	1.85	2.33	6.01	2.82	11.20	4.49	6.42	0.23
Othag	3.83	2.86	-1.64	3.23	6.75	7.11	8.31	11.07	5.84	6.97	7.09	2.65	2.71	5.42
Cattle	4.76	10.13	7.15	7.15	-2.95	11.72	12.83	3.24	10.91	4.20	6.03	10.28	15.44	-7.74
Livestock	10.02	10.84	8.90	6.08	7.93	4.99	10.08	5.39	8.38	5.96	3.09	11.53	17.85	21.84
Frs	2.02	3.19	2.60	1.21	3.26	6.33	2.20	5.05	6.97	0.69	1.53	0.20	2.36	1.29
Beef	4.34	13.99	5.93	7.26	-15.48	58.87	13.45	8.84	12.55	3.04	4.70	9.15	17.96	-12.12
Othm_ dairy	6.84	10.61	9.67	5.69	10.10	9.42	-7.34	9.54	6.71	6.90	8.36	10.82	20.69	6.43
Soyoil	-1.72	9.97	8.79	8.04	16.16	7.75	9.67	21.00	14.09	41.48	9.83	17.10	-14.86	2.12
Palmoil	-	-	37.97	10.94	8.61	75.02	11.38	11.53	-	-	-	134.11	27.62	0.80
Othvol	8.13	37.81	70.14	1.56	12.16	-7.35	-2.24	-16.12	-11.42	-5.81	29.46	22.21	-30.88	-45.91
Feed	17.07	24.07	14.70	15.63	8.79	19.76	12.74	14.25	23.04	15.90	14.04	25.27	31.53	32.14
Ofd	4.38	10.86	1.65	9.17	10.08	3.60	8.56	3.21	4.35	14.63	2.91	7.73	14.93	5.36
Woodp	11.96	-8.42	5.08	7.88	-6.36	14.42	2.34	57.82	2.77	-1.20	-25.15	37.94	14.96	-6.08
Ethanol	-4.29	-36.66	-39.04	31.68	-19.40	-21.14	-34.61	-18.05	-2.12	5.07	-11.04	5.86	0.23	-34.37
Biodiesel	-12.67	21.12	23.47	37.87	1.39	87.28	39.71	37.40	36.28	29.80	30.34	44.75	47.59	43.35

Note: US = United States. RNAM = Rest of North America. SAM = South America (Argentina, Bolivia, Brazil, and Paraguay). RSA = Rest of South America. SEA = Indonesia and Malaysia. ROA = Rest of Asia. REU = Rest of Europe. FSO = Former Soviet Republics. MENA = Middle East and North Africa. SSA = Sub-Saharan Africa. OCE = Oceania. V_f = Fruits, vegetables, and nuts. Palmk = Palm kernel. Othag = Sugar, other crops. Frs = Forestry. Othm_dairy = Pork, poultry, dairy products. Othvol = Other vegetable oils. Ofd = Other food, beverages and tobacco. Woodp = Products made from wood.

Source: USDA, Economic Research Service (ERS) using the USDA, ERS, Market and Trade Economic Division/Global Trade Analysis Project model.

Appendix table C.2

Price changes from reference scenario (percent change)

	US	RNAM	SAM	RSA	SEA	India	China	ROA	EU	REU	FSO	MENA	SSA	OCE
Grains	33.67	33.27	43.44	36.60	35.42	36.05	37.13	30.49	30.68	27.84	30.59	34.70	37.61	32.28
Coarse grains	27.34	27.34	42.23	32.56	38.51	36.43	45.76	28.32	26.22	26.65	24.50	29.72	42.82	30.69
V_f	31.07	34.47	40.35	34.31	35.19	39.32	37.72	29.29	27.28	28.69	24.35	32.14	41.18	33.89
Soybeans	44.71	33.83	44.39	35.29	26.34	43.71	37.26	30.10	14.20	35.13	28.64	35.98	44.02	42.82
Palmk	-	-	104.70	40.23	39.76	44.19	41.90	31.43	-	-	-	43.25	47.22	36.70
Other oilseeds	34.08	29.61	96.34	34.23	36.51	35.25	22.89	24.91	25.20	29.60	32.00	34.70	40.29	27.02
Othag	38.63	39.54	38.45	40.33	38.25	43.32	38.20	33.73	34.50	33.71	32.74	39.27	41.10	38.95
Cattle	8.68	11.17	11.98	14.48	33.71	29.00	45.91	13.55	7.82	7.98	13.27	6.37	10.69	17.23
Livestock	5.83	9.92	11.69	14.67	25.52	36.10	40.00	8.13	10.44	9.37	13.11	6.82	11.28	11.55
Frs	288.78	287.96	302.33	346.24	323.47	234.97	318.31	282.02	266.87	272.00	316.13	269.23	299.32	322.93
Beef	-2.65	-4.27	1.99	1.53	23.28	-6.61	4.56	-4.01	-2.96	-1.52	1.84	-0.42	-7.93	7.87
Othm_ dairy	-3.85	-3.92	0.31	2.50	-0.48	1.92	28.21	-5.50	-3.43	-4.30	-4.32	-2.21	-6.56	2.98
Soyoil	31.09	25.77	35.83	18.43	12.82	21.48	23.65	1.36	-1.09	-0.54	7.20	-3.42	25.07	14.06
Palmoil	21.86	-5.89	5.81	-3.63	15.14	6.40	17.72	-7.25	-7.30	8.06	-5.88	4.37	-6.33	13.51
Othvol	11.46	4.92	4.06	11.62	13.66	18.10	21.41	21.23	11.45	12.16	4.18	5.57	23.24	25.32
Feed	0.89	-0.18	19.05	4.58	4.77	19.52	25.13	0.17	1.46	0.75	8.25	6.82	6.60	6.59
Ofd	-5.17	-5.57	12.88	-0.63	-1.30	18.00	15.01	-5.57	-3.82	-6.05	3.84	2.00	-1.39	1.16
Woodp	-10.31	-6.10	-4.69	-6.67	-4.31	-8.76	-2.86	-15.49	-8.52	-6.00	5.32	-12.98	-7.85	-2.90
Ethanol	-14.04	-2.54	30.78	-4.07	-1.67	2.24	13.55	-3.10	-12.46	-2.51	-3.13	-3.62	-4.95	12.97
Biodiesel	-12.49	-20.56	-18.94	-26.32	-17.68	-30.44	-22.33	-27.59	-26.87	-22.98	-20.96	-26.19	-25.27	-23.57

Note: US = United States. RNAM = Rest of North America. SAM = South America (Argentina, Bolivia, Brazil, and Paraguay). RSA = Rest of South America. SEA = Indonesia and Malaysia. ROA = Rest of Asia. REU = Rest of Europe. FSO = Former Soviet Republics. MENA = Middle East and North Africa. SSA = Sub-Saharan Africa. OCE = Oceania. V_f = Fruits, vegetables, and nuts. Palmk = Palm kernel. Othag = Sugar, other crops. Frs = Forestry. Othm_dairy = Pork, poultry, dairy products. Othvol = Other vegetable oils. Ofd = Other food, beverages and tobacco. Woodp = Products made from wood.

