United States Department of Agriculture

Economic
Research
Service

Economic
Research
Report
Number 210

June 2016

# Brazil's Agricultural Land Use and Trade: Effects of Changes in Oil Prices and Ethanol Demand

Constanza Valdes, Kim Hjort, and Ralph Seeley

USDA

United States Department of Agriculture

Economic Research Service
www.ers.usda.gov

Access this report online:

www.ers.usda.gov/publications/err-economic-research-report/err210

Download the charts contained in this report:

- Go to the report's index page www.ers.usda.gov/publications/err-economic-research-report/err210
- Click on the bulleted item "Download err210.zip"
- Open the chart you want, then save it to your computer

Recommended citation format for this publication:

Valdes, Constanza, Kim Hjort, and Ralph Seeley. *Brazil's Agricultural Land Use and Trade: Effects of Changes in Oil Prices and Ethanol Demand,* ERR-210, U.S. Department of Agriculture, Economic Research Service, June 2016.

Cover image: Shutterstock.

Use of commercial and trade names does not imply approval or constitute endorsement by USDA.

In accordance with Federal civil rights law and U.S. Department of Agriculture (USDA) civil rights regulations and policies, the USDA, its Agencies, offices, and employees, and institutions participating in or administering USDA programs are prohibited from discriminating based on race, color, national origin, religion, sex, gender identity (including gender expression), sexual orientation, disability, age, marital status, family/parental status, income derived from a public assistance program, political beliefs, or reprisal or retaliation for prior civil rights activity, in any program or activity conducted or funded by USDA (not all bases apply to all programs). Remedies and complaint filing deadlines vary by program or incident.

Persons with disabilities who require alternative means of communication for program information (e.g., Braille, large print, audiotape, American Sign Language, etc.) should contact the responsible Agency or USDA's TARGET Center at (202) 720-2600 (voice and TTY) or contact USDA through the Federal Relay Service at (800) 877-8339. Additionally, program information may be made available in languages other than English.

To file a program discrimination complaint, complete the USDA Program Discrimination Complaint Form, AD-3027, found online at How to File a Program Discrimination Complaint and at any USDA office or write a letter addressed to USDA and provide in the letter all of the information requested in the form. To request a copy of the complaint form, call (866) 632-9992. Submit your completed form or letter to USDA by: (1) mail: U.S. Department of Agriculture, Office of the Assistant Secretary for Civil Rights, 1400 Independence Avenue, SW, Washington, D.C. 20250-9410; (2) fax: (202) 690-7442; or (3) email: program.intake@usda.gov.

USDA is an equal opportunity provider, employer, and lender.

United States Department of Agriculture

**Economic Research Service**

Economic Research Report Number 210

June 2016

# Brazil's Agricultural Land Use and Trade: Effects of Changes in Oil Prices and Ethanol Demand

Constanza Valdes, Kim Hjort, and Ralph Seeley

## Abstract

A prominent issue related to land-use changes in Brazil is the westward expansion of agriculture into the country's frontier region, which includes the surrounding Cerrados savannah. The conversion of range, pasture, and other land into cropland in Brazil is due to rising domestic and international food demand but is also a consequence of ethanol production and policies that have increased the demand for sugarcane (ethanol feedstock). Because the supply and demand for ethanol are inexorably linked to that of petroleum, oil prices can affect production and land-use decisions for ethanol feedstocks and related agricultural commodities. This study examines the effects of longrun changes in oil prices on ethanol production in Brazil and resulting cropping patterns. Given a sustained fall in oil prices, ethanol use would be expected to fall, leading to a decrease in area planted to sugarcane and an increase in land available for other agricultural commodities. However, a sustained increase in oil prices would be expected to increase the incentives to produce ethanol, thereby expanding sugarcane production and planting area. Given Brazil's dominant position in multiple global commodity export markets, adjustments to output and exports would lead to changes in world prices.

**Keywords:** Brazil, agriculture, agricultural sector model, oil prices, ethanol, crops, livestock, land use.

## Acknowledgments

The authors thank Andrew Muhammad and Joseph Cooper of USDA's Economic Research Service (ERS); Renee Schwartz, Robert Tetrault, Fahran Robb, Megan Davidow, and Sergio Barros of USDA's Foreign Agricultural Service; Wyatt Thompson of the University of Missouri; Sílvia Helena Galvão de Miranda and Heloisa Burnquist of São Paulo University, Luiz de Queiroz College of Agriculture (ESALQ); and two anonymous peer reviewers for their valuable comments and suggestions. Thanks to Chris Dicken of ERS for cartographic output and John Weber and Curtia Taylor of ERS for editorial and design assistance.

# Contents

**Abstract** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . i

**Acknowledgments** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . i

**Contents** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .ii

**Summary** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . iii

**Introduction** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .1

**Oil Price Projections** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .5

**Ethanol and Sugarcane Markets in Brazil** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .7

**Brazil's Crops, Livestock, and Land Use to 2024: Reference Scenario** . . . . . . . . . . . . . . . . . . .11

Ethanol Sector . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .15

**High- and Low-Oil-Price Scenarios: Brazilian Prices and Production** . . . . . . . . . . . . . . . . . . .18

**High-Oil-Price Scenario** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .20

Ethanol and Sugarcane Sector Impacts . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .20

Agricultural Returns and Land Use Impacts . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .21

Production and Trade Impacts . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .21

**Low-Oil-Price Scenario** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .24

Ethanol and Sugarcane Sector Impacts . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .24

Agricultural Returns and Land Use Impacts . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .24

Production and Trade Impacts . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .25

**Conclusion** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .27

**References** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .29

**Appendix 1: Characteristics of Brazil's Land Base** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .35

**Appendix 2: Land Use in Brazil** . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .36

**Appendix 3: Brazil Regional Model Structure and Data Sources** . . . . . . . . . . . . . . . . . . . . . . .37

United States Department of Agriculture

*A report summary from the Economic Research Service* June 2016

Find the full report at *www.ers.usda.gov/publications/err-economic-research-report/err210*

# Brazil's Agricultural Land Use and Trade: Effects of Changes in Oil Prices and Ethanol Demand

Constanza Valdes, Kim Hjort, and Ralph Seeley

## What Is the Issue?

A prominent issue related to land-use changes in Brazil is the westward expansion of agriculture into the country's frontier region, which includes the surrounding Cerrados savannah. The conversion of range, pasture, and other land to cropland in Brazil is due not only to rising domestic and international food demand but also to rising ethanol production, expanding demand for sugarcane, the main feedstock used in Brazil. In fact, sugarcane area increased 35 percent in the period 2008-14, and sugarcane is now planted on 14 percent of Brazil's total cropland (65.4 million hectares) (1 hectare equals 2.47 acres). Since the demand for ethanol is inexorably linked to that of petroleum, oil prices can affect production and land-use decisions for ethanol feedstocks and, in turn, for other agricultural commodities. This study examines how longrun changes in oil prices could affect Brazilian ethanol production and resulting cropping patterns. It also considers the implications for world agricultural markets.

## What Did the Study Find?

The study examined the effects of two oil-price scenarios—sustained high prices and sustained low prices from 2015 to 2024—on Brazilian agricultural land use. A reference scenario is based on the assumptions in USDA's *Agricultural Projections to 2024*.

*High-price scenario*. In this scenario, the oil price rises 40 percent above the reference, or baseline, price in 2015, followed by another 7-percent increase in 2016 and small changes relative to the baseline price thereafter through 2024 (for a sustained average increase of 45 percent above the base price). With increasing oil prices, the demand for ethanol increases relative to that for gasoline, raising the price of ethanol and creating incentives to increase production. Consequently, sugarcane area increases by 946,000 hectares during the forecast period, or about 11 percent of current sugarcane area. This expansion helps boost sugarcane production by 75 million tons as well as the share of sugarcane milled for ethanol production. Most of the additional ethanol produced in Brazil would be consumed domestically, while a small share would be exported. With sustained higher oil prices, higher crop production costs, and lower returns for most crops, the area planted to food and feed crops other than sugarcane falls by an annual average of 12,300 hectares in 2015-19. With continued demand for food and feed crops, after 2019, prices and returns for other crops and livestock recover, leading to an additional 293,000 hectares of arable land brought into "other" crop and livestock production. With lower domestic production of sugar, corn, soybeans, rice, and cotton due to high oil prices, Brazilian exports of these commodities decline over the period. Given Brazil's dominant position in global export markets for sugar, soybeans, and corn, this leads to higher world prices for these commodities throughout the period.

*Low-price scenario*. In this scenario, the oil price decreases 18 percent below the reference price in 2015, followed by 6-percent declines over the next 2 years and a 1-percent annual decline thereafter through 2024. A sustained fall in oil prices would be expected to trigger a drop in demand for ethanol as well as a drop in prices for agricultural inputs (energy, fertilizer, etc.). In this scenario, ethanol use in Brazil falls by an average of 16 percent annually in 2015-24. Over the same period, expected returns to Brazilian sugarcane producers would fall about 10 percent annually, leading to a decrease in production and freeing up nearly 4 million hectares of land for other agricultural uses. With lower oil prices, additional arable land is brought into field crop production (2.5 million hectares), livestock production (1.1 million hectares), and permanent crop production (46,000 hectares), while the remaining 335,000 hectares remain fallow. With lower energy costs and higher production, Brazil's exports of sugar, soybeans, corn, cotton, rice, and meat increase during 2015-24.

Oil prices in the reference scenario are projected to continue to increase during the next decade, although at a slower pace than over the last half decade. In the high-price scenario, oil prices reflect parallel changes with respect to the reference price whereas oil prices in the low-price scenario reflect the continued (and divergent) decline in oil prices relative to the reference price. As a result, the increase in land use in the high-price scenario is not symmetric to the decrease in land use in the low-price scenario, where the reduction in revenue arising from ethanol production outweighs the benefits of lower chemical, fertilizer, and energy-related input costs.

## How Was the Study Conducted?

A dynamic multicommodity model of Brazilian agriculture based on policy, macroeconomic, and world petroleum price assumptions underlying USDA's 2014 longrun baseline and on ERS-derived projections for Brazilian ethanol was used to generate projections of supply, demand, and trade for grains, oilseeds and products, cotton, livestock products, sugarcane, sugar, and ethanol. The model was combined with 41 other country/regional models to generate global commodity supply, demand, trade, and equilibrium prices for 2015-24. The model was enhanced by the following: (1) explicitly linking the sugarcane sector to ethanol and gasoline demand; (2) modeling the stock of agricultural land (cropland and pasture); (3) adding regional detail to the sugarcane, soybean, corn, and cattle components of the model; (4) including a cropping intensity index in the land-use allocation system to account for the cultivation of more than one crop in a given plot of land in one year; and (5) including region-specific prices paid by farmers for fertilizers and energy inputs. Changes in incentives to produce ethanol and other commodities were derived from high- and low oil-price projections by the U.S. Department of Energy.

# Brazil's Agricultural Land Use and Trade: Effects of Changes in Oil Prices and Ethanol Demand

Constanza Valdes, Kim Hjort, and Ralph Seeley

## Introduction

Expansion of global biofuel production has raised concerns about associated land-use changes in biofuel-producing countries (Malcolm et al., 2009; Nassar et al., 2008). Concerns about ethanol-related land-use changes in Brazil have centered on the westward expansion of agriculture into the country's Cerrados savannah biome.[1] The focus of this study is the degree to which production of ethanol drives agricultural land-use changes. Several researchers have argued that increasing production of biofuels would have direct and indirect impacts on land use and lead to intensified competition for land currently planted to nonfeedstock crops or used for grazing (e.g., Nassar et al., 2008; Elobeid et al., 2011). In Brazil, such a change in production activity could force other crop and livestock production further west into the surrounding Cerrados (Fearnside, 1997; Chomitz and Kumari, 1998; Von Blottnitz and Curran, 2006).

A recent ERS study provides a comprehensive assessment of modeling efforts that estimate indirect land-use changes due to biofuel demand (Marshall et al., 2011). The study describes the types of land-use change arising from biofuel production and summarizes the analytic methods used to estimate the impact of biofuel-feedstock production on land use. It also provides a chronology of indirect land-use change estimates, which were found to be highly sensitive to underlying assumptions about land productivity and conversion efficiency. Other studies have analyzed the economic effects of biofuel policies on grain-producing regions of the world and on world food production, using agricultural sector or multisector economy-wide models to assess policy and trade implications of increased ethanol production (Sheldon and Roberts, 2008; Tyner and Taheripour, 2008; Thompson et al., 2009). Schmidhuber (2006) and Lapan and Moschini (2008) sought to identify links between the agricultural sector, the energy sector, and government intervention through taxes/subsidies and biofuel mandates.

The estimated land-use changes in past studies depend on the agriculture-energy nexus in downstream markets (i.e., price transmission between energy and agricultural markets) (Muhammad and Kebede, 2009; Sands and Westcott, 2011; McPhail et al., 2012). A more recent survey of biofuel

---

[1] The term "biome" refers to the ecosystem that sustains native plants and animals. Brazil recognizes six biomes—Amazonia, the Atlantic Forest, the Caatinga, the Cerrado, the Pantanal, and the Pampa (see app. 1).

effects on price transmission concludes that energy prices drive longrun agricultural price levels and that instability in energy markets is transferred to food markets (Serra and Zilberman, 2013).[2]

Focusing on Brazil, Nassar et al. (2008) assess the direct and indirect land-use changes from sugarcane expansion, estimating the amount of land needed to produce an additional 1 million liters of ethanol per year and the likely constraints to expansion from enforcement of land-use regulations. Nassar et al. were challenged by significant limitations, including a lack of economic models that could help to explain and predict land allocation and land use as a consequence of the dynamics of demand for crops and livestock products. Elobeid et al. (2011) use a regional model of Brazilian agriculture to assess the effects of biofuel expansion on Brazilian land use and conclude that sugarcane area expansion displaces other crops and pasture and leads to intensification in land use. A more recent study of the market effects of Brazil's ethanol policies examines the tradeoff between ethanol production and sugar production in Brazil and finds that higher gasoline prices, blending fuel mandates, and ethanol tax exemptions have the impact of increasing ethanol and sugar prices (de Gorter et al., 2013).