Source: USDA, Economic Research Service (ERS) using the USDA, ERS, Market and Trade Economic Division/Global Trade Analysis Project model.

Appendix table C.3

Change in net exports from reference scenario (percent change)

	US	RNAM	SAM	RSA	SEA	India	China	ROA	EU	REU	FSO	MENA	SSA	OCE
Grains	8.27	7.50	-19.92	14.23	-18.87	5.89	-15.60	39.08	17.32	37.25	24.70	5.89	-12.60	8.91
Coarse grains	12.19	9.69	-6.84	-2.85	-12.55	5.01	-22.99	17.05	12.14	13.90	21.75	8.39	-9.56	10.67
V_f	14.88	11.36	-7.87	7.57	4.37	-4.85	-5.68	30.56	11.63	19.34	27.15	14.90	-9.99	11.25
Soybeans	24.72	33.89	-7.41	10.64	59.98	13.76	19.20	83.43	166.90	-7.10	31.08	35.87	15.56	19.98
Other oilseeds	6.63	12.50	17.51	8.61	-0.01	-1.95	41.14	31.79	18.47	22.33	2.33	1.27	-18.65	17.63
Othag	11.24	2.19	8.49	3.47	9.26	-9.41	8.75	36.44	18.59	23.36	32.28	7.63	-3.74	8.97
Cattle	18.35	3.05	6.92	6.93	-41.51	-34.75	-39.89	18.79	16.36	16.60	1.24	24.11	9.98	21.92
Livestock	77.89	33.87	15.34	17.94	-14.78	-50.55	-53.18	39.93	27.54	24.21	13.86	31.61	47.54	67.59
Frs	100.15	122.57	-0.23	-49.53	-28.13	377.97	-10.82	97.86	77.74	59.82	24.77	97.03	33.65	8.10
Beef	24.04	38.83	-3.79	-1.07	-79.46	77.65	-22.09	41.19	30.54	15.45	-5.98	4.57	82.05	-39.29
Othm_ dairy	49.77	29.37	13.76	-7.92	15.31	-18.03	-82.08	70.62	19.00	32.91	22.84	20.76	59.49	6.32
Soyoil	-2.09	15.25	-66.71	22.72	16.35	-3.68	-19.28	155.84	65.82	100.78	25.46	36.91	-49.26	-0.06
Palmoil	-34.77	78.12	39.71	93.68	10.27	77.59	-20.21	241.63	279.31	57.32	358.55	135.63	313.62	1.36
Othvol	12.59	51.48	70.42	1.44	12.17	-18.78	-33.97	-36.92	-13.01	-15.26	54.33	48.28	-35.78	-48.86
Feed	39.65	38.88	-18.81	28.66	21.93	-22.63	-34.67	44.38	32.88	40.41	13.97	17.86	17.16	21.83
Ofd	22.23	17.56	-28.91	7.50	5.80	-42.73	-37.57	23.70	12.25	26.45	-3.09	0.44	8.71	0.88
Woodp	29.24	-20.87	-20.23	-7.09	-36.04	1.91	-42.04	131.67	3.13	-20.88	-65.67	69.25	-1.39	-40.40
Ethanol	-4.44	-29.34	-51.14	36.90	13.72	-12.13	-17.56	-18.57	2.49	-	-	-	-	-29.56
Biodiesel	-42.58	-4.04	-3.95	31.59	-13.71	57.09	8.36	45.30	70.39	11.75	0.95	29.86	24.31	15.89

Note: US = United States. RNAM = Rest of North America. SAM = South America (Argentina, Bolivia, Brazil, and Paraguay). RSA = Rest of South America. SEA = Indonesia and Malaysia. ROA = Rest of Asia. REU = Rest of Europe. FSO = Former Soviet Republics. MENA = Middle East and North Africa. SSA = Sub-Saharan Africa. OCE = Oceania. V_f = Fruits, vegetables, and nuts. Palmk = Palm kernel. Othag = Sugar, other crops. Frs = Forestry. Othm_dairy = Pork, poultry, dairy products. Othvol = Other vegetable oils. Ofd = Other food, beverages and tobacco. Woodp = Products made from wood.

Source: USDA, Economic Research Service using the Markets and Trade Economic Division/Global Trade Analysis Project model.

Appendix table C.4

Change in net imports from reference scenario (percent change)

	US	RNAM	SAM	RSA	SEA	India	China	ROA	EU	REU	FSO	MENA	SSA	OCE
Grains	16.23	12.22	13.37	19.16	20.48	21.49	40.91	5.26	3.66	4.28	14.10	17.54	23.86	16.44
Coarse grains	-1.31	8.83	7.33	4.95	10.59	6.19	22.99	4.20	1.02	8.17	4.70	10.11	17.34	2.69
V_f	11.52	16.29	17.85	13.27	14.49	17.28	32.02	5.61	0.79	7.31	7.05	18.80	26.01	17.20
Soybeans	25.56	6.55	94.44	-3.36	2.78	20.53	10.77	-3.86	-35.41	11.82	-5.79	0.38	28.75	4.17
Other oilseeds	18.27	34.96	156.62	14.06	24.24	10.05	9.34	-4.80	-7.08	0.45	29.14	22.01	35.72	-7.50
Othag	6.60	12.68	12.60	15.96	12.17	40.01	13.49	14.25	-1.79	5.68	-0.97	12.90	23.31	13.28
Cattle	3.32	18.71	14.12	8.32	29.47	107.27	71.42	9.20	6.81	6.02	13.09	5.62	18.34	9.68
Livestock	-11.00	19.00	7.37	17.59	38.41	72.32	89.43	6.55	1.29	4.69	9.57	10.85	14.77	13.88
Frs	27.73	52.62	71.39	180.61	150.62	-35.64	88.20	54.85	3.10	27.96	111.85	41.52	56.43	100.79
Beef	-5.30	7.26	12.07	15.85	83.28	-5.51	30.42	-1.63	-12.26	15.05	19.31	24.03	3.13	22.16
Othm_ dairy	-0.59	7.41	12.71	21.82	13.73	29.34	163.38	-0.62	-2.93	3.31	3.25	11.24	4.02	29.95
Soyoil	16.79	-1.13	111.96	15.85	11.79	55.36	53.03	-12.15	-30.17	6.60	19.42	15.25	44.52	12.34
Palmoil	4.55	23.16	65.92	6.05	37.22	29.91	8.18	8.98	31.99	7.08	105.89	37.40	19.77	-2.53
Othvol	3.51	7.05	27.14	9.89	10.81	22.76	40.07	11.84	7.99	2.50	5.04	8.71	15.14	3.15
Feed	15.40	21.52	43.74	16.90	11.06	57.53	59.47	7.44	16.97	15.05	23.78	35.22	41.44	47.22
Ofd	-0.58	8.16	27.44	11.47	12.77	49.14	47.04	-3.58	-1.62	3.03	15.47	19.04	19.90	13.02
Woodp	-0.62	25.34	30.78	20.06	39.53	27.39	81.95	-18.98	9.78	24.83	64.87	5.28	28.11	49.98
Ethanol	-80.51	-19.95	23.88	29.02	10.57	-3.76	11.15	-4.66	1.14	12.67	45.11	38.63	11.37	18.84
Biodiesel	45.61	-3.97	32.95	-9.13	37.09	-18.97	18.07	5.94	-11.02	2.09	20.10	1.42	0.91	-4.42

Note: US = United States. RNAM = Rest of North America. SAM = South America (Argentina, Bolivia, Brazil, and Paraguay). RSA = Rest of South America. SEA = Indonesia and Malaysia. ROA = Rest of Asia. REU = Rest of Europe. FSO = Former Soviet Republics. MENA = Middle East and North Africa. SSA = Sub-Saharan Africa. OCE = Oceania. V_f = Fruits, vegetables, and nuts. Palmk = Palm kernel. Othag = Sugar, other crops. Frs = Forestry. Othm_dairy = Pork, poultry, dairy products. Othvol = Other vegetable oils. Ofd = Other food, beverages and tobacco. Woodp = Products made from wood.

Source: USDA, Economic Research Service using the Markets and Trade Economic Division/Global Trade Analysis Project model.

Appendix table C.5

Production changes from tariff removal scenario relative to reference scenario (percent change)

	US	RNAM	SAM	RSA	SEA	India	China	ROA	EU	REU	FSO	MENA	SSA	OCE
Grains	-0.32	-0.11	-0.24	-0.04	-0.27	-0.08	0.03	-0.01	0.32	0.42	0.50	0.10	0.27	-0.20
Coarse grains	0.10	0.06	-0.25	0.07	-0.23	0.01	0.03	0.10	-0.56	-0.93	-0.57	-0.36	-0.17	-0.10
V_f	-0.11	-0.08	-0.33	-0.10	-0.19	-0.04	0.04	0.11	0.28	0.44	0.00	-0.08	-0.14	-0.11
Soybeans	0.47	1.57	0.24	0.17	8.83	0.76	-1.10	-0.46	-2.16	-5.10	1.59	0.57	-0.08	0.37
Palmk	-	-	1.54	-0.05	1.19	4.59	-0.10	0.18	-	-	-	5.93	-0.37	-0.05
Other oilseeds	-0.33	0.13	1.15	0.15	-0.97	0.22	-0.45	-0.01	0.54	0.62	1.27	0.41	-0.02	-0.23
Othag	-0.13	-0.14	-0.43	-0.11	-0.40	0.09	0.11	0.27	0.00	0.22	0.38	0.04	0.18	-0.14
Cattle	3.59	1.88	5.74	5.34	-0.11	-1.63	0.17	-8.06	-25.70	-35.18	-5.09	-6.50	-0.16	7.36
Livestock	-0.48	0.01	-0.84	-0.71	-0.04	0.05	0.08	1.40	1.75	3.58	-0.28	0.11	-0.10	-2.04
Frs	-0.02	-0.02	-0.10	-0.01	-0.01	-0.02	-0.02	-0.03	-0.05	0.00	-0.01	0.00	-0.02	-0.01
Beef	4.33	2.44	7.13	7.79	-0.97	-27.20	-3.16	-22.13	-50.18	-72.58	-7.62	-14.66	0.84	10.30
Othm_ dairy	-0.42	-0.20	-1.24	-0.87	-0.30	-0.01	-0.17	1.73	1.42	3.09	0.23	0.62	-0.09	-1.99
Soyoil	-1.91	7.15	0.65	0.09	14.11	1.54	-0.75	-5.83	-1.59	-27.23	4.77	3.35	-10.80	9.30
Palmoil	-	-	1.68	-0.08	1.71	89.94	-0.10	-	-	-	-	124.65	-1.68	-0.19
Othvol	-0.03	1.44	1.93	-0.21	-2.29	0.47	-0.32	-0.53	-0.32	1.58	3.10	2.33	1.91	-0.18
Feed	0.37	0.41	1.90	0.22	-0.16	-0.02	0.10	0.16	-9.54	-2.10	-1.60	-1.08	-0.10	0.44
Ofd	-0.07	-0.19	-0.12	-0.14	-0.23	-0.05	-0.09	0.15	-0.18	1.32	0.06	0.03	-0.13	-0.05
Woodp	-3.16	-8.60	-10.99	-8.95	2.43	3.34	4.26	23.20	-1.97	2.73	-19.02	-8.93	-22.14	-12.35
Ethanol	-0.06	0.06	-0.55	0.41	-0.02	-0.34	-0.37	-0.57	1.65	0.92	-0.09	-0.06	-0.28	-0.47
Biodiesel	4.02	3.82	3.41	0.65	-2.45	-2.44	-0.77	-1.44	-11.49	-4.34	-2.14	-1.59	-0.67	1.80

Note: US = United States. RNAM = Rest of North America. SAM = South America (Argentina, Bolivia, Brazil, and Paraguay). RSA = Rest of South America. SEA = Indonesia and Malaysia. ROA = Rest of Asia. REU = Rest of Europe. FSO = Former Soviet Republics. MENA = Middle East and North Africa. SSA = Sub-Saharan Africa. OCE = Oceania. V_f = Fruits, vegetables, and nuts. Palmk = Palm kernel. Othag = Sugar, other crops. Frs = Forestry. Othm_dairy = Pork, poultry, dairy products. Othvol = Other vegetable oils. Ofd = Other food, beverages and tobacco. Woodp = Products made from wood.