This study examines land-use changes in Brazil that arise from links between petroleum, ethanol, and agricultural markets and the competition between sugarcane, other crops, and cattle for land resources (fig. 1). The land area of Brazil comprises forest land, other land not suitable for agricultural purposes, and agricultural land. In the model used in the study, the focus is on the economic determinants of the use of land for agricultural purposes. The study approach incorporates the dynamics of crop production and cattle-rearing activities that cause conversion of pastureland to cropland. To this end, the model incorporates two regions, traditional and frontier, to measure direct and indirect land-use change. Similar to Marshall et al. (2011), direct land-use change refers to the conversion of land from other uses into sugarcane production due to increased ethanol demand. Indirect land-use change is the expansion of cropland for the agricultural commodities displaced by expanding sugarcane production. This expansion could occur within or across the defined regions in this study (traditional and frontier regions). Cattle grazing in the traditional region gets pushed out into the frontier region as growing demand for soybeans and corn leads to increased acreage, and where the nutrient-rich pastureland make its conversion into soybeans and corn more profitable. Rising land prices in the traditional region and the need for economies of scale are the driving forces behind the migration of sugarcane production to the frontier region. These dynamics are captured in the model with regional disaggregation of land use for the production of sugarcane, soybeans, corn, and cattle.

Agricultural land is further disaggregated by use into cropland and pastureland and cannot exceed total potential crop, pastureland, and onfarm forests.[3, 4] Pastureland in each region is divided into two classes—used and degraded—with degraded pasture rising with higher (and falling with lower) stocking rates (number of cattle per hectare). For cropland, a distinction is made between land used for permanent crops and temporary crops.

---

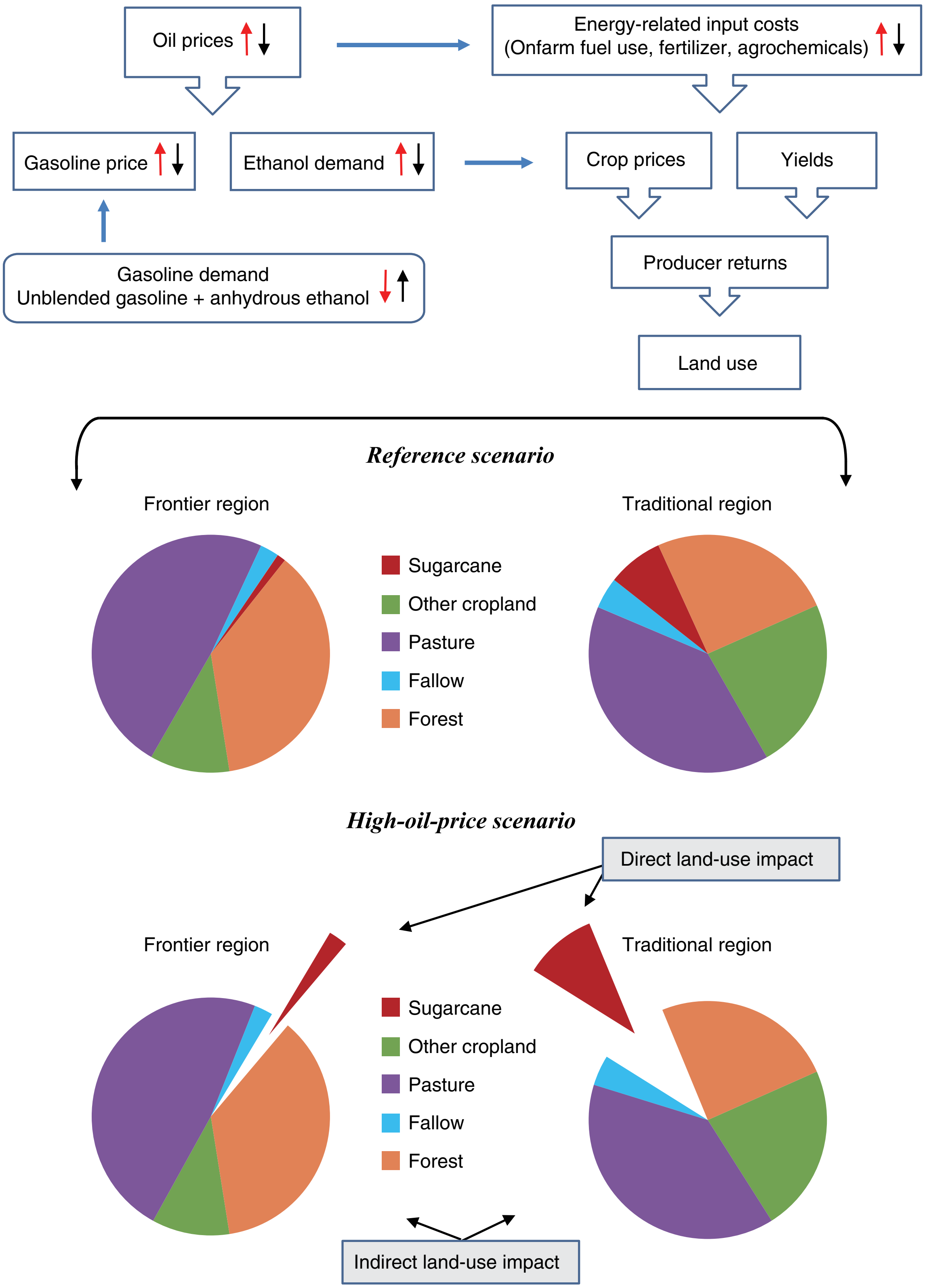
[2] Others have investigated the welfare effects of biofuel policies by using multimarket partial equilibrium models (Elobeid et al., 2007; Tokgoz et al., 2007) or general equilibrium models (Steinbuks and Hertel, 2011), emphasizing the effect of policies on market outcomes (production, consumption, and prices) and on welfare measures (consumer and producer surplus).

[3] Total potential crop and pastureland (220 million hectares in 2014) is the total land area of Brazil less land occupied by cities and towns, infrastructure, indigenous territories, and other reserved land.

[4] We assume that current reforms to restrict deforestation continue so that forest land on farms remains at fixed shares of 35-80 percent in the frontier region and 20 percent in the traditional region.

Figure 1

**Energy prices affect ethanol production and regional land use**



Based on historical evidence, the conversion of land under permanent crops is derived from returns to cattle rearing and expectations of the medium-term foreign and domestic demand for permanent crops. The multiple cropping index, which measures the number of crops grown on a single hectare of land (about 2.47 acres), dictates the addition of temporary crop land. Fallowed land depends on cropping intensity and pasture use in the frontier region.

The model incorporates technological change, allowing crop yield growth to alleviate some of the pressure on land-use changes. The model also incorporates productivity increases in ethanol conversion processes. This approach differs from those in other studies by developing an economic model of land-use changes that replicates empirical evidence about Brazil's agricultural sector, where agricultural profitability (i.e., rates of return for crops and cattle ranching) and land-use strategies intersect.

To illustrate how ethanol production in Brazil could affect agricultural production patterns and land use, the analysis considers three scenarios: a reference scenario of agricultural supply and demand from 2015 through 2024 and two alternative scenarios that assume either a sustained rise or a fall in world oil prices. The reference scenario uses USDA's 2014 baseline projections for global macroeconomic conditions, petroleum prices, and international commodity prices. The alternative scenarios are based on the U.S. Department of Energy (USDOE/AEO, 2014) long-term projections for high and low oil prices. Given Brazil's position as a major producer and exporter of sugar, ethanol, and various other commodities, the study also considers the implications for world agricultural markets.

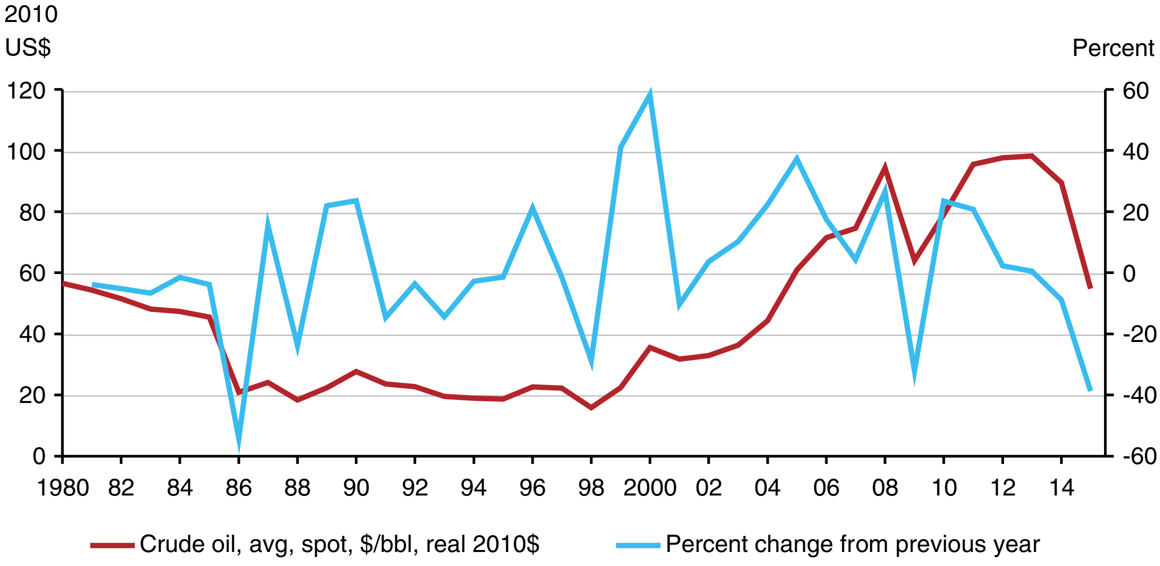
## Oil Price Projections

Historical oil prices reflect elevated levels of volatility in crude oil markets and an upward trend (fig. 2). Crude oil prices in January 2015 averaged $51 per barrel, the lowest level since April 2009 and more than 50 percent lower than the June 2014 high. Despite the high uncertainty in the price outlook going forward, USDOE estimates the probability of crude oil prices exceeding $80 per barrel at nearly three times higher than the probability of them falling below $30 per barrel (USDOE/STEO).[5] This suggests that a high-oil-price scenario is a more likely outcome than a low-oil-price scenario, reinforcing expectations of rising oil prices over the long term, despite current oil price levels.

To analyze the impact of ethanol production in Brazil on Brazil's crop and livestock production and agricultural land use, this study compares Brazil's ethanol demand, agricultural production, and land use under alternative crude oil price projections from 2015 through 2024. These comparisons enable one to ascertain the impacts of higher and lower oil prices versus a reference price level, holding other factors (i.e., macroeconomic, agricultural and trade policies, and weather) constant. Long-term high- and low-oil-price forecasts are from USDOE; projecting or forecasting petroleum prices is beyond the scope of this report. Crude oil prices for the reference scenario are projected to rise faster than the general inflation rate and remain historically high over the next decade. By 2024, the crude

Figure 2

**Average crude oil spot price and annual percent change**



Source: USDA, Economic Research Service using data from World Bank, Global Economic Monitor Database and U.S. Department of Energy (DOE)/AEO, Office of Integrated and International Energy Analysis, U.S. Energy Information Administration. *Annual Energy Outlook 2014.*

---

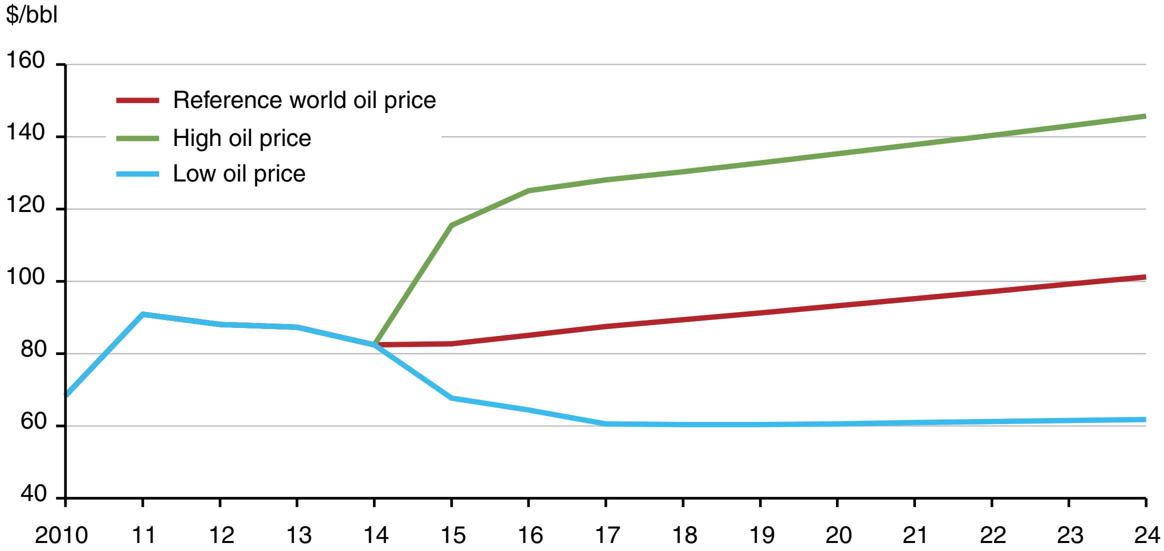
[5] Long-term crude oil price projections depend on highly unpredictable global petroleum supply-and-demand conditions. A number of factors may influence future prices of petroleum, including rising oil production from Organization of Petroleum Exporting Countries (OPEC), world economic growth, and fuel demand from regions that are not members of the Organization for Economic Co-operation and Development (USDOE/AEO, 2014).

oil price is projected to be $101 (in 2005 dollars) per barrel, compared with about $82 (in 2005 dollars) per barrel projected for 2014 (fig. 3).

Under the high-oil-price scenario, petroleum prices rise 40 percent in 2015, followed by additional annual increases averaging 6 percent through 2024, which yields a 44-percent higher price in 2024 relative to the reference price. Under the low-oil-price scenario, petroleum prices fall 18 percent in 2015, followed by another 6 percent in each of the next 2 years and a 1-percent per year decline thereafter until the price in 2024 is 39 percent lower than the reference price.

Figure 3

**Reference world oil price versus high/low oil prices**



Source: U.S. Department of Agriculture, Office of the Chief Economist, World Agricultural Outlook Board (USDA/OCE/WAOB) (2014). *USDA Agricultural Projections to 2023*. No. (OCE-141). High/Low oil price scenarios based on USDOE/AEO (2013) and USDOE/AEO (2014).

# Ethanol and Sugarcane Markets in Brazil

Government support of the Brazilian ethanol industry began in 1975 with the *Proálcool* program to produce ethanol from sugarcane in response to soaring crude oil prices and low sugar prices. Under the program, Brazil's Government provided fiscal and financial support for the construction of distilleries and facilitated foreign investment to establish ethanol plants and mills with annexed distilleries. Vehicles that ran only on ethanol were introduced in Brazil in 1979, and by 2003, flex-fuel cars capable of being powered by gasoline and/or ethanol in any proportion became available. To ensure a domestic ethanol market, the Government stimulated demand through mandatory blending of ethanol with gasoline, tax exemptions for ethanol-powered cars, and subsidized credit for automotive industries that developed ethanol-powered cars (UNICA, 2013).

Brazil's ethanol production is determined by the relationship between sugar and gasoline prices, hydrous and anhydrous ethanol prices, and, to some extent, the mills' ethanol storage capacity (UNICA, 2013).[6,7] When international sugar prices are high, Brazil's sugar production and sugar exports take precedence over its production of ethanol. Under the *Proálcool* and through the mid-1990s, the breakdown between sugarcane crushed for sugar or for ethanol production was controlled by a policy instrument used to regulate sugar production and counter the oversupply of sugar and low international sugar prices. Now the ratio is set by millers before harvest and is based on the expected price and demand growth for sugar and ethanol (UNICA, 2013).

Production of both sugar and ethanol in Brazil has expanded rapidly since the second half of the 1990s. Sugarcane production in Brazil totaled 640 million tons in 2014, up 173 percent since 1990. The increase reflects an expansion in area planted to sugarcane to around 9 million hectares and improvements in yields. In 2014, 55 percent of sugarcane harvested in Brazil was crushed and distilled into ethanol, and the other 45 percent was used to produce over 40 million tons of sugar (fig. 4).

Brazilian States are grouped into two distinct regions according to their geographic and land characteristics.[8] The *traditional region* encompasses the administrative/geographical regions of Brazil's south, most of its southeast, and its northeast. The *frontier region* includes Brazil's center-west and north regions, as well as Minas Gerais, Tocantins, Bahia, Maranhão, and Piauí because their primary agricultural areas are within the Cerrados biome. Sugarcane area in the traditional region (accounting for 69 percent of Brazil's total sugarcane area) grew 0.3 percent annually between 2010 and 2014 (table 1). This growth was fueled by the addition of over 162,000 hectares to sugarcane area in São Paulo in 2010-14 (CANASAT, 2014). During this period, São Paulo State's natural pasture area decreased by 37,000 hectares, as did its corn area (34,411 hectares), its soybean area (54,981 hectares), and and its area for permanent crops, like oranges (29,828 hectares) and coffee (5,634 hectares) (CONAB, 2014). In the frontier region, sugarcane area expanded 10 percent annually in 2010-14, with 359,000 hectares added in Goiás and 274,000 hectares added in Minas Gerais (CONAB, 2014).

---

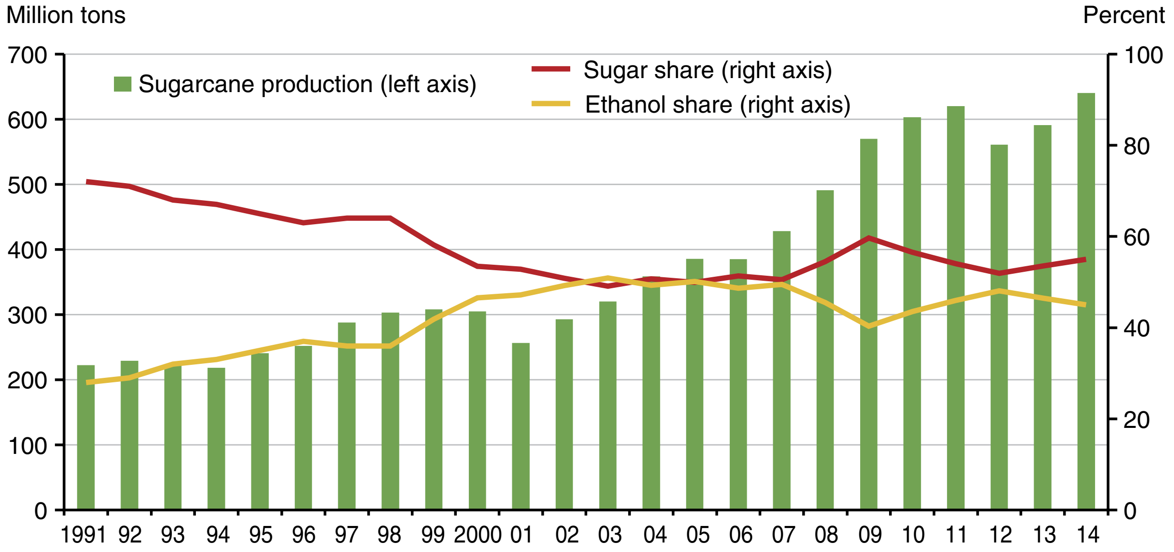
[6] Two types of ethanol are produced in Brazil: anhydrous ethanol and hydrous ethanol (E100). Anhydrous ethanol is blended with gasoline (varying from 18.0 to 27.5 percent). Hydrous ethanol is used in 100 percent ethanol-fueled cars and "flex-fuel" cars, which run on any fuel combination—from 100 percent ethanol to 100 percent gasoline (UNICA, 2013).

[7] Recently, corn has emerged as an ethanol feedstock, but it currently accounts for a minimal amount of ethanol production.

[8] These region definitions are intended to include most of the Cerrados soils in the frontier region (see app. 1). Therefore, the term "frontier" may not be comparable to definitions of the "frontier" and "traditional" regions used by other sources.

Figure 4

## Brazil's sugarcane production and milling shares



Source: USDA, Economic Research Service using data from USDA Foreign Agricultural Service.

Table 1

## Sugarcane area, yield, and production by region and State

| Major sugarcane regions/States | Area planted to sugarcane | | | | | | 5-year average yields, 2010-14 | Production average, 2010-14 |
|---|---|---|---|---|---|---|---|---|
| | 2010 | 2011 | 2012 | 2013 | 2014 | Average annual growth, 2010-14 | | |
| | *1,000 hectares (ha)* | | | | | *Percent* | *Tons/ha* | *1,000 tons* |
| Brazil total | 8,050 | 8,490 | 8,890 | 8,700 | 9,140 | 2.8 | 70.0 | 605,020 |
| Traditional region | 6,177 | 6,298 | 6,468 | 6,216 | 6,322 | 0.3 | 59.8 | 440,037 |
| São Paulo | 4,454 | 4,605 | 4,715 | 4,608 | 4,616 | 0.7 | 74.1 | 340,460 |
| Paraná | 550 | 567 | 598 | 549 | 569 | 0.4 | 69.0 | 39,881 |
| Alagoas | 382 | 384 | 395 | 379 | 443 | 2.9 | 59.2 | 23,520 |
| Pernambuco | 318 | 305 | 283 | 258 | 273 | -4.6 | 48.7 | 13.982 |
| Other States[1] | 473 | 437 | 477 | 422 | 421 | -2.7 | 47.8 | 22,194 |
| Frontier region | 1,873 | 2,192 | 2,422 | 2,484 | 2,818 | 9.9 | 65.5 | 164,983 |
| Goias | 508 | 616 | 668 | 732 | 868 | 13.2 | 74.8 | 50,123 |
| Mato Grosso do Sul | 351 | 438 | 509 | 547 | 554 | 12.0 | 66.9 | 32,244 |
| Mato Grosso | 187 | 200 | 225 | 241 | 247 | 7.7 | 63.2 | 14,081 |
| Minas Gerais | 656 | 734 | 805 | 763 | 930 | 7.6 | 74.7 | 57,020 |
| Other States[2] | 172 | 204 | 216 | 201 | 220 | 4.9 | 48.0 | 11,514 |

1. Other States in the traditional region are Rio Grande do Sul, Santa Catarina, Espírito Santo, Rio de Janeiro, Ceará, Paraíba, Rio Grande do Norte, and Sergipe.
2. Other States in the frontier region are Bahia, Maranhão, Piauí, Acre, Amazonas, Amapá, Pará, Rondônia, Roraima, and Tocantins.

Source: USDA, Economic Research Service using data from USDA, Foreign Agricultural Service and CONAB (2014).

As a result of gains in yields and area, sugarcane production grew 4.9 percent annually between 1975 and 2014. Brazil is now the world's largest sugarcane producer, accounting for 39 percent of world production (FAO, 2014).

Most distilleries are located in the traditional region of Brazil, where close to three-fourths of all sugarcane is produced. In this region, the State of São Paulo distilled 14.2 billion liters in 2014, producing 46 percent of Brazil's total hydrous ethanol production and 55 percent of Brazil's anhydrous ethanol for blending with gasoline (ANP, 2015). Brazil's newest ethanol-producing area includes the States of Goiás, Mato Grosso do Sul, and Mato Grosso. These frontier region States are at the forefront of westward expansion of agriculture in Brazil. The new investments in sugarcane production and the creation of new distilleries have enabled the frontier region to increase ethanol production 14 percent per year since 2005, nearly tripling the rate of growth for Brazil as a whole over the same period (ANP, 2015).[9]

In 2006-14, Brazil's ethanol production increased rapidly (4 percent per year), reaching a high of more than 28.6 billion liters in 2014 (USDA/FAS, 2015). Between 2006 and 2010, the number of ethanol plants (distilleries and mixed sugar-ethanol mills) in Brazil increased by 84 to 436. However, this trend reversed in 2011, when mills started to reduce investments in fields and capacity use (UNICA, 2013).

With a large sugarcane base able to support both an ethanol and a sugar industry, Brazil has the potential to expand ethanol exports more rapidly than any other country by diverting more sugarcane into ethanol production. However, this potential is constrained by the country's need to satisfy its large domestic sugar and ethanol requirements and by policy initiatives. For example, the main trigger for the historical ethanol expansion in Brazil was the *Proálcool* program; however, as oil prices declined in the late 1980s, the Brazilian Government began to reduce subsidies, discouraging ethanol production. Falling oil prices, rising international sugar prices, and Government efforts to maintain a constant ratio of ethanol to gasoline prices led to ethanol shortages in the 1990s and a drastic reduction in the production of ethanol-only fueled cars (ANFAVEA, 2014). The introduction of flex-fuel cars in 2003 revived hydrous consumption, which increased 6.4 percent annually in 2004-13 (MME/BEN, 2014). Anhydrous consumption increased just 3.3 percent per year over the period as the blending rate of ethanol with gasoline did not sufficiently offset lower gasoline demand (MME/BEN, 2014). In 2010, consumption of hydrous ethanol reached 24.2 billion liters. The slower growth that followed is attributed to poor sugarcane crops, a swing toward sugar production, lower ethanol tax exemptions for consumers, and the holding of gasoline prices below international levels, which requires the State-owned oil company Petrobras to subsidize Brazilian fuel prices (ANP, 2014).

Continued agricultural expansion in the frontier region has limits, as the Government has implemented policies aimed at curbing conversion of land covered by native vegetation to agricultural uses. Since 2009, Brazil's Agricultural Zoning Regulation has tightened the expansion of land used for sugarcane, soybeans, and corn in the frontier region (MAPA, 2013a). To halt the loss of forest land, the Brazilian Government has placed 30 million hectares under Federal protection and over 41 million hectares under sustainable use protection. In addition, both the Amazonia and Cerrado biomes receive varying levels of legal protection from deforestation by means of regulation and

---

[9] Since 2010, 40 sugar-ethanol mills in Brazil have gone out of business, due in part to Government subsidies for gasoline that keep prices low to avoid inflation, reducing ethanol producers' revenues and investments in the sector (UNICA, 2013; FAS/USDA, GAIN Report: BR14004).

enforcement of sustainable land use. The environmental legal framework includes the Forest Code (Código Forestal) and the Environmental Protocol Guidelines, which embody Brazil's approach toward environmentally sustainable food and bioenergy production.[10] The Forest Code establishes farmers' legal responsibility to protect the environment by way of two individual directives: the Legal Forest Reserve (Reserva Legal, or RL) and the Permanent Preservation Area (Proteção de Áreas de Preservação Permanente, or APP). The RL requires rural property owners outside the Legal Amazon region to conserve 20 percent of their native vegetation as uncultivated land. The APP requires farmers in Cerrado areas along the frontier with the Amazon to maintain a legal reserve of 35 percent, and those located in the Legal Amazon (rainforest) are required to conserve 80 percent of the vegetation.

---

[10] Brazil's Soybeans and Cattle Moratoriums—two private-sector initiatives established to reduce deforestation—further enforce compliance by farmers of the country's Forest Code as Brazilian soybean farmers and meat producers must comply with established safeguards for soybeans and cattle sourcing for export.

# Brazil's Crops, Livestock, and Land Use to 2024: Reference Scenario

To assess the impacts of sustained changes in oil prices on Brazil's agricultural land use, regional agricultural production, and trade, we use a dynamic model of Brazilian agriculture in a system of linked models (see box "A Model of Brazilian Agriculture and the Country-Commodity Linked System"). The stand-alone Brazil model includes feed grains (corn, sorghum, barley, and other coarse grains); food grains (wheat and rice); oilseeds (soybeans, other oilseeds, and their meals and oils); other crops (sugarcane and cotton); and animal products (beef, pork, milk, and poultry). The model includes agricultural land, which comprises pasture, arable land, and fallow land. To fully account for the land-use linkages, pasture (classified as either used or degraded[11]) is modeled on a regional basis, as are cattle inventories. To capture differences in crop production and the potential for acreage expansion, regional detail was also added to the sugarcane, soybean, and corn model components, which together account for 90 percent of the country's stock of arable land. The stock of arable land includes fallowed land and a hypothetical continuation of a long-term growth trend in land devoted to permanent crops (perennials). The stock of arable land is rounded out with a multiple cropping index, which measures the number of times a crop is planted on the same plot of land.

In 2006, the year of the most recent agricultural census, Brazil had 160 million hectares of pastureland, of which 10 million hectares were degraded and unsuitable for grazing cattle. Used pasture in the frontier region was estimated at 104 million hectares in 2014, about 2.75 times that in the traditional region. Pasture is the primary source of feed for the 208 million head of cattle in Brazil, although over the last decade, feedlot operations have been gaining market share in the Brazilian beef industry as an option for finishing cattle. In the frontier, the number of fed (confined) cattle was equivalent to 2.3 percent of the total inventory in 2006. Confined feeding is more common in the traditional region but still affects less than 5 percent of the herd. In the frontier, cattle are raised on less-nutrient-dense land, which requires frequent movement onto new pasture. This characteristic of Brazil's beef sector is considered the driving force behind westward land expansion. It has been argued that the increased demand for Brazilian beef drives the expansion of pastures into the agricultural frontier region and the conversion of forest to pasture (Binswanger, 1991; Brandão et al., 2006; and Nassar et al., 2013).