Source: USDA, Economic Research Service using the Markets and Trade Economic Division/Global Trade Analysis Project model.

Appendix table C.6

Price changes from tariff removal scenario relative to reference scenario (percent change)

	US	RNAM	SAM	RSA	SEA	India	China	ROA	EU	REU	FSO	MENA	SSA	OCE
Grains	0.36	0.36	0.72	0.35	1.00	0.17	1.10	0.53	-0.17	-0.33	-0.37	-0.23	-0.03	0.56
Coarse grains	0.70	0.46	0.95	0.39	1.09	0.30	1.22	0.69	-0.76	-1.36	-1.15	-0.55	-0.53	0.63
V_f	0.52	0.38	0.64	0.27	1.18	0.30	1.22	0.70	-0.21	-0.51	-0.72	-0.39	-0.47	0.65
Soybeans	1.25	1.50	1.45	0.55	6.67	1.08	0.09	0.23	-0.99	-4.19	0.30	-0.04	-0.45	1.18
Palmk	-	-	4.19	0.40	2.54	4.68	1.08	0.74	-	-	-	4.06	-0.69	0.73
Other oilseeds	0.53	0.55	3.18	0.53	0.49	0.53	0.63	0.59	-0.03	-0.83	0.11	0.01	-0.39	0.44
Othag	0.55	0.37	0.42	0.30	0.99	0.41	1.12	0.80	-0.42	-0.44	-0.26	-0.24	-0.06	0.72
Cattle	1.44	0.64	2.59	2.96	0.67	-0.02	1.54	-3.19	-1.41	-8.10	-2.18	-1.16	-0.46	3.56
Livestock	0.99	0.56	1.70	2.07	0.68	-0.10	1.36	-1.33	-1.52	-6.27	-1.95	-0.99	-0.40	1.84
Frs	-7.73	-9.06	-47.45	-24.68	-1.47	-2.87	-6.79	-2.74	-8.07	-7.71	-14.34	-10.58	-9.71	-5.02
Beef	0.64	0.17	1.28	1.57	0.75	0.16	-0.22	-1.44	-0.92	-7.83	-1.81	-0.73	-0.36	1.96
Othm_ dairy	0.46	0.17	0.64	1.09	0.48	0.11	1.14	-0.18	-0.40	-2.17	-0.66	-0.57	-0.33	0.83
Soyoil	0.98	0.88	1.15	0.39	4.07	0.11	0.56	0.53	-0.31	-1.28	-0.27	-1.67	-1.13	0.44
Palmoil	0.48	-0.24	0.26	0.12	1.57	-6.62	-0.32	0.29	-0.47	-2.89	-0.51	-5.45	-0.69	0.24
Othvol	0.33	0.11	0.12	0.33	0.84	0.25	0.72	0.50	0.14	-0.62	-0.43	-0.43	-0.39	0.42
Feed	0.22	0.12	0.17	0.19	0.98	0.34	0.86	0.58	-0.23	-1.00	-0.47	-0.30	-0.24	0.09
Ofd	0.10	0.00	0.00	0.11	0.54	0.25	0.83	0.61	-0.11	-0.72	-0.53	-0.30	-0.25	-0.07
Woodp	-0.04	-0.45	-1.50	-0.69	0.12	0.09	0.33	0.66	-0.01	-0.14	-1.33	-0.22	-0.65	-0.46
Ethanol	-0.02	-0.16	0.32	0.03	0.47	0.32	0.85	0.79	-0.76	-0.07	-0.30	-0.03	-0.12	0.16
Biodiesel	-0.93	0.04	-0.61	-0.40	1.46	0.34	0.58	0.94	3.55	1.47	0.26	0.32	-0.05	-0.64

Note: US = United States. RNAM = Rest of North America. SAM = South America (Argentina, Bolivia, Brazil, and Paraguay). RSA = Rest of South America. SEA = Indonesia and Malaysia. ROA = Rest of Asia. REU = Rest of Europe. FSO = Former Soviet Republics. MENA = Middle East and North Africa. SSA = Sub-Saharan Africa. OCE = Oceania. V_f = Fruits, vegetables, and nuts. Palmk = Palm kernel. Othag = Sugar, other crops. Frs = Forestry. Othm_dairy = Pork, poultry, dairy products. Othvol = Other vegetable oils. Ofd = Other food, beverages and tobacco. Woodp = Products made from wood.
Source: USDA, Economic Research Service using the Markets and Trade Economic Division/Global Trade Analysis Project model.

There is little trade globally in palm kernels (palmk) and frs, so production changes for these products are not very different from the reference scenario. Vegetable oil production is generally higher compared to the reference scenario; however, U.S. soyoil production declines compared to the reference scenario. (Soybean meal is not included as a separate commodity in the GTAP database, rather it is included in the feed category.) For Indonesia and Malaysia (SEA), there is an increase in both palm kernal and palm oil production relative to the reference scenario.

Trade

Although tariffs on soybeans are small for most countries, the tariff removal scenario still generates changes in trade relative to the reference scenario (tables C.7 and C.8). The United States has an increase in net soybean trade (exports minus imports) of 2.44 percent due to increasing exports. Along with the United States, South American (SAM) countries are the world's largest exporters of soybeans; SAM actually has a reduction in soybean exports relative to the reference scenario. The United States does have a decrease in exports for many other agricultural commodities relative to the reference scenario as resources are redeployed to the soybeans and beef.

Appendix table C.7

Export changes from tariff removal scenario relative to reference scenario (percent change)