Demand for pasture, as well as constraints on the number of animals that can be supported by the pasture, are reflected in the stocking rate (number of animals per hectare) for each region. Historically, the stocking rate in the traditional region has been higher than in the frontier region, reflecting grazing area constraints and higher land prices (Oliveira, 2010). The stocking rate was estimated from Brazil's agricultural census cattle inventories and used pasture data. In the reference scenario, the frontier region stocking rate increases 2.3 percent annually between 2014 and 2024. In the traditional region, the stocking rate grows at a slower rate (0.6 percent per year) during the same period. The slower growth in the traditional region reflects current land reserve requirements to protect native vegetation and the incorporation of new technologies in beef production systems. Double cropping in Brazil is extensive. In the frontier region in Mato Grosso, first and second corn and soybean

---

[11] Degraded pastures are those with low nitrogen and phosphorus nutrients following a 4- to 10-year period of grazing (Oliveira, 2010). While crop-livestock integration is used as an alternative method of rehabilitating degraded pastures, current legal constraints on conversion of native land to pasture means that maintaining or expanding the size of the cattle herd requires an increase in the stocking rate on nondegraded pasture.

## A Model of Brazilian Agriculture and the Country-Commodity Linked System

The Brazil model is a dynamic, partial-equilibrium, agricultural-sector model covering supply, use, prices, and policies for 27 commodities including wheat, rice, corn, sorghum, barley, other coarse grains, soybeans and their products, other oilseeds and their products, cotton, sugar, ethanol, beef, pork, poultry, milk, and eggs. The model includes assumptions of key macroeconomic variables (income, population, interest rates, and exchange rates), petroleum and fertilizer prices, trade policies (import tariffs), Government policies, production technology, and input prices. The model takes market-clearing world prices as given, both in the historical and projected years. The world prices feed into determination of Brazil's commodity prices, which, in turn, generate supply-and-demand balances for modeled commodities for 10 or more years into the future (see app. 3).

The base year for the Brazil model is crop year 2012/13, which is aligned with calendar year 2013 for macroeconomic and animal product numbers. The stock and use of land for growing crops and rearing livestock also are modeled. The rate of deforestation on nonagricultural land in 2014-24 is assumed to continue at the same pace as was the case in 2005-10 after the Forest Code was enacted. On agricultural land, reforestation on farms is assumed to meet the requirements of the Legal Forest Reserve. With rising forest area on farms, the annual deforestation rate for all forests in Brazil falls from 1.6 million hectares in 2013-14 to 5,000 hectares in 2023/24. In the model, agricultural area is distinct from forest land. That is, the amount of land available for agricultural activities is equal to the total land area less forest land and other land not suitable for agricultural activities (e.g., cities, towns, roads, infrastructure). This effectively excludes the possibility that agricultural activities will encroach on forest land above recent rates. The allocation of land suitable for agricultural activities may vary according to the relative profitability of permanent crops, temporary crops, and cattle rearing and the land stewardship responsibilities of fallowing cropland and rebuilding degraded pastures. Cattle inventories are constrained by stocking rates and the share of pasture that is degraded. The quantity of land available for temporary crops is constrained by that devoted to permanent crops, minimum fallow requirements, and limits on multiple cropping. In the Brazil model, the production of corn, soybeans, and sugarcane, as well as cattle inventories and pasture land, is modeled on a regional basis. Land allocated to crops depends on the expected costs of producing alternative crops relative to the expected revenue for each crop. Expected costs include direct energy-related inputs such as fuel and indirect energy-related input costs such as for fertilizer as well as costs of labor and other production inputs. National average urea, phosphate, and potash fertilizer prices are derived from exogenous world nutrient prices, which are linked to petroleum prices. Regional fertilizer costs for corn, soybeans, sugarcane, and pasture are projected from national average urea, phosphate, and potash fertilizer prices, which are projected from the world oil price. Energy-related production costs for other crops are projected directly from world petroleum prices. In the scenarios implemented for this research, the world petroleum price is increased (decreased) over the 10-year projection period. This generates changes in crop production costs, which alters farmer's expectations of the profitability of alternative crops, leading to

—continued

## A Model of Brazilian Agriculture and the Country-Commodity Linked System—continued

changes in area harvested and cost-induced yield impacts. These supply-side impacts change the allocation of available land to competing crops.

The Brazil model is incorporated into the Country-Commodity Linked System (CCLS), which combines 42 country or region models and determines world equilibrium prices and trade. The CCLS simultaneously clears 24 agricultural commodity markets and enables scenario projections by year for 10 years into the future. As in the Brazil model, the stand-alone country and regional models included in the CCLS take market-clearing world prices as given, both in the historical and projected years. World market-clearing prices are determined by the interaction of country-specific agricultural and trade policies, producer responses to changes in production incentives, and consumer demands for commodities, which yield export supply and import demand. World prices change, generating changes in commodity prices in each country/region, until world export supplies and world import demand are equal. The commodity markets cleared include feed grains (corn, sorghum, barley, and other coarse grains); food grains (wheat and rice); oilseeds and products (soybeans, rapeseed, sunflowerseed, other oilseeds, and the corresponding meals and oils); other crops (cotton and sugar); and animal products (beef and veal, pork, poultry, and eggs). Major exporting and importing countries/regions are included. In the scenario analyses, world oil price changes affect linked models through variables such as fertilizer and processing costs. Additionally, in the Linked System, these countries are allowed to respond to Brazilian market changes.

crops are typical. In the traditional region in São Paulo, common crop rotations are soybeans-corn and soybeans-cotton (Nassar et al., 2008). To incorporate this intensification of crop production and accompanying production gains, the model includes a cropping intensity index in the land-use allocation system. Indeed, recent literature emphasizes the importance of cropping intensity as a factor in correctly predicting adjustments in crop production and land-use practices (Langeveld et al., 2013).

On the basis of soil, climate, and agronomic characteristics, sugarcane competes for land in Brazil's traditional region with soybeans, corn, rice, wheat, and cattle. In the frontier region, sugarcane competes with soybeans, corn, cotton, and cattle. Noncompeting crops in both regions include barley, sorghum, and other oilseeds. To allow for changes in agricultural productivity over time in the model, crop yields rise with expected technological advancements. Land allocation and the competition for land among crops depend on expected returns to alternative agricultural activities, where expected returns (profitability) are a function of input costs and market prices for the end products. Expected variable costs for cattle and each crop depend on input prices. Depending on the commodity, input costs may include the price of petroleum, the minimum wage, the real interest rate, and the price of fertilizer.[12] The petroleum price is included to capture energy-dependent costs such as trans-

---

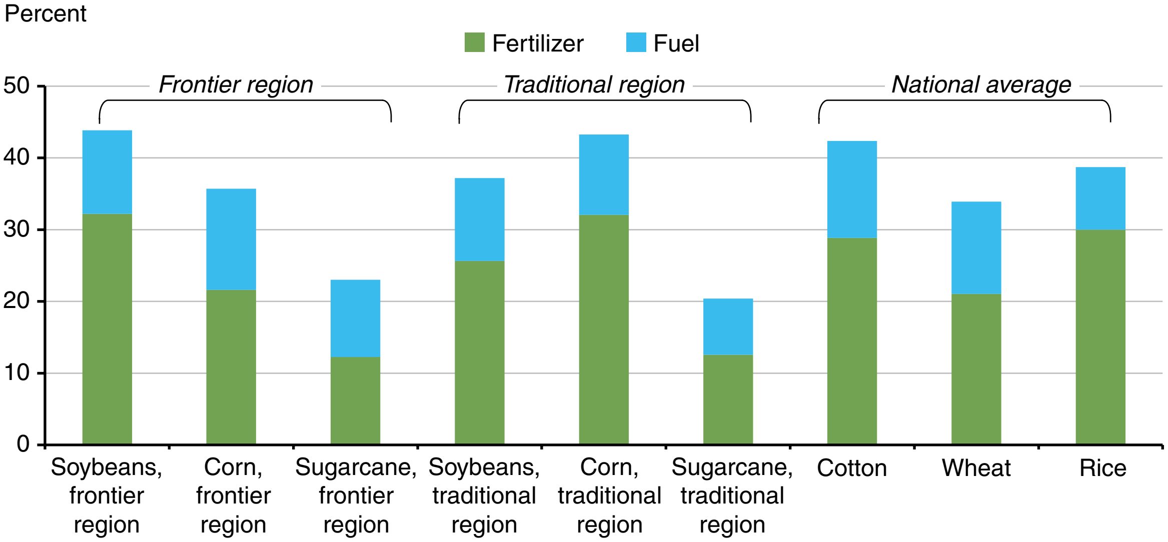
[12] About 60 percent of the intermediate raw materials used for the production of fertilizers in Brazil are imported, and large shares of compound fertilizers come from imports (73 percent for nitrogen, 34 percent for phosphate, and 92 percent for potash), so changes in the oil price will directly affect farm-level costs (ANDA, 2014).

portation and operation of machinery. Other input costs are estimated from the minimum wage,[13] which represents labor costs, and the general price index, which captures the cost of non-energy-related inputs such as storage and insurance. In the case of sugarcane, major production costs include fertilizer and labor. The share of fuel and fertilizers in total operating costs differs across crops and regions, reflecting soil and climatic conditions, as well as the scale of production and farmers' production practices. Corn, rice, and cotton are impacted the most when nutrient prices change, as these three crops are the largest consumers of nitrogen and phosphates. The composition of fertilizers used differ across the frontier and traditional regions (fig. 5). Soybeans in the frontier region and corn in the traditional region have the highest share of energy-related inputs and fertilizer use (30 percent), followed by rice and cotton. Fertilizer costs account for 25 percent of total operating costs for soybeans in the traditional region and 21 percent for corn in the frontier and, on a national basis, wheat. Fertilizer expenses for sugarcane average 12 percent in both regions (CONAB, 2014a).

The area elasticities with respect to expected returns in the traditional region are 0.35, 0.25, and 0.20 for sugarcane, soybeans, and corn producers, respectively, and 0.25, 0.28, and 0.28 for the same commodities in the frontier region.[14] With more available land, producers in the frontier region have the highest response to changes in agricultural returns for soybeans and corn. In contrast, producers in the traditional region have very little additional land that can be converted to agricultural

Figure 5

**Energy input costs as a share of variable costs for crops, 2013-14**



Source: USDA, Economic Research Service using data from CONAB, Cost of Production Estimates in 2013/14.

---

[13] The minimum wage is the benchmark for agricultural wages in Brazil; 75 percent of farmworkers earn at least a minimum wage, and 25 percent of agricultural (temporary) workers earn half of the minimum wage (DIIESE, 2014).

[14] Area elasticities for sugarcane are based on research conducted under ERS's Cooperative Agreement with Centro de Estudos Avançados em Economia Aplicada, CEPEA (see Burnquist et al., 2013). Values for other elasticities and parameters in the model are taken from studies conducted by ERS and others, as well as other models such as SWOPSIM, Organization for Economic Co-operation and Development's AgLink, and the Food and Agricultural Policy Research Institute's model. The elasticities and parameters in the ERS Brazil Baseline Projections Model are reviewed each year and revised or updated as structural changes occur in Brazil's agricultural sector.

uses, which results in lower area elasticities. In the case of sugarcane, the area elasticity is higher in the traditional region, where most sugarcane mills are located.

In the reference scenario, production costs and prices for sugarcane, soybeans, and corn vary by region, while yields vary with technological advances and costs of yield-enhancing inputs, including fertilizers. In the case of sugarcane, principal costs of production include fertilizers and labor; regional producer prices are the unit values of production calculated from Brazilian Institute of Geography and Statistics (IBGE) data. The domestic demand specification includes food, feed, industrial uses, and ending stocks for the commodities included in the model. The model is solved at the national level, but production of sugarcane, soybeans, corn, and cattle is solved for each region separately on the basis of regional prices and costs. Capital costs, which are a major component of commodity costs, are accounted for in the model using interest rates. Transport premiums arising from below-market fuel prices are also incorporated in the costs of production, and producer prices used in the model account for the minimum price supports provided by the Government.

## Ethanol Sector

All gasoline sold in Brazil is a blend of pure gasoline A and anhydrous ethanol. Thus, the model's gasoline price is endogenously determined from the price of crude oil and the price of anhydrous ethanol. The model includes an alcohol blend rate, which affects demand for hydrous ethanol due to its competition with gasoline in powering flex-fuel cars.  The alcohol blend rate is projected from a composite of the producer price of sugar and anhydrous ethanol. Flex-fuel car inventories depend on relative prices of fuels (ethanol and gasoline) and income growth.

In Brazil, higher oil prices are only partially transmitted to the domestic market because the Brazilian energy firm Petrobras sells gasoline below cost at Government-set prices to shield motorists from crude prices that more than doubled between 2009 and 2013.[15] The USDOE's overall assumptions for the reference oil-price projections incorporate current laws and regulations for crude oil production and trade and expectations for growth in income, population, labor, capital, and productivity (USDOE/AEO, 2014). Figure 6 compares the global oil price and Brazil's gasoline and ethanol prices. When the gasoline price has risen above that which would occur without Government intervention, consumers have tended to favor hydrous ethanol. Similarly, when the gasoline price has been kept below market prices, consumers have favored gasoline consumption at the expense of hydrous ethanol (Burnquist et al., 2013).

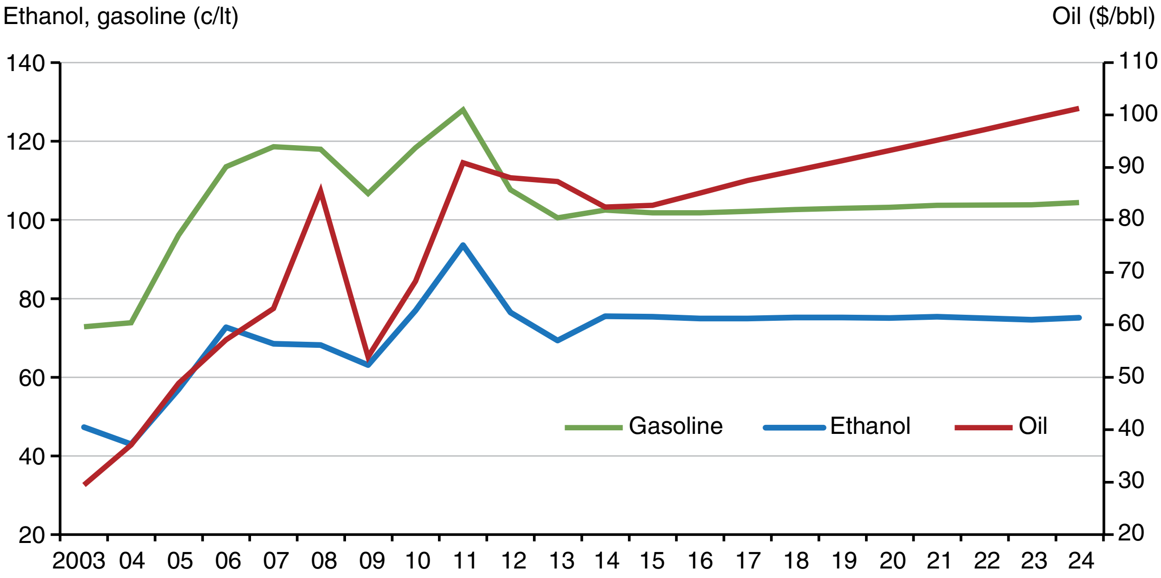
In the reference scenario, important assumptions underlie Brazil's ethanol projections, including continuous economic growth, longer run increases in oil and gasoline prices, and growing demand for flex-fuel cars. These factors influence projected prices for ethanol (determined by flex-fuel car demand, ethanol stocks, and the consumer price of gasoline) and projected prices for gasoline (influenced by changes in crude oil prices and the price of hydrous ethanol). They also yield the price projections shown in figure 6. Policy incentives include the historical mandate for the use of renewable fuels in gasoline and tax exemptions for ethanol. These factors combine to maintain demand for ethanol and support increases in domestic consumption and trade.