	US	RNAM	SAM	RSA	SEA	India	China	ROA	EU	REU	FSO	MENA	SSA	OCE
Grains	-0.51	-0.18	-1.15	0.08	-3.26	-0.94	-2.79	-1.41	1.14	2.95	2.30	1.64	1.14	-0.55
Coarse grains	-0.45	-0.28	-1.15	0.02	-0.89	0.66	-1.06	-0.04	0.35	2.08	1.79	0.66	0.93	-0.65
V_f	-0.24	-0.11	-1.14	-0.16	-1.39	0.02	-1.52	0.00	0.39	1.03	0.94	0.37	1.17	-0.34
Soybeans	2.13	-2.30	-0.11	1.17	18.50	1.89	3.87	7.90	22.56	14.57	-1.27	10.78	9.68	0.45
Other oilseeds	-0.40	-0.03	-1.30	0.19	-0.86	-0.47	-1.40	-1.05	1.15	4.58	0.41	1.35	2.10	-0.71
Othag	0.13	-0.15	-0.82	-0.19	-2.07	0.36	-2.69	-1.99	1.89	2.46	3.17	1.66	1.04	-0.18
Cattle	-13.88	3.33	0.33	-14.78	-4.68	-5.44	-0.91	10.32	-18.44	6.45	-2.61	-8.57	-6.66	-11.55
Livestock	-2.22	0.05	-5.99	-5.87	-0.06	0.13	-1.59	8.73	6.45	29.51	7.37	1.70	4.07	-6.00
Frs	3.36	12.31	149.04	25.15	-5.47	103.11	8.54	-8.48	3.05	-3.62	17.25	37.38	11.92	1.95
Beef	79.76	19.35	55.74	111.87	-8.71	-38.70	-34.21	-47.99	-46.77	-35.67	-47.07	-49.21	205.10	25.11
Othm_ dairy	-2.30	0.05	-3.72	-4.86	-2.74	-0.21	-0.79	5.25	3.94	25.52	4.32	3.68	3.46	-3.81
Soyoil	8.48	54.06	4.32	1.69	14.49	44.02	35.68	93.50	191.80	57.40	33.67	97.06	18.13	21.90
Palmoil	0.34	7.93	1.76	2.21	6.74	94.03	4.10	3.37	30.83	45.31	65.47	126.90	37.99	1.81
Othvol	0.08	1.94	1.94	-0.32	-2.31	0.59	-1.00	-0.23	-0.22	3.42	6.03	5.99	2.33	-0.25
Feed	-1.43	-1.28	-1.61	-2.05	-3.39	-1.66	-1.77	-2.73	-4.62	0.47	0.60	-2.09	-2.93	-0.58
Ofd	-0.03	0.06	0.03	-0.04	-1.09	-0.27	-1.11	-1.77	-0.19	2.92	1.52	0.52	0.41	0.77
Woodp	-4.53	-8.46	-12.42	-17.18	21.14	25.09	30.02	67.90	1.30	12.58	-9.37	-5.37	-16.62	-4.98
Ethanol	0.77	-0.12	-0.32	3.33	-0.31	0.05	-1.61	-0.81	0.36	-	-	-	-	0.05
Biodiesel	9.35	11.66	16.83	5.81	-1.82	0.61	-0.46	-3.09	-33.78	-5.74	0.92	0.95	3.01	6.53

Note: US = United States. RNAM = Rest of North America. SAM = South America (Argentina, Bolivia, Brazil, and Paraguay). RSA = Rest of South America. SEA = Indonesia and Malaysia. ROA = Rest of Asia. REU = Rest of Europe. FSO = Former Soviet Republics. MENA = Middle East and North Africa. SSA = Sub-Saharan Africa. OCE = Oceania. V_f = Fruits, vegetables, and nuts. Palmk = Palm kernel. Othag = Sugar, other crops. Frs = Forestry. Othm_dairy = Pork, poultry, dairy products. Othvol = Other vegetable oils. Ofd = Other food, beverages and tobacco. Woodp = Products made from wood.

Source: USDA, Economic Research Service using the Markets and Trade Economic Division/Global Trade Analysis Project model.

Appendix table C.8

Import changes from tariff removal scenario relative to reference scenario (percent change)

	US	RNAM	SAM	RSA	SEA	India	China	ROA	EU	REU	FSO	MENA	SSA	OCE
Grains	-0.08	-0.09	0.22	-0.17	0.71	0.07	2.33	0.35	-0.95	-0.03	-0.79	-0.64	-0.79	0.57
Coarse grains	0.49	-0.11	0.31	-0.30	0.18	0.15	0.67	0.12	-1.30	-1.70	-0.56	-0.55	-0.68	3.18
V_f	0.15	-0.12	0.31	-0.20	0.58	-0.31	1.20	0.41	-0.26	-0.25	-1.39	-1.07	-0.78	0.21
Soybeans	-2.40	6.12	3.43	-1.11	22.30	3.97	0.91	-3.49	-3.30	-1.78	1.85	6.12	19.83	1.14
Other oilseeds	0.09	1.28	7.71	-0.13	-1.61	1.30	0.24	0.00	-0.58	-0.06	1.81	-0.48	-0.50	0.21
Othag	0.25	-0.25	-0.66	-0.46	0.90	0.16	1.52	1.88	-1.83	0.07	-0.79	-1.01	-1.10	0.39
Cattle	6.07	0.79	10.09	4.99	-4.63	-26.32	-5.29	-12.33	-26.36	-42.28	-11.83	-11.06	-0.11	6.85
Livestock	0.72	-0.24	2.56	1.30	1.89	-2.10	2.29	-0.59	-1.87	-8.46	-2.79	-0.62	-1.11	1.70
Frs	1.17	1.86	-42.43	3.05	41.39	22.92	7.35	15.75	2.21	2.24	108.99	8.12	32.12	3.04
Beef	6.27	1.37	4.27	8.10	3.37	53.50	18.19	65.01	180.08	550.91	89.74	85.56	49.68	3.80
Othm_ dairy	1.78	-0.76	0.02	1.91	0.72	0.22	5.61	-0.15	-1.62	-5.23	-1.95	-1.83	-1.25	2.40
Soyoil	58.94	8.52	-9.42	-0.11	1.38	78.22	41.57	18.75	14.48	508.15	69.09	92.85	92.17	-6.63
Palmoil	-0.16	2.60	1.89	-0.05	6.01	34.49	0.74	-0.91	4.87	21.38	18.20	23.67	-2.62	0.87
Othvol	0.09	-0.22	0.77	0.01	0.04	0.14	0.34	-0.12	-0.54	-0.31	-0.21	0.67	-0.46	-0.39
Feed	1.51	0.17	1.05	0.03	0.98	0.07	1.74	1.75	-6.14	-11.87	-1.11	-1.92	-0.51	-2.14
Ofd	-0.02	-0.37	-0.06	0.01	0.29	0.05	1.36	0.86	-0.95	-1.02	-0.80	-0.48	-0.62	-0.67
Woodp	11.64	18.01	91.25	30.51	34.64	74.31	90.78	17.68	12.29	1.40	42.77	22.85	48.71	38.63
Ethanol	-0.22	-0.13	-0.74	-0.09	0.99	26.27	1.01	1.11	0.13	-3.37	1.04	3.72	-0.60	0.22
Biodiesel	-12.12	3.16	-2.91	-3.13	5.46	3.48	-0.19	-6.17	6.25	1.25	-0.51	0.66	-2.89	-3.97

Note: US = United States. RNAM = Rest of North America. SAM = South America (Argentina, Bolivia, Brazil, and Paraguay). RSA = Rest of South America. SEA = Indonesia and Malaysia. ROA = Rest of Asia. REU = Rest of Europe. FSO = Former Soviet Republics. MENA = Middle East and North Africa. SSA = Sub-Saharan Africa. OCE = Oceania. V_f = Fruits, vegetables, and nuts. Palmk = Palm kernel. Othag = Sugar, other crops. Frs = Forestry. Othm_dairy = Pork, poultry, dairy products. Othvol = Other vegetable oils. Ofd = Other food, beverages and tobacco. Woodp = Products made from wood.