---

[15] For example, in October 2013, the Brazilian Government increased the ex-refinery gasoline price by about 8 percent, which only translated into a 4-percent increase in the consumer price of gasoline (LMC, 2013).

Figure 6

**Brazil's historical and projected ethanol and gasoline prices, and world oil prices**



Source: USDA, Economic Research Service using data from Brazil's National Petroleum, National Gas, and Biofuels Agency, LMC (2013), and research results.

USDA's long-term projections to calendar year 2024 reflect the continuing expansion of the ethanol sector in Brazil. Based on an ERS-derived projection for Brazil, under the reference scenario, sugarcane area is projected to increase from 8.8 million hectares in 2014 to 11 million hectares in 2024, with most of the expansion in the traditional sugarcane-producing region where expected returns to production are higher.

Brazil's ethanol exports are expected to reach 4.3 billion liters by 2024; to meet domestic and foreign demand for fuel ethanol, ethanol production is projected to rise from nearly 29 billion liters in 2014 to 41.5 billion liters by 2024 (table 2 and fig. 7).

Table 2

**Brazil's sugarcane, sugar, and ethanol in the reference scenario**

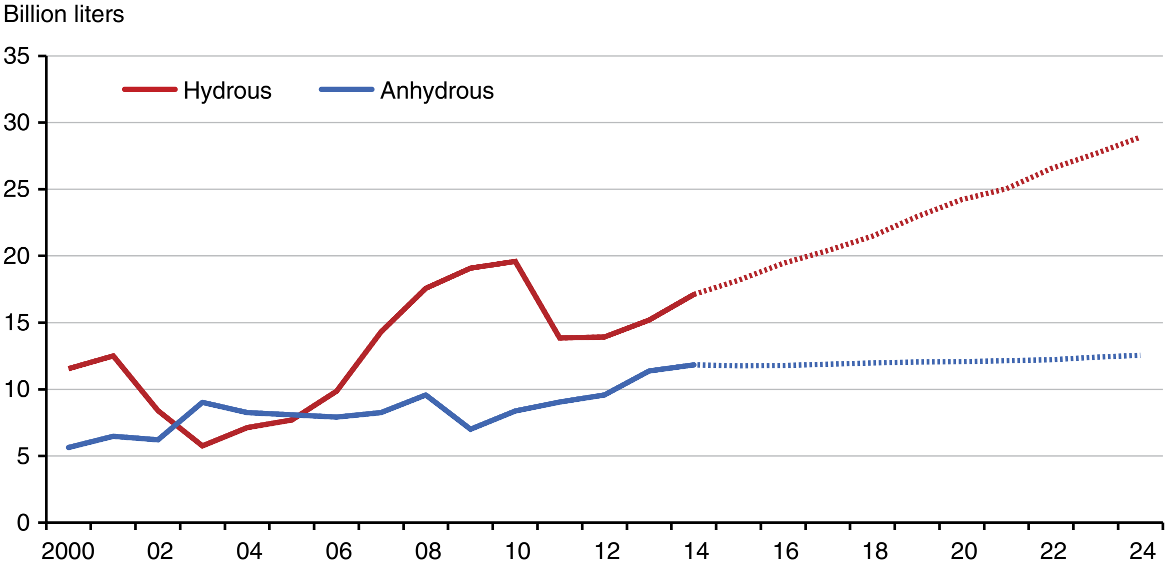
| | Units | 2014 | 2017 | 2020 | 2024 | Annual growth rate, 2014-24 |
|---|---|---|---|---|---|---|
| Sugarcane production: | | | | | | |
| Traditional agricultural region | Mil. tons | 469.1 | 551.7 | 595.0 | 670.2 | 3.4% |
| Frontier agricultural region | Mil. tons | 170.9 | 204.4 | 222.1 | 247.7 | 3.6% |
| Sugar production | Mil. tons | 40.4 | 47.8 | 50.8 | 57.4 | 3.3% |
| Ethanol production | Bil. liters | 28.9 | 32.3 | 36.3 | 41.5 | 3.7% |
| Hydrous ethanol | Bil. liters | 17.1 | 20.4 | 24.2 | 28.9 | 5.4% |
| Anhydrous ethanol | Bil. liters | 11.8 | 11.9 | 12.1 | 12.6 | 0.6% |
| Ethanol exports | Bil. liters | 3.7 | 3.3 | 3.9 | 4.3 | 3.1% |
| Ethanol imports | Bil. liters | 0.3 | 0.3 | 0.3 | 0.4 | 5.3% |
| Ethanol consumption | Bil. liters | 26.1 | 29.3 | 32.5 | 37.8 | 3.6% |
| Hydrous ethanol | Bil. liters | 14.2 | 17.5 | 20.4 | 25.2 | 5.6% |
| Anhydrous ethanol | Bil. liters | 11.8 | 11.9 | 12.1 | 12.6 | 0.6% |

Note: Ethanol stocks are not included in the table.

Source: USDA, Economic Research Service, based on analysis from the Country Commodity Linked System model.

Figure 7

**Brazil's ethanol production in the reference scenario**



Note: Dashed lines are projections.
Source: USDA, Economic Research Service using data from Brazil's National Petroleum, Natural Gas, and Biofuels Agency and Research Results.

# High- and Low-Oil-Price Scenarios: Brazilian Prices and Production

Table 3 shows Brazilian production and price projections for commodities in the reference scenario and the high- and low-oil-price scenarios. In the high-oil-price scenario, the petroleum price rises 40 percent in 2015 and then another 7 percent in 2016. After that, the increase relative to the base remains roughly constant, averaging 45 percent (see fig. 2). The magnitudes of the changes in the low-oil-price scenario are smaller than in the high-oil-price scenario. In the low-oil-price scenario, the petroleum price falls 18 percent in 2015, followed by 6-percent declines in each of the next 2 years and 1-percent declines in 2018-24.

The demand for biofuels is inexorably linked to demand for petroleum because biofuels and petroleum are fuel substitutes and petroleum is also a key input in crop production. In the high-oil-price scenario, price increases begin in 2016 (compared to 2019 in the low-oil-price scenario), leading to changes in returns, crop choices, and area, much earlier in the projection period. In the high-oil-price scenario, arable land use falls earlier than in the low-oil-price scenario but recovers as ethanol production expands.

Compared to the reference scenario, high oil prices result in an increase in sugarcane and ethanol prices and production, while low oil prices result in relatively lower sugarcane and ethanol prices and production. Under the high-oil-price scenario, sugarcane output rises to an average of 814 million tons over 2015-24, which yields an average of 25 billion liters of ethanol per year over the same period (table 3). In the low-oil-price scenario, production costs decline significantly and the resulting increase in supply further reduces prices, leading to declining returns to production, particularly for sugarcane. As crop area increases, cattle operations are pushed westward. The new land is more fragile and of lower productivity, which gives producers incentive to intensify stocking rates on previously used land. As stocking rates rise, pasture degrades, which over 10 years, reduces pasture by more than 2.5 million hectares. Returns to cattle production rise in the low-oil-price scenario because fuel and pasture-related expenses fall, which encourages producers to increase inventories. In both the high- and low-oil-price scenarios, the largest changes are for ethanol.

Table 3

**Change in prices, area, and production relative to the reference scenario, 2015-24**

| | | Producer price Average, 2015-24 | | | Change from reference (%) Average, 2015-24 | |
|---|---|---|---|---|---|---|
| Commodities | | Reference scenario | High-oil-price scenario | Low-oil-price scenario | High-oil-price scenario | Low-oil-price scenario |
| Sugarcane | $/ton | 20.5 | 20.8 | 19.7 | 1.78 | -3.58 |
| Soybeans | $/ton | 183.7 | 183.6 | 183.4 | -0.06 | -0.20 |
| Corn | $/ton | 110.7 | 114.4 | 108.0 | 3.33 | -2.48 |
| Cotton | $/ton | 1,185.8 | 1,212.4 | 1,165.4 | 2.28 | -1.75 |
| Wheat | $/ton | 143.2 | 146.8 | 141.1 | 2.59 | -1.49 |
| Rice | $/ton | 142.9 | 145.9 | 140.4 | 2.11 | -1.74 |
| Cattle | $/ton | 2,344.9 | 2,341.6 | 2,346.7 | -0.14 | 0.08 |
| Sugar | $/ton | 142.2 | 144.2 | 138.0 | 1.42 | -2.95 |
| Ethanol | ¢/liter | 42.6 | 43.4 | 36.2 | 1.96 | -14.84 |

| | | Area harvested Average, 2015-24 | | | Change from reference (%) Average, 2015-24 | |
|---|---|---|---|---|---|---|
| Commodities | | Reference scenario | High-oil-price scenario | Low-oil-price scenario | High-oil-price scenario | Low-oil-price scenario |
| Sugarcane | Mil. ha | 10.2 | 10.3 | 9.8 | 0.92 | -3.78 |
| Soybeans | Mil. ha | 32.6 | 32.5 | 32.7 | -0.04 | 0.29 |
| Corn | Mil. ha | 16.1 | 16.0 | 16.2 | -0.54 | 0.90 |
| Cotton | Mil. ha | 1.3 | 1.2 | 1.3 | -0.92 | 0.69 |
| Wheat | Mil. ha | 2.1 | 2.1 | 2.2 | -1.35 | 1.85 |
| Rice | Mil. ha | 2.4 | 2.4 | 2.5 | -0.97 | 1.16 |
| Pasture for cattle | Mil. ha | 136.3 | 136.4 | 136.1 | 0.04 | -0.19 |
| Cane milled for sugar | Mil. ha | 4.4 | 4.3 | 4.5 | -1.53 | 1.76 |
| Cane milled for ethanol | Mil. ha | 5.8 | 5.9 | 5.3 | 2.82 | -8.03 |

| | | Production Average, 2015-24 | | | Change from reference (%) Average, 2015-24 | |
|---|---|---|---|---|---|---|
| Commodities | | Reference scenario | High-oil-price scenario | Low-oil-price scenario | High-oil-price scenario | Low-oil-price scenario |
| Sugarcane | Mil. tons | 806.4 | 814.1 | 774.9 | 0.93 | -3.77 |
| Soybeans | Mil. tons | 103.3 | 103.0 | 103.8 | -0.29 | 0.46 |
| Corn | Mil. tons | 83.0 | 82.5 | 83.8 | -0.62 | 0.97 |
| Cotton | Mil. tons | 2.3 | 2.3 | 2.3 | -1.36 | 1.06 |
| Wheat | Mil. tons | 5.3 | 5.2 | 5.4 | -1.68 | 2.19 |
| Rice | Mil. tons | 8.7 | 8.7 | 8.8 | -0.71 | 0.85 |
| Beef | Mil. tons | 10.9 | 10.8 | 11.0 | -0.19 | 0.38 |
| Sugar | Mil. tons | 50.6 | 50.0 | 51.1 | -1.18 | 1.10 |
| Ethanol | Bil. liters | 23.5 | 25.1 | 20.2 | 7.19 | -13.33 |

Ha=hectares. Source: USDA, Economic Research Service, research results.

# High-Oil-Price Scenario

The impact of high petroleum prices on ethanol production and agriculture in Brazil would come first through a reduction of the quantity of imported crude oil and gasoline production. Some crude oil would also be displaced by ethanol for flex-fuel cars as consumers would respond to increases in the price of gasoline. A second effect of higher oil prices on agricultural production would come from the higher costs of energy-intensive inputs, especially fertilizers.

## Ethanol and Sugarcane Sector Impacts

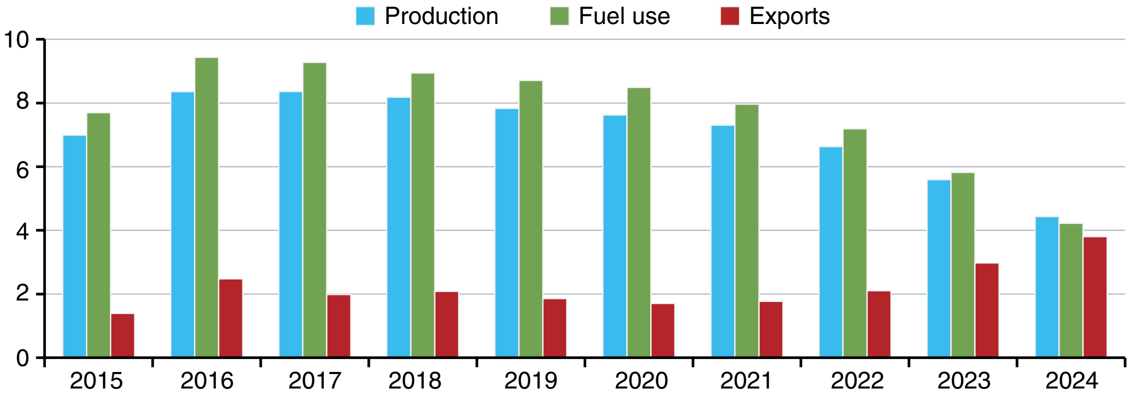
Under the high-oil-price scenario, gasoline prices in Brazil increase and gasoline use declines relative to the reference levels by an average of 5.2 percent per year through 2024. As gasoline demand weakens, demand for hydrous ethanol increases 8 percent annually and an additional 15.2 billion liters of hydrous ethanol are consumed in 2015-24 relative to the reference scenario. Under the same scenario, anhydrous ethanol demand drops as consumers switch from gasoline to hydrous ethanol. The initial 40-percent increase in the world petroleum price in 2015 followed by a sustained increase of 45 percent above reference oil prices through 2024 leads to a more rapid increase in ethanol demand and production in the earlier years of the period, with fuel use and production rising at a slower rate after 2020 (fig. 8). To meet domestic and export demand, total ethanol production increases by nearly 10 billion liters over 2015-24 under the high-oil-price scenario. Brazil's exports of 4.5 billion liters in the year 2024 are 3.8 percent higher than in the reference scenario.