Source: USDA, Economic Research Service using the Markets and Trade Economic Division/Global Trade Analysis Project model.

For products made from wood, very little frs is traded; instead forest products are the raw input into the woodp category. Many regions see a decrease in exports of woodp relative to the reference scenario, including the United States (-4.53 percent).

Alternative Scenario: Prohibiting Imports of Illegally Produced Forest Products

Production and Prices

This chapter focuses on the production and prices change from the forest policy scenario relative to the reference scenario. For the United States, all agricultural activities have a decrease in production compared to the reference scenario (appendix table C.9). Most other regions also have a decrease in production of agricultural commodities.

Appendix table C.9

Production changes from forest policy scenario relative to the reference scenario (percent change)

	US	RNAM	SAM	RSA	SEA	India	China	ROA	EU	REU	FSO	MENA	SSA	OCE
Grains	-0.21	-0.51	-0.10	-0.10	-0.09	-0.05	0.15	0.09	-0.27	-0.40	-0.50	-0.24	-0.63	0.12
Coarse grains	-0.13	0.10	0.08	0.02	0.14	0.02	-0.24	0.29	-0.11	-0.41	-0.01	0.04	-0.02	0.04
V_f	-0.19	-0.05	-0.05	-0.08	-0.14	0.02	0.03	-0.19	-0.04	-0.06	-0.05	-0.04	-0.07	-0.40
Soybeans	-0.19	-0.51	-0.42	-0.05	-1.03	-0.10	0.73	-0.26	-0.30	-0.74	-0.14	-0.17	-0.27	-0.52
Palmk	-	-	-0.32	-0.04	0.03	-0.14	-0.27	-0.35	-	-	-	-0.46	0.11	-0.03
Other oilseeds	0.00	-0.37	0.08	-0.23	-0.06	-0.12	2.22	0.51	-0.29	-0.31	-0.78	-0.42	-0.01	-0.32
Othag	-0.08	-0.08	-0.20	-0.14	-0.19	-0.09	0.38	-0.37	-0.02	-0.10	-0.25	0.19	-0.32	-0.10
Cattle	-0.06	-0.35	0.29	0.05	0.14	-0.32	-0.92	-0.64	-0.84	-0.36	-0.05	-0.03	-0.04	0.80
Livestock	-0.93	-0.06	-0.06	0.01	-0.08	0.12	0.17	-0.69	-0.94	-0.48	0.19	0.17	-0.24	-2.30
Frs	0.22	0.34	0.02	0.12	-0.01	0.07	0.26	0.23	0.86	0.10	-0.20	0.03	-0.41	0.15
Beef	-0.09	-0.16	0.36	0.08	0.74	-4.30	0.10	1.02	-1.04	-0.40	-0.12	0.03	-0.19	0.85
Othm_ dairy	-0.53	0.27	-0.07	0.06	0.11	0.04	1.08	0.20	-1.09	-0.47	-0.20	-0.28	0.09	-1.42
Soyoil	0.15	0.41	0.25	0.20	-1.60	-0.16	0.09	0.44	0.05	-2.92	0.27	-0.33	0.14	-2.43
Palmoil	-	-	-0.35	0.07	0.04	-2.20	-0.29	-	-	-	-	-9.02	-0.02	0.04
Othvol	-1.21	-1.67	0.27	0.73	-0.16	-0.04	1.78	1.55	-0.12	-0.01	-1.06	-1.74	0.07	0.70
Feed	-1.22	-0.45	0.04	-0.22	-0.10	-0.22	0.00	-0.74	-1.54	-0.76	-0.17	-0.27	-0.45	-2.69
Ofd	-0.12	0.48	0.11	-0.05	0.08	0.15	0.20	-0.05	0.01	-0.77	-0.06	0.13	0.10	0.17
Woodp	12.63	-0.20	-4.03	2.00	0.48	-1.33	-1.54	-59.81	18.79	2.08	25.05	28.91	10.85	9.69
Ethanol	-0.55	0.12	0.65	-1.12	1.02	0.98	2.30	1.86	-0.05	-0.28	0.81	0.59	0.91	1.62
Biodiesel	0.54	0.98	0.63	0.12	1.27	-2.53	1.10	-1.49	-1.65	-1.06	-1.01	-1.68	-0.23	-0.27

Note: US = United States. RNAM = Rest of North America. SAM = South America (Argentina, Bolivia, Brazil, and Paraguay). RSA = Rest of South America. SEA = Indonesia and Malaysia. ROA = Rest of Asia. REU = Rest of Europe. FSO = Former Soviet Republics. MENA = Middle East and North Africa. SSA = Sub-Saharan Africa. OCE = Oceania. V_f = Fruits, vegetables, and nuts. Palmk = Palm kernel. Othag = Sugar, other crops. Frs = Forestry. Othm_dairy = Pork, poultry, dairy products. Othvol = Other vegetable oils. Ofd = Other food, beverages and tobacco. Woodp = Products made from wood.

Source: USDA, Economic Research Service using the Markets and Trade Economic Division/Global Trade Analysis Project model.

The price of frs (the raw input into forest products) increases tremendously relative to the reference scenario due to the export restriction on wood products (appendix table C.10). This high price, in turn, leads to a reduction in woodp production for most regions, especially those where woodp exports are restricted.

Trade

The forest policy leads to large decreases in exports for many agricultural commodities (appendix table C.11). Some regions where forest product exports are reduced do have increases in agricultural production and trade. China, in particular, has export gains for almost all agricultural commodities.

For the United States, the forest policy scenario leads to a reduction in imports (and decrease in exports) of most agricultural commodities (appendix table C.12). This is in addition to decreases in exports for most agricultural commodities. The United States does gain in woodp exports, one of the few countries to do so.