Higher ethanol demand in 2015-24 increases the price of sugarcane by about 1.8 percent per year. With higher sugarcane prices and less energy-intensive inputs relative to those used for competing crops, sugarcane producers see higher returns and increased incentives to expand cultivated sugarcane area. As a result, nearly 1 million additional hectares are planted to sugarcane over the projection period. Note that the total sugarcane area of 11.1 million hectares in 2024 reflects a doubling of the area expansion rate during 2015-24 in the high-oil-price scenario, compared with the historical 2010-14 period. While increases in sugarcane area occur in both the traditional and frontier regions,

Figure 8

**Impact of high oil price on Brazil's ethanol production, fuel use, and exports**

Percent differences from reference scenario



Source: USDA, Economic Research Service, research results.

the traditional region accounts for nearly 70 percent of the additional land brought into production. The additional hectares planted to sugarcane in both regions include former pasture land, land previously planted to other temporary crops, and fallow land brought back into cultivation. Over the period, sugarcane production increases by more than 7.5 million tons per year (0.9 percent) (average over 2015-24) to 926 million tons in 2024 (see table 3).

## Agricultural Returns and Land Use Impacts

As higher oil prices lead to an increase in the land used for sugarcane production, competition for available agricultural land intensifies, and farmers in both regions respond by making adjustments in the location and magnitude of crop and livestock production. This effect, which is derived from changes in relative prices, will cause displacement of competing crops to other land in each region (indirect land-use impact). In addition, these crops will respond to changes in production costs as oil prices rise. Along with fuel costs, fertilizer costs can influence commodity production outcomes. In the high-oil-price scenario, the domestic prices of urea and phosphate rise by an average of 5.5 and 5.1 percent, respectively, while the price of potash rises, on average, by 6.8 percent in 2015-24. Corn, rice, and cotton production are affected the most by high crude prices, as these three crops are large consumers of nitrogen and phosphates (ANDA, 2014). With high oil prices in 2015-24, producer returns to corn in the frontier region fall an average of nearly 7 percent annually through 2024. This reduced incentive to produce corn leads to a cumulative decline in area of 1.2 million hectares during 2015-24. In the traditional region, where about 5 percent of cattle are in feedlots, continued feed demand keeps returns to corn positive. As a result, corn area increases 0.5 percent annually between 2015 and 2024. During the same period, soybean returns in both regions fall but by a much smaller rate (less than 1 percent annually) than those of corn. Soybean area rises by an annual average of 0.5 million hectares in the frontier region but falls by 0.6 million hectares in the traditional region. The average percentage change in area of other crops is greater than that of corn but from a much smaller base. The decline in production leads to higher producer prices of most minor commodities. However, the producer price increases are not enough to compensate for higher cultivation costs and, therefore, overall producer returns are reduced for those commodities as well.

Following the shock of high oil prices, the higher cost of production and lower returns for most crops lead to a decline in agricultural area (72,000 hectares, average over 2016-20). After 2020, increasing prices and returns lead to a cumulative addition of 293,000 hectares of land being used for agricultural activities in Brazil. The gain in used agricultural area includes nearly 27,000 hectares per year of fallow land and nearly 15,000 hectares of previously degraded pastureland brought back into production. As sugarcane production becomes more profitable, the price of cropland increases in the traditional region, thereby increasing the incentive to use pastureland in the frontier region. As a consequence, 54,000 hectares per year (average over 2015-24) are brought into cattle ranching in the frontier region (table 4).

## Production and Trade Impacts

With higher prices for feed grains, domestic feed demand is lower by an average of 0.4 percent, and poultry production is affected more than pork production. Since Brazil is a major global producer, consumer, and exporter of cereal grains, soybeans, and meats, lower production leads to higher world prices for most commodities in the high-oil price scenario (table 5). And, as Brazil is the world's largest exporter of sugar (46 percent of the global market), the fall in Brazil's sugar exports leads to higher world sugar prices, averaging $4.4 per ton higher over 2015-24, which further drive

Table 4

**Change in agricultural land use under high-oil-price scenario, 2015-24 average**

| | Average annual change | |
|---|---|---|
| | *1,000 hectares* | *Percent* |
| Used pasture: Frontier region | 53.7 | 0.100 |
| Used pasture: Traditional region | -1.1 | -0.002 |
| Degraded pasture: Frontier region | -14.9 | -0.100 |
| Degraded pasture: Traditional region | -2.1 | -0.100 |
| Fallow lands (fallowed less than 4 years) | -27.1 | -0.300 |

Source: USDA, Economic Research Service, research results.

Table 5

**Change in world reference prices under high-oil-price scenario, 2015-24 average**

| | *Percent* | *Dollars per ton* |
|---|---|---|
| Sugar | 1.20 | 4.43 |
| Soybeans | -0.16 | -0.52 |
| Corn | 3.96 | 4.74 |
| Cotton | 2.66 | 34.42 |
| Wheat | 3.08 | 4.92 |
| Rice | 3.25 | 11.69 |
| Soybean oil | 8.88 | 56.85 |
| Soybean meal | -4.50 | -14.24 |
| Beef | -0.38 | -5.81 |

Source: USDA, Economic Research Service, research results.

the expansion of sugarcane. Given the increase in ethanol production in the scenario, Brazil's sugar production and sugar exports are down by an annual average of 1.18 percent and 1.48 percent, respectively, over the period (table 3 and table 6). The reduction in Brazilian sugar exports is mostly offset by growth in sugar exports from Australia, India, and Ukraine.

Soybeans remain the single most important commodity for the Brazilian economy in this scenario despite a decline in exports (averaging 0.3 percent lower over 2015-24), which benefits soybean exports from Argentina and the Ukraine. A slowdown in demand for Brazilian soybeans, particularly from China (down an average of 0.4 percent), is partially offset by increased demand from Thailand (up 0.6 percent) and the EU (up 0.04 percent). Global soybean oil prices rise enough (up an average of 8.9 percent) in the scenario to encourage the United States to crush more soybeans into oil and meal and, therefore, export less soybeans (averaging 0.46 percent lower over 2015-24). Higher corn prices in the United States (up an average of 3.56 percent) and increasing ethanol demand trigger lower U.S exports of corn and higher use of corn for ethanol production. Since Brazilian cotton prices are projected to be greater than international prices, Brazilian cotton exports decline an average of 2.42 percent over the period. India—the world's second-largest cotton producer—is projected to increase cotton exports by an average of 23.8 percent, as China's import demand increases (up 5.3 percent). Marginal declines in beef exports from the United States and, to a lesser extent, Brazil and Canada are more than offset by shipments from Argentina (up 5.36 percent).

Table 6

**Change in exports under high-oil-price scenario, 2015-24 average**

| Exporter | Sugar | Soybeans | Corn | Cotton | Wheat | Rice | Beef |
|---|---|---|---|---|---|---|---|
| | | | | *1,000 tons* | | | |
| Brazil | -540.8 | -155.1 | -182.5 | -26.2 | 2.9 | -44.1 | -6.6 |
| United States | n.a. | -215.6 | -2,895.9 | -244.5 | -2,826.4 | -208.8 | -14.6 |
| Argentina | -2.9 | 94.6 | 132.2 | n.a. | -347.9 | 30.7 | 15.1 |
| Canada | n.a. | -38.3 | n.a. | n.a. | 246.8 | n.a. | -2.8 |
| European Union | n.a. | n.a. | 57.5 | n.a. | 513.5 | n.a. | 0.4 |
| Australia | 24.7 | n.a. | n.a. | 5.6 | 141.8 | 4.2 | -0.1 |
| India | 8.1 | n.a. | 139.4 | 374.2 | n.a. | n.a. | -8.9 |
| Ukraine | 1.5 | 8.6 | 799.3 | n.a. | 729.4 | n.a. | n.a. |
| Russia | n.a. | n.a. | 192.6 | n.a. | -685.0 | n.a. | n.a. |
| | | | | *Percent* | | | |
| Brazil | -1.48 | -0.29 | -1.14 | -2.42 | 0.42 | -3.84 | -0.28 |
| United States | n.a. | -0.46 | -5.46 | -10.00 | -9.77 | -5.68 | -1.13 |
| Argentina | -0.69 | 0.71 | 0.57 | n.a. | -4.74 | 4.77 | 5.36 |
| Canada | n.a. | -0.99 | n.a. | n.a. | 1.26 | n.a. | -0.61 |
| European Union | n.a. | n.a. | 2.0 | n.a. | 1.87 | n.a. | 0.16 |
| Australia | 0.75 | n.a. | n.a. | 0.51 | 0.75 | 0.83 | -0.01 |
| India | 1.16 | n.a. | 5.52 | 23.8 | n.a. | n.a. | -0.38 |
| Ukraine | 0.72 | 0.34 | 3.95 | n.a. | 6.21 | n.a. | n.a. |
| Russia | n.a. | n.a. | 9.23 | n.a. | -3.01 | n.a. | n.a. |

Note: n.a. = not applicable.
Source: USDA, Economic Research Service, research results.

# Low-Oil-Price Scenario

We also examine the implications of USDOE's low-oil-price projections for 2015-24. In the advent of significantly lower crude oil prices and lower gasoline prices, the demand for ethanol in Brazil and the rest of the world falls, as do agricultural input costs.

## Ethanol and Sugarcane Sector Impacts

As oil prices fall, the cost of importing gasoline falls below Brazil's domestic price. Gasoline prices in Brazil fall by 17.2 percent per year, on average, in the scenario while gasoline use in Brazil increases by an average of 1.7 percent per year relative to the reference scenario. As gasoline demand rises, the blend rate increases consumption of anhydrous ethanol by 2.4 percent per year on average, while demand for hydrous ethanol falls by an average of 16 percent annually between 2015 and 2024. These demand changes lead to a shift in sugarcane mills' output and investment strategies, with total sugarcane used for ethanol production decreasing during the projection period.

Hydrous ethanol production in Brazil declines 13 percent per year through 2024 (3.2 billion liters per year on average over the 10-year period) (see table 3). With the large decline in Brazil's domestic demand for hydrous ethanol, Brazil's exports of 4.4 billion liters in the year 2024 are 3.2 percent higher than in the reference scenario. Lower ethanol demand lowers the price of sugarcane by about 3.6 percent per year. With lower sugarcane prices, returns to sugarcane production in Brazil fall about 10 percent annually, resulting in a 3.8-percent per year decline in sugarcane area. The traditional area accounts for 80 percent of the decline in sugarcane area.

## Agricultural Returns and Land Use Impacts

During the projection period (2015-24), the reduction in sugarcane area frees up nearly 4 million hectares for other agricultural activities, changing the composition of crop and livestock production. In Brazil, lower energy costs enhance producer returns and favor expansion of annual crops, especially soybeans and corn. Lower oil prices result in lower production costs for agriculture. The magnitude of the cost reductions for individual commodities depends on the share and composition of energy-related inputs used in production. Consequently, production costs decline more for cotton (down 6.5 percent), rice (down 5.8 percent), wheat (down 5.4 percent), and corn (down 5.1 percent) than for soybeans (averaging 0.6 percent lower over 2015-24). The largest land-use impact in the low-oil-price scenario is an increase of 1.5 million hectares in corn in Brazil's frontier region, resulting in a cumulative production increase of 8 million tons over the 10-year period. The expansion of corn area reflects the more rapid growth in nitrogen and potash fertilizer demand from second-crop corn cultivation in Brazil's frontier region (MAPA, 2013a). Soybean area in the traditional region rises about 1 million hectares over the 10-year period, yielding an additional 5 million tons of soybeans. The expansion in area planted to cotton, wheat, rice, and other coarse grains accounts for an additional 940,000 hectares of area previously under sugarcane cultivation. An increase of 335,000 hectares of fallow land account for the remaining freed-up sugarcane area.

As pasture-related expenses fall in the low-price scenario, returns to cattle increase and producers increase inventories and intensify grazing. With increasing returns for cattle operations, stocking rates increase 2.5 percent annually in the frontier region between 2015 and 2024 and at a slower 0.7 percent annually in the traditional region. Cattle inventories in the frontier increase over 1 million head each year between 2015 and 2024, which increases degraded pasture by an average of 100,000 hectares each year. Total land used for crops and livestock actually declines due to a combination of double cropping and a 0.3-percent increase per year, on average, in fallowed land (table 7).

## Production and Trade Impacts

Lower oil prices lead to lower production of sugarcane (down nearly 32 million tons per year, on average, over 2015-24). Annual agricultural production of other crops increases in response to lower production costs: corn, up 8 million tons; soybeans, up 5 million tons; wheat, up 1.2 million tons; rice, up 752,000 tons; sorghum, up 557,000 tons; cotton, up 251,000 tons; and barley, up 35,000 tons. With lower prices for corn (-2.5 percent), sorghum (-0.5 percent), and soybeans (-0.2 percent) and only moderately higher prices for barley (0.4 percent), livestock feed costs in Brazil decrease in the low-oil-price scenario. As a result, domestic feed demand increases by an average of 0.3 percent per year, which stimulates annual poultry and pork production by 1.2 percent and 1 percent, respectively, over the 10-year period.

With lower energy costs, economic incentives encourage increased plantings and higher production of grains and oilseeds in Brazil and in other countries around the world, which leads to lower world prices (table 8). For corn, the combined influence of higher corn production and exports from Brazil and higher corn production and exports from the United States—the world's largest corn producer and exporter—results in a 2.94-percent reduction in the world corn price. In the United States, corn production increases an average of 2.41 percent in 2015-24 and exports increase by 2 million tons (up 3.82 percent). Higher world reference prices for beef reflect increased demand from Russia, averaging 3.89 percent per year higher over 2015-24.

Table 7

**Change in agricultural land use under low-oil-price scenario, 2015-24 average**

| | Average annual impact | |
|---|---|---|
| | *1,000 hectares* | *Percent* |
| Used pasture: Frontier region | -179.9 | -0.2 |
| Used pasture: Traditional region | -69.3 | -0.2 |
| Degraded pasture: Frontier region | 101.6 | 0.9 |
| Degraded pasture: Traditional region | 12.1 | 0.7 |
| Fallow lands (fallowed less than 4 years) | 33.5 | 0.3 |

Source: USDA, Economic Research Service, research results

Table 8

**Change in world reference prices under low-oil-price scenario, 2015-24 average**

| | *Percent* | *Dollars per ton* |
|---|---|---|
| Sugar | -1.00 | -3.71 |
| Soybeans | -0.22 | -0.69 |
| Corn | -2.94 | -3.54 |
| Cotton | -2.06 | -26.76 |
| Wheat | -1.75 | -2.81 |
| Rice | -2.65 | -13.52 |
| Soybean oil | -7.16 | -45.49 |
| Soybean meal | 3.11 | 9.79 |
| Beef | 0.18 | 2.73 |

Source: USDA, Economic Research Service, research results.