Appendix table C.10

Price changes from forest policy scenario relative to the reference scenario (percent change)

	US	RNAM	SAM	RSA	SEA	India	China	ROA	EU	REU	FSO	MENA	SSA	OCE
Grains	-5.64	-5.52	-5.55	-5.42	-5.56	-5.00	-7.77	-6.13	-5.23	-4.87	-4.88	-5.04	-5.42	-5.91
Coarse grains	-5.14	-4.93	-5.32	-5.15	-5.43	-4.89	-8.84	-5.99	-4.83	-4.31	-4.11	-4.43	-5.03	-5.89
V_f	-5.34	-5.44	-5.32	-5.33	-5.55	-5.08	-8.57	-6.36	-4.76	-4.73	-4.14	-4.62	-5.03	-5.63
Soybeans	-6.33	-5.50	-5.87	-5.36	-5.60	-5.35	-7.57	-5.99	-4.17	-5.53	-4.41	-4.96	-5.30	-6.35
Palmk	-	-	-8.39	-5.67	-5.59	-5.40	-8.88	-6.63	-	-	-	-5.52	-5.17	-5.58
Other oilseeds	-5.57	-5.29	-7.53	-5.50	-5.52	-5.02	-5.61	-5.64	-4.86	-5.04	-4.96	-5.10	-4.96	-4.91
Othag	-5.94	-5.65	-5.43	-5.62	-5.75	-5.36	-7.51	-6.60	-5.17	-5.30	-4.93	-4.88	-5.39	-6.22
Cattle	-3.97	-3.63	-4.06	-4.18	-4.99	-4.32	-8.72	-7.04	-3.63	-2.90	-3.50	-3.10	-3.60	-5.24
Livestock	-3.65	-3.94	-4.04	-4.14	-4.62	-4.36	-8.01	-6.17	-4.06	-3.25	-3.34	-3.13	-3.52	-4.28
Frs	201.09	186.55	-7.72	197.60	-17.77	0.79	217.00	50.89	213.34	214.07	-128.58	204.37	-160.52	225.67
Beef	-2.79	-2.84	-3.60	-3.23	-4.55	-2.75	-5.32	-5.34	-2.74	-2.61	-2.86	-2.79	-2.63	-4.10
Othm_dairy	-2.64	-2.97	-3.52	-3.26	-3.29	-3.05	-6.84	-4.96	-2.78	-2.57	-2.62	-2.63	-3.01	-3.35
Soyoil	-5.27	-5.02	-5.44	-4.35	-4.57	-4.27	-6.82	-4.47	-2.78	-2.53	-3.44	-2.49	-4.39	-3.51
Palmoil	-4.65	-2.84	-3.80	-2.98	-4.24	-3.67	-4.78	-3.96	-2.21	-3.44	-2.15	-3.27	-3.23	-2.83
Othvol	-3.76	-3.62	-3.73	-4.00	-4.19	-4.15	-6.17	-5.07	-3.72	-3.74	-3.37	-3.16	-4.35	-4.69
Feed	-2.99	-3.33	-4.41	-3.47	-3.80	-4.06	-6.49	-4.56	-3.11	-3.10	-3.27	-3.27	-3.57	-3.60
Ofd	-2.35	-2.81	-4.11	-3.03	-3.39	-4.01	-5.54	-4.26	-2.63	-2.60	-3.09	-2.97	-3.22	-2.98
Woodp	-0.18	3.01	-2.79	2.26	-2.74	-2.32	1.10	-2.96	0.40	1.82	-7.28	-1.02	-5.56	1.50
Ethanol	-2.00	-2.78	-5.07	-3.13	-3.46	-3.40	-6.22	-4.61	-1.69	-3.04	-2.60	-2.75	-3.00	-4.24
Biodiesel	-2.28	-2.22	-2.56	-2.21	-2.36	-1.46	-3.28	-2.18	-1.11	-1.62	-1.50	-1.31	-2.04	-1.89

Note: US = United States. RNAM = Rest of North America. SAM = South America (Argentina, Bolivia, Brazil, and Paraguay). RSA = Rest of South America. SEA = Indonesia and Malaysia. ROA = Rest of Asia. REU = Rest of Europe. FSO = Former Soviet Republics. MENA = Middle East and North Africa. SSA = Sub-Saharan Africa. OCE = Oceania. V_f = Fruits, vegetables, and nuts. Palmk = Palm kernel. Othag = Sugar, other crops. Frs = Forestry. Othm_dairy = Pork, poultry, dairy products. Othvol = Other vegetable oils. Ofd = Other food, beverages and tobacco. Woodp = Products made from wood.

Source: USDA, Economic Research Service using the Markets and Trade Economic Division/Global Trade Analysis Project model.

Appendix table C.11

Export changes from forest policy scenario relative to the reference scenario (percent change)

	US	RNAM	SAM	RSA	SEA	India	China	ROA	EU	REU	FSO	MENA	SSA	OCE
Grains	-0.16	-1.07	-0.61	-0.35	-1.05	-2.84	8.20	3.37	-0.36	-2.32	-2.13	-2.70	-1.91	0.18
Coarse grains	0.09	-0.13	0.08	-0.18	-0.43	-0.92	4.30	1.97	0.24	-0.63	-0.69	-0.70	-0.63	0.98
V_f	-1.19	-0.27	-0.24	-0.42	-2.51	-1.95	6.29	-0.59	-0.12	-0.44	-1.52	-1.00	-1.25	-1.42
Soybeans	-0.40	-1.14	-0.96	-0.71	-1.60	-3.85	7.70	1.68	-2.13	1.02	-2.66	-1.11	-3.48	0.19
Other oilseeds	0.13	-0.23	-0.74	-0.43	-0.19	-1.67	3.50	2.93	-0.47	-0.08	-0.98	-0.71	-1.81	-0.98
Othag	-1.15	-0.82	-1.15	-0.77	-1.36	-3.49	7.06	5.10	-0.72	-0.15	-3.92	-3.02	-1.67	-0.53
Cattle	-0.28	-1.12	0.27	-0.67	-2.57	-4.87	2.34	9.94	-1.20	-4.51	-1.99	-2.12	-0.13	0.38
Livestock	-10.47	-4.71	-1.03	-3.52	-5.79	-1.54	2.36	4.66	-2.30	-4.53	-5.49	-3.04	-7.15	-6.57
Frs	1.00	63.94	-79.77	47.53	-28.37	-387.97	-39.18	-137.86	-3.86	27.88	-54.77	2.45	-83.65	0.82
Beef	-5.04	-2.70	3.03	0.12	0.60	-6.16	11.52	27.07	-3.36	-4.41	-2.26	-3.00	-3.31	1.35
Othm_ dairy	-9.84	-3.56	-0.06	-2.31	-3.31	-2.58	2.14	19.32	-4.30	-5.96	-2.69	-3.05	-0.84	-3.97
Soyoil	0.58	0.12	1.67	-0.20	-1.62	-7.32	7.50	-1.90	-4.54	-6.84	0.94	-1.37	1.18	-6.10
Palmoil	0.66	-2.99	-0.38	-4.85	0.02	-2.28	2.04	13.36	-23.92	-4.57	-42.48	-9.13	-3.74	-7.31
Othvol	-1.49	-2.68	0.27	0.76	-0.16	-0.25	6.84	2.40	-0.53	-0.43	-2.20	-4.97	0.02	0.69
Feed	-4.15	-1.36	0.08	-2.44	-1.49	-0.91	3.10	2.83	-2.72	-3.10	-2.32	-1.81	-1.33	-2.84
Ofd	-3.25	0.07	1.16	-0.91	-0.25	0.31	3.03	4.33	-1.14	-1.80	-1.17	-0.46	0.53	-1.55
Woodp	48.73	2.11	-59.77	5.09	-20.46	-11.91	-7.96	-171.67	33.28	11.37	35.67	84.31	-48.61	15.35
Ethanol	-2.04	0.68	1.02	-5.11	-2.23	-1.52	3.38	3.77	-0.13	-	-	-	-	1.46
Biodiesel	0.42	2.39	5.64	4.12	3.07	0.19	9.37	4.48	-12.54	-0.47	-1.40	-1.80	2.78	1.11