The effects of lower oil prices benefit agricultural exports from the United States more than exports from other countries, particularly exports of U.S. corn and wheat (table 9). Sugar exports from Brazil (up 1.3 percent per year, or 461,000 tons) increase more than sugar exports from other countries. Brazil's corn exports rise 3.2 percent per year (609,000 tons), and its soybean exports increase by 0.5 percent per year (277,000 tons).

Table 9

**Change in exports under low-oil-price scenario, 2015-24 average**

| Exporter | Sugar | Soybeans | Corn | Cotton | Wheat | Rice | Beef |
|---|---|---|---|---|---|---|---|
| | | | | *1,000 tons* | | | |
| Brazil | 461.2 | 276.9 | 609.4 | 21.8 | -1.77 | 58.9 | 10.1 |
| United States | n.a. | 102.7 | 2,047.0 | 198.9 | 2,308.8 | 152.3 | 12.5 |
| Argentina | 2.7 | -201.7 | 9.4 | n.a. | 373.1 | -26.5 | 2.3 |
| Canada | n.a. | 29.7 | n.a. | n.a. | -172.6 | n.a. | 1.4 |
| European Union | n.a. | n.a. | -48.6 | n.a. | -328.0 | n.a. | -0.3 |
| Australia | -20.5 | n.a. | n.a. | -4.6 | -86.0 | -3.6 | 0.1 |
| India | -7.3 | n.a. | -99.4 | -343.4 | n.a. | n.a. | 4.2 |
| Ukraine | 0.6 | -12.7 | -759.6 | n.a. | -654.5 | n.a. | n.a. |
| Russia | n.a. | n.a. | -470.8 | n.a. | 35.8 | n.a. | n.a. |
| | | | | *Percent* | | | |
| Brazil | 1.27 | 0.50 | 3.20 | 1.89 | -0.26 | 5.30 | 0.41 |
| United States | n.a. | 0.22 | 3.82 | 8.12 | 7.94 | 4.13 | 0.94 |
| Argentina | 0.67 | -1.46 | 0.08 | n.a. | 5.06 | -4.04 | 0.79 |
| Canada | n.a. | 0.76 | n.a. | n.a. | -0.88 | n.a. | 0.31 |
| European Union | n.a. | n.a. | -1.66 | n.a. | -1.17 | n.a. | -0.13 |
| Australia | -0.62 | n.a. | n.a. | -0.4 | -0.45 | -0.70 | 0.01 |
| India | -1.04 | n.a. | -4.02 | -20.7 | n.a. | n.a. | 0.18 |
| Ukraine | -0.03 | -0.49 | -3.83 | n.a. | -5.44 | n.a. | n.a. |
| Russia | n.a. | n.a. | -21.74 | n.a. | 0.16 | n.a. | n.a. |

n.a. = not applicable.

Source: USDA, Economic Research Service, research results.

# Conclusion

This study examines the effects of changes in crude oil prices on Brazil's ethanol sector, agriculture, and associated land use. We examine commodity interactions in Brazil for grains, oilseeds, livestock, sugarcane, and energy (ethanol and gasoline) and estimate the impact of changes in ethanol production on the regional distribution of sugarcane production, other temporary crops production, and cattle ranching. The use of regional data enables one to evaluate the degree to which sugarcane displaces soybeans, corn, other temporary/permanent crops, and meat production. It also allows for analysis of the degree to which pastureland expands or contracts to accommodate expansion of crop production.

Higher oil and petroleum prices would likely reduce domestic gasoline demand in Brazil, resulting in higher ethanol use through a higher blending rate and increased demand for ethanol and sugarcane. Agricultural producers in Brazil respond to this higher demand by altering their land-use decisions in response to annual rates of return for crops and cattle ranching for beef production. Higher prices for fertilizer and diesel fuel raise the cost of production for all crops, but the largest increases in variable costs are for crops that use more energy-related inputs: corn, rice, and cotton. The resulting decline in crop production, with the exception of sugarcane, leads to higher prices over the projection period, providing some gains in revenues from crop sales, which partially offset the lower returns to production. Arable land expands by 6.9 million hectares in the high-oil-price scenario, reaching 73.6 million hectares by 2024. The expansion includes an average annual net addition of 27,100 hectares of fallow land brought into crop production, compared with the reference scenario.

The expansion in ethanol production in this scenario leads to an increase in area planted to sugarcane. We find that production of an additional 10 billion liters of ethanol requires an expansion of Brazil's sugarcane acreage by nearly 1 million hectares, or 11 percent of current area, by 2024, displacing other crops and pasture. A larger share of the sugarcane area expansion occurs in the traditional region of Brazil, reflecting the direct land-use impact from increased ethanol production.

The study also examines the implications of low oil prices. Lower crude oil and gasoline prices cause ethanol use to fall in Brazil and the rest of the world. Due to the cost structure in Brazil, lower energy prices favor expansion of annual crops, especially soybeans and corn. As demand for ethanol falls, total sugarcane production in Brazil decreases, freeing up land for other agricultural activities.

Although the focus here is on oil prices, findings suggest that policies designed to encourage ethanol production will affect land-use and expansion, which can take place on pastureland that has yet to be exhausted in both the frontier and traditional regions. Based on ERS-derived long-term projections, Brazil's ethanol production during the coming decade is expected to rise 38 percent to 42 billion liters by 2024. However, Brazil's ability to provide the bulk of world ethanol trade will depend on its domestic ethanol demand, global sugar and oil prices, exchange rates, and the capacity of its infrastructure to move ethanol to ports.

An increase in ethanol demand in Brazil will lead to direct land-use changes as ethanol feedstock production increases. But it will also lead to indirect land-use changes requiring conversion of agricultural land area into cropland and pastureland. Moreover, increased production of crop-based ethanol will lead to an expansion of agriculture in the country, reflecting the indirect land-use impact from increased ethanol production.

Technology advances in sugarcane production and ethanol conversion processes, changes to ethanol production and blending mandates, and economic policies (i.e., exchange rate policy where a weakening (strengthening) of the *real* will lower (increase) ethanol prices in dollar terms) will influence Brazil's biofuel market. Additionally, the exploitation of Brazil's offshore deep-sea areas has the potential to significantly increase oil production in the country, which may reduce the pressure of international oil prices on the Brazilian economy. Falling oil prices could drive down gasoline retail prices and put additional downward pressure on hydrous ethanol demand. Lastly, the study did not consider Brazil's potential to produce ethanol from corn and the emergence of cellulosic ethanol production from sugarcane bagasse. The potential to increase cellulosic ethanol production capacity could have implications as less land would be required to produce the same amount of ethanol.

# References

Agência Nacional do Petróleo, Gás Natural e Biocombustíveis (ANP). 2015. *Yearbook 2014*, www.anp.gov.br (accessed November 2015).

Agência Nacional do Petróleo, Gás Natural e Biocombustíveis (ANP). 2014. *Yearbook 2013*, www.anp.gov.br (accessed June 2014).

Associação Nacional dos Fabricantes de Veículos Automotores (ANFAVEA). 2014. *Anuário da Indústria Automobilística*, www.anfavea.com.br (accessed June 2014).

Associação Nacional para Difusão de Adubos (ANDA). 2014. São Paulo, SP, Brazil, www.anda.org.br (accessed January 2014).

Binswanger, Hans Peter. 1991. "Brazilian Policies That Encourage Deforestation in the Amazon," *World Development* 19(7): 821-29.

Brandão, Antonio Salazar Pessoa, Gervásio Castro de Rezende, and Roberta Wanderley da Costa Marques. 2006. "Crescimento Agrícola no Período 1999/2004: A Explosão da Soja e da Pecuária Bovina e Seu Impacto Sobre o Meio Ambiente," *Economia Aplicada* 10(2):249-266.

Burnquist, Heloisa Lee, Cinthia Cabral da Costa, and Constanza Valdes. 2013. "Supply Behavior of Hydrous Ethanol in Brazil (unpublished)," CEPEA. Centro de Estudos Avançados em Economia Aplicada - ESALQ/USP.

Caldas, Marcellus M., Cynthia Simmons, Robert Walker, Stephen Perz, Stephen Aldrich, Ritaumaria Pereira, Flavia Leite, and Eugenio Arima. 2010. "Settlement Formation and Land Cover and Land Use Change: A Case Study in the Brazilian Amazon," *Journal of Latin American Geography* 9(1): 125-144.

CANASAT. 2014. Mapeamento da Cana via Imagens de Satélite de Observação da Terra, www.dsr.inpe.br/laf/canasat (accessed June 2014).

Carrero, Gabriel C., and Phillip M. Fearnside. 2011. "Forest Clearing Dynamics and the Expansion of Landholdings in Apuí, a Deforestation Hotspot on Brazil's Transamazon," *Ecology and Society* 16(2): 26. www.ecologyandsociety.org (accessed June 2013).

Central de Informações Agropecuárias, Companhia Nacional de Abastecimento (CONAB). 2014a. www.conab.gov.br

Central de Informações Agropecuárias, Companhia Nacional de Abastecimento (CONAB). 2014b. *Safras, Séries Históricas de Cana de Açucar*, www.conab.gov.br (accessed December 2014).

Centro de Estudos Avançados em Economia Aplicada (CEPEA). 2013a. ESALQ/USP. AGROMENSAL-ESALQ/BM&F, Informações de Mercado, CEPEA - AÇÚCAR & ÁLCOOL, Análise Conjuntural e Séries Estatísticas, www.cepea.esalq.usp.br/ (accessed June 2014).

Centro de Estudos Avançados em Economia Aplicada (CEPEA). 2013b. ESALQ/USP, Indicador Semanal Etanol Hidratado CEPEA/ESALQ Combustível, www.cepea.esalq.usp.br/ (accessed June 2014).

Chomitz, Kenneth M., and Kanta Kumari. 1998. "The Domestic Benefits of Tropical Forests: A Critical Review," *World Bank Research Observer* 13: 13-35.

Departamento Intersindical de Estatística e Estudos Socioeconômicos (DIEESE). 2014. *O Mercado de Trabalho Assalariado Rural Brasileiro.* October.

De Gorter, Harry, Dusan Drabik, Erika M. Kliauga, and Govinda R. Timilsina. 2013. *An Economic Model of Brazil's Ethanol-Sugar Markets and Impacts of Fuel Policies,* World Bank, Policy Research Working Paper 6524. June.

Elobeid, Amani, and Chad Hart. 2007. "Ethanol Expansion in the Food Versus Fuel Debate: How Will Developing Countries Fare?" *Journal of Agricultural & Food Industrial Organization* 5(2).

Elobeid, Amani, Miguel Carriquiry, and Jacinto Fabiosa. 2011. "Global Biofuel Expansion and the Demand for Brazilian Land: Intensification Versus Expansion." Iowa State University, Center for Agricultural and Rural Development, Selected paper prepared for presentation at the Agricultural and Applied Economics Association's 2011 Joint Annual Meeting, Pittsburg, PA, July 24-26, 2011.

Fearnside, Philip M. 1997. "Environmental Services as a Strategy for Sustainable Development in Rural Amazonia," *Ecological Economics* 20:53-70.

Food and Agriculture Organization of the United Nations (FAO). 2014. "FAOSTAT Agricultural Databases," Rome. http://faostat.fao.org/ (accessed December 2014).

Food and Agriculture Organization of the United Nations (FAO). 2004. "Fertilizer Use by Crop in Brazil," Rome.

Gasques, José Garcia, Eliana Testes Bastos, Constanza Valdes, and Miriam Rumenos Piedade Bacchi. 2012. "Total Factor Productivity in Brazilian Agriculture," In *Productivity Growth in Agriculture: An International Perspective*, Keith Fuglie, Sun Ling Wang, and Eldon Ball (eds.), CAB International North America.

Global Trade Information Services (GTIS). 2013. *World Trade Atlas* (subscription service), Available online: www.gtis.com (accessed September 2013).

Hausman, Catherine. 2009. *Biofuels and Land Use Change: Sugarcane and Soybean Acreage Response in Brazil,* University of California, Berkeley, Department of Agricultural & Resource Economics, September, http://ssrn.com/abstract=1478094

Huang, Wen-yuan. 2009. *Factors Contributing to the Recent Increase in U.S. Fertilizer Prices, 2002-08*, Economic Outlook Report AR-33, U.S. Department of Agriculture, Economic Research Service, www.ers.usda.gov/publications/ar-agricultural-resources-situation-and-outlook/ar-33.aspx

Instituto Brasileiro de Geografia e Estatística (IBGE). 2014. *Levantamento Sistemático da Produção Agrícola*, www.ibge.gov.br (accessed December 2014).

Instituto Brasileiro de Geografia e Estatística (IBGE). 2010. *Censo Agropecuário de 2006,* www.ibge.gov.br (accessed December 2013).

Langeveld, Johannes W.A., John Dixon, Herman van Keulen, and P.M. Foluke Quist-Wessel. 2013. *Analyzing the Effect of Biofuel Expansion on Land Use in Major Producing Countries: Evidence of Increased Multiple Cropping Biomass*, Research Report 1301, Biomass Research, Wageningen, July, www.biomassresearch.eu

Lapan, Harvey, and Gian Carlo Moschini. 2008. "Second-Best Biofuel Policies: Subsidies vs. Mandates," NC-1034 conference on Energy and Agriculture: Emerging Policy and R&D Issues, Washington, DC, March 7, 2008.

LMC International (LMC). 2014. *Ethanol Market Report Q2 2014* (subscription service).

LMC International (LMC). 2013. *Ethanol Market Report Q2 2013* (subscription service).

Malcolm, Scott A., Marcel Aillery, and Marca Weinberg. 2009. *Ethanol and a Changing Agricultural Landscape*, Economic Research Report 86, U.S. Department of Agriculture, Economic Research Service, www.ers.usda.gov/publications/err-economic-research-report/err86.aspx

Margulis, Sergio. 2013. "Causas do Desmatamento da Amazônia Brasileira," The World Bank, Brasília, July.