Note: US = United States. RNAM = Rest of North America. SAM = South America (Argentina, Bolivia, Brazil, and Paraguay). RSA = Rest of South America. SEA = Indonesia and Malaysia. ROA = Rest of Asia. REU = Rest of Europe. FSO = Former Soviet Republics. MENA = Middle East and North Africa. SSA = Sub-Saharan Africa. OCE = Oceania. V_f = Fruits, vegetables, and nuts. Palmk = Palm kernel. Othag = Sugar, other crops. Frs = Forestry. Othm_dairy = Pork, poultry, dairy products. Othvol = Other vegetable oils. Ofd = Other food, beverages and tobacco. Woodp = Products made from wood.

Source: USDA, Economic Research Service using the Markets and Trade Economic Division/Global Trade Analysis Project model.

Appendix table C.12

Import changes from forest policy scenario relative to the reference scenario (percent change)

	US	RNAM	SAM	RSA	SEA	India	China	ROA	EU	REU	FSO	MENA	SSA	OCE
Grains	0.00	0.28	0.12	0.46	1.14	2.66	-6.41	-1.24	0.22	0.12	0.76	0.91	0.73	-0.15
Coarse grains	-0.49	0.32	0.08	-0.09	-0.07	0.45	-2.74	-0.29	-0.41	-0.03	0.75	0.90	0.22	-0.76
V_f	-0.26	0.13	0.18	0.15	1.47	0.98	-4.47	-1.24	0.08	0.04	0.62	1.08	0.61	-0.12
Soybeans	-0.81	0.54	-0.84	0.37	-1.63	-0.03	-1.22	-0.83	0.62	-1.71	1.21	1.39	-0.71	-1.35
Other oilseeds	-1.44	-1.43	0.83	0.04	-0.25	0.18	-0.40	-0.07	0.00	0.00	-0.25	0.53	-0.05	0.32
Othag	-0.39	-0.18	0.30	-0.13	0.54	3.02	-3.66	-4.23	0.55	-0.49	0.74	1.85	1.21	-0.27
Cattle	-0.82	0.35	0.04	0.03	2.28	-3.69	-5.86	-6.51	-0.33	1.14	0.99	1.19	0.12	-0.31
Livestock	1.45	-0.25	0.20	-0.79	0.89	2.19	-9.14	-8.98	-0.23	1.36	2.92	2.22	1.43	-0.49
Frs	-8.42	-22.08	-156.11	-84.19	-232.24	-57.71	-20.84	-114.07	-3.47	-3.69	-207.76	-12.66	-155.05	-40.63
Beef	1.50	-0.36	-0.79	0.86	-1.66	1.66	-4.86	-7.20	2.04	0.48	1.57	2.15	1.18	-0.57
Othm_ dairy	1.54	-0.39	-0.97	0.62	-0.36	0.73	-18.96	-6.67	2.91	0.69	0.77	1.58	-0.57	-0.79
Soyoil	-0.18	0.58	-0.41	0.10	0.01	1.06	-7.85	-0.71	0.93	0.61	-0.76	0.09	1.53	2.83
Palmoil	-0.95	-0.50	0.12	0.35	-0.64	-0.90	0.24	0.36	-2.97	-0.80	-10.88	-2.06	0.00	-0.16
Othvol	-0.28	0.44	0.09	-0.05	-0.04	0.19	-4.55	-0.33	0.45	0.12	-0.16	0.52	0.01	0.67
Feed	-0.10	-0.71	-0.97	-0.22	0.20	-0.08	-4.85	-2.30	-0.59	-0.64	0.30	0.17	-0.62	-3.42
Ofd	1.43	0.25	-1.15	0.10	0.33	-0.07	-3.74	-1.91	1.24	0.14	0.03	0.41	-0.41	1.10
Woodp	-21.43	-2.96	-41.37	-13.20	-48.40	-32.12	-39.28	-31.66	-17.54	-2.79	-35.34	-16.56	-41.29	-27.12
Ethanol	1.15	-0.66	-1.99	-1.59	-1.01	6.08	-3.07	-2.58	0.72	0.16	-0.33	0.50	-1.08	0.59
Biodiesel	-1.61	-0.50	-2.37	-0.05	0.17	0.53	-6.45	-5.07	4.02	2.06	2.96	3.25	0.07	1.26

Note: US = United States. RNAM = Rest of North America. SAM = South America (Argentina, Bolivia, Brazil, and Paraguay). RSA = Rest of South America. SEA = Indonesia and Malaysia. ROA = Rest of Asia. REU = Rest of Europe. FSO = Former Soviet Republics. MENA = Middle East and North Africa. SSA = Sub-Saharan Africa. OCE = Oceania. V_f = Fruits, vegetables, and nuts. Palmk = Palm kernel. Othag = Sugar, other crops. Frs = Forestry. Othm_dairy = Pork, poultry, dairy products. Othvol = Other vegetable oils. Ofd = Other food, beverages and tobacco. Woodp = Products made from wood.

Source: USDA, Economic Research Service using the Markets and Trade Economic Division/Global Trade Analysis Project model.