Marshall, Elizabeth, Margriet Caswell, Scott Malcolm, Mesbah Motamed, Jim Hrubovcak, Carol Jones, and Cynthia Nickerson. 2011. *Measuring the Indirect Land-Use Change Associated With Increased Biofuel Feedstock Production: A Review of Modeling Efforts: Report to Congress*, U.S. Department of Agriculture, Economic Research Service, www.ers.usda.gov/publications/ap-administrative-publication/ap-054.aspx

Marshall, Elizabeth, and Margriet Caswell. 2011. "Biofuels and Land-Use Change: Estimation Challenges," *Amber Waves*, U.S. Department of Agriculture, Economic Research Service, June, www.ers.usda.gov/amber-waves/2011-june/biofuels-and-land-use-change.aspx#

May, Peter H., Britaldo Silveira Soares-Filho, and Jon Strand. 2013. "How Much Is the Amazon Worth? The State of Knowledge Concerning the Value of Preserving Amazon Rainforests," Policy Research Working Paper 6668, The World Bank, October.

McPhail, Lihong, and Xiaodong Du. 2012. "Ethanol Strengthens the Link Between Agriculture and Energy Markets," *Amber Waves*, U.S. Department of Agriculture, Economic Research Service, June, www.ers.usda.gov/amber-waves/2012-june/ethanol-strengthens-the-link.aspx#

McPhail, Lihong Lu, Xiaodong Du, and Andrew Muhammad. 2012. "Disentangling Corn Price Volatility: The Role of Global Demand, Speculation, and Energy," *Journal of Agricultural and Applied Economics* 44(3):401-410.

Mendonça, Mário Jorge, Paulo R.A. Loureiro, and Adolfo Sachsida. 2013. "The Dynamics of Land-Use in Brazilian Amazon," *Ecological Economics* 84:23-36, http://dx.doi.org/10.1016/j.ecolecon.2012.08.014 (accessed November 2013).

Ministério da Agricultura, Pecuária e Abastecimento (MAPA). 2013a. *Informativo de Economia Agrícola,* Ano 06, Volume 01, September, www.agricultura.gov.br (accessed May 2014).

Ministério da Agricultura, Pecuária e Abastecimento (MAPA). 2013b. *Usinas e Destilarias Cadastradas,* www.agricultura.gov.br/Desenvolvimento_Sustentavel/ (accessed December 2013).

Ministério de Minas e Energia, Empresa de Pesquisa Energética (MME/BEN). 2014. *Balanço Energético Nacional*, www.epe.gov.br (accessed June 2014).

Muhammad, Andrew, and Ellene Kebede. 2009. "The Emergence of an Agro-Energy Sector: Is Agriculture Importing Instability From the Oil Sector?" *CHOICES*, 1st Quarter, 24, www.choicesmagazine.org (accessed December 2013).

Nassar, André Meloni, Bernardo F.T. Rudorff, Laura Barcellos Antoniazzi, Daniel Alves de Aguiar, Miriam Rumenos Piedade Bacchi and Marcos Adami. 2008. "Prospects of the Sugarcane Expansion in Brazil: Impacts on Direct and Indirect Land Use Changes," In *Sugarcane Ethanol: Contributions to Climate Change Mitigation and the Environment.* Peter Zuurbier and Jos van de Vooren (eds.).

Nassar, André Meloni, and Marcelo Moreira. 2013. "Evidence on Sugarcane Expansion and Agricultural Land Use Changes in Brazil," ICONE, June 12, 2013, www.iconebrasil.org.br (accessed January, 2014).

Nassar, André Meloni, Leila Harfuch, Marcelo M.R. Moreira, Luciane C. Bachion, Laura B. Antoniazzi, and Rodrigo C. Lima. 2011. "*Simulating Land Use and Agriculture Expansion in Brazil: Food, Energy, Agro-Industrial and Environmental Impacts,*" Instituto de Estudos do Comércio e Negociações Internacionais (ICONE), São Paulo, www.iconebrasil.org.br (accessed June, 2014).

Oliveira, Octávio Costa de. 2010. "Chemical and Biological Parameters Related to the Degradation of Brachiaria Pastures in the Brazilian Cerrados," *Seropédica*, UFRRJ, 2000 (Tese, Doutorado em Agronomia, Ciência do Solo).

Overbeck, Gerhard E., Sandra C. Muller, Alessandra Fidelis, Jorg Pfadenhauer, Valerio D. Pillar, Carolina C. Blanco, Ilsi I. Boldrini, Rogerio Both, and Eduardo D. Forneck. 2007. "Brazil's Neglected Biome: The South Brazilian Campos," *Perspectives in Plant Ecology, Evolution and Systematics* 9, 101-116, www.elsevier.de/ppees

Sands, Ronald, and Paul Westcott (cords.), J. Michael Price, Jayson Beckman, Ephraim Leibtag, Gary Lucier, William McBride, David McGranahan, Mitch Morehart, Edward Roeger, Glenn Schaible, and Timothy R. Wojan. 2011. *Impacts of Higher Energy Prices on Agriculture and Rural Economies*, Economic Research Report 123, U.S. Department of Agriculture, Economic Research Service, www.ers.usda.gov/publications/err-economic-research-report/err123.aspx

Schmidhuber, Joseph. 2006. "Impact of an Increased Biomass Use on Agricultural Markets, Prices, and Food Security: A Longer-Term Perspective," Paper presented at the International Symposium of Notre Europe, Paris, France, November 2006.

Serra, Teresa, and David Zilberman. 2013. "Biofuel-Related Price Transmission Literature: A Review," *Energy Economics*, Vol. 37, Issue C, pp. 141-151.

Sheldon, Ian, and Matthew Roberts. 2008. "U.S. Comparative Advantage in Bioenergy: A Hechscher–Ohlin-Ricardian Approach," *American Journal of Agricultural Economics* 90, n5.

Steinbuks, Jevgenijs, and Thomas W. Hertel. 2011. “The Optimal Allocation of Global Land Use in the Food-Energy-Environment Trilemma,” GTAP Working Paper No. 64.

Thompson, Wyatt, Seth Meyer, and Patrick Westhoff. 2008. “Potential for Uncertainty About Indirect Effects of Ethanol on Land Use in the Case of Brazil,” In *Transition to a Bioeconomy: Environmental and Rural Development Impacts*, M. Khanna (ed.), Proceedings of Farm Foundation-USDA Conference, St. Louis, MO. October 15-16.

Tokgoz, Simla, Amani Elobeid, Jacinto F. Fabiosa, Dermot J. Hayes, Bruce A. Babcock, Tun-Hsiang Yu, Fengxia Dong, Chad E. Hart, and John C. Beghin. 2007. “Emerging Biofuels: Outlook of Effects on U.S. Grain, Oilseed, and Livestock Markets,” CARD Staff Report 07-SR 101, Iowa State University, Center for Agricultural and Rural Development, July (Revised). www.card.iastate.edu/publications/

Tyner, Wallace E., and Farzad Taheripour. 2008. “Biofuels, Policy Options, and Their Implications: Analyses Using Partial and General Equilibrium Approaches,” *Journal of Agricultural and Food Industrial Organization* 6(2), Special Issue.

Uniao da Indústria de Cana-de-Açucar (UNICA). 2013. “The Industry Background, Sugarcane: The Economic Cycle,” www.unica.com.br (accessed June 2013).

U.S. Department of Agriculture, Foreign Agriculture Service (USDA/FAS) 2015. *Biofuels GAIN Report BR110013, BR15006.* http://fas.usda.gov

U.S. Department of Agriculture, Office of the Chief Economist, World Agricultural Outlook Board, USDA/OCE/WAOB. 2014. *USDA Agricultural Projections to 2023*, Report No. OCE-141, February, www.ers.usda.gov/publications/oce-usda/oce141.aspx

U.S. Department of Energy (USDOE). 2015. *Petroleum and Other Liquids Data, Weekly Cushing, OK WTI Spot Price FOB*, www.eia.gov/dnav/pet/hist/(accessed February 2015).

U.S. Department of Energy, Energy Information Administration. 2014. *International Energy Statistics*, www.eia.gov/cfapps/ipdbproject/ (accessed May 2014).

U.S. Department of Energy, Energy Information Administration. 2013. *Annual Energy Outlook 2013 With Projections to 2040*, www.eia.gov (accessed May 2014).

U.S. Department of Energy, Office of Integrated and International Energy Analysis, Energy Information Administration (USDOE/STEO). 2015. *Short-Term Energy Outlook (STEO),* January 2015, www.eia.gov/forecasts/steo

U.S. Department of Energy, Office of Integrated and International Energy Analysis, Energy Information Administration (USDOE/AEO). 2014. *Annual Energy Outlook (AEO) 2013 and 2014,* www.eia.gov/forecasts/aeo

Von Blottnitz, Harro, and Mary Ann Curran. 2006. “A Review of Assessments Conducted on Bio-Ethanol as a Transportation Fuel From Net Energy, Greenhouse Gas, and Environmental Life-Cycle Perspective,” *Journal of Cleaner Production.* March.

Walter, Arnaldo, Paulo Dolzan, Oscar Quilodran, Janaina de Oliveira, Cinthia da Silva, Fabricio Piacentea, Anna Segerstedt. 2011. “Sustainability Assessment of Bio-Ethanol Production in Brazil Considering Land Use Change, GHG Emissions and Socio-Economic Aspects,” *Energy Policy* 39:5703-5716.

World Bank. *Global Economic Monitor Databank*. http://data.worldbank.org/data-catalog/global-economic-monitor

# Appendix 1: Characteristics of Brazil's Land Base

The composition and distribution of land in Brazil defines the constraint that the agricultural sector faces as well as the potential for land-cover changes (i.e., conversion of savannah, or grassland into cropland or pastureland) and frontier expansion on the Cerrados. The Cerrados is Brazil's second largest biome and, with 200 million hectares, accounts for 24 percent of Brazil's territory (IBGE, 2014). The Cerrados, consisting of mostly savannahs and grasslands, is irregularly distributed across 11 Brazilian States: most of the State of Goiás and parts of the States of Mato Grosso, Mato Grosso do Sul, Paraná, Minas Gerais, São Paulo, Bahia, Piauí, Maranhão, Tocantins, and Rondônia (app. fig. 1). The Cerrados constitutes Brazil's agricultural frontier, and its topography, climate, and soil characteristics have encouraged investments in large cattle-raising operations and favored the large-scale, technologically intensive cultivation of soybeans, corn, cotton, and sugarcane. It is estimated that close to 39 percent of Cerrados forest has been cleared for cropland and pastureland (IBGE, 2010).

Appendix figure 1

**Brazilian biomes**

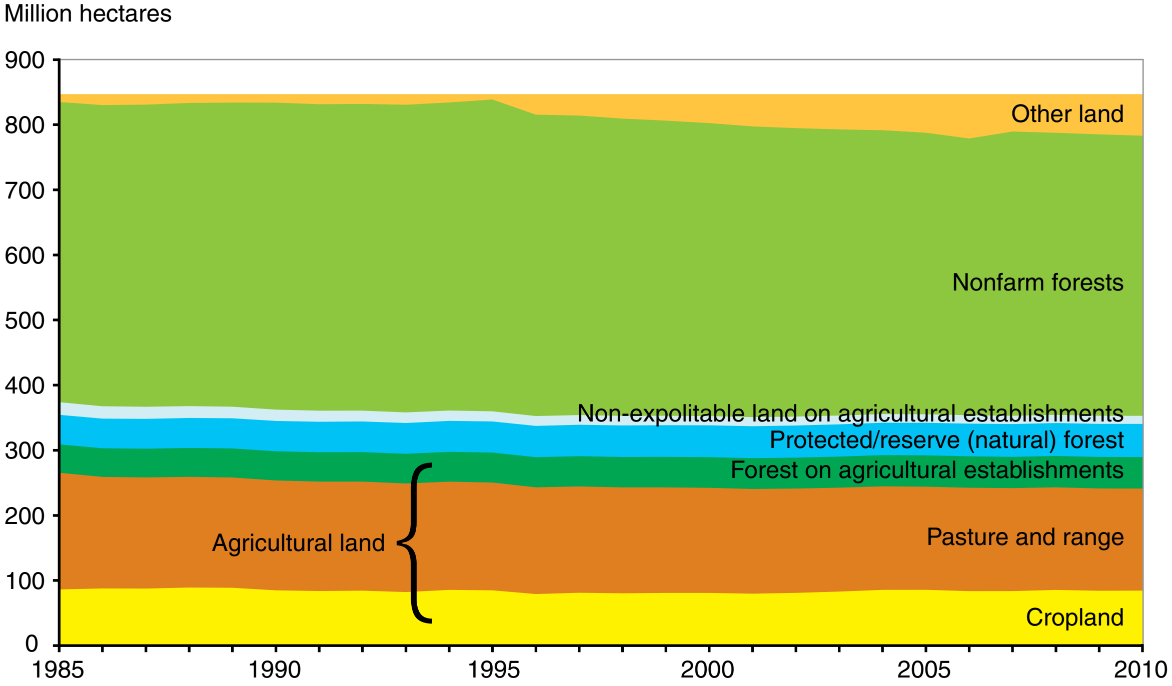
Source: USDA, Economic Research Service using data from Brazilian Institute of Geography and Statistics (IBGE), 2006.

# Appendix 2: Land Use in Brazil

A number of various, and often interrelated, factors contribute to the process of frontier expansion in Brazil: deforestation and land-use restrictions; climate change adaptation; and infrastructure and logistical developments (Fearnside, 1997; Chomitz and Kumari, 1998; Searchinger et al., 2008; Marshall et al., 2011). Brazil's land area covers nearly 846 million hectares. The proportion of the land base in agricultural uses has declined from 44.3 percent in 1985 to 41.8 percent in 2010. Gradual declines have occurred in cropland and range, while pastureland has decreased more rapidly. In 2010, 85.5 million hectares of agricultural land were in cropland (down 2 percent from 1985), 156.7 million hectares were in pasture and range (down 13 percent), 12.4 million hectares were in non-exploitable land on agricultural establishments (down 36 percent), and 99.3 million hectares were in forestland on agricultural establishments (up 12 percent). Nonfarm natural forests were 430.2 million hectares (down 7 percent). Forests and savannahs account for about 60 percent of Brazil's surface area (IBGE, 2010) (app. fig. 2).

Appendix figure 2

**Agricultural land uses in Brazil**



Source: USDA, Economic Research Service calculations based on data from MAPA, Agricultural Census 1985-2006, IBGE, and FAO.

# Appendix 3: Brazil Regional Model Structure and Data Sources

| Commodities | Exogenous variables | Endogenous variables | Agricultural regions | Land |
|---|---|---|---|---|
| Sugarcane | Industrial country GDP | Area | Traditional region | Temporary crops |
| Wheat | U.S.GDP | Yield | *Paraná* | Permanent crops |
| Rice | U.S. CPI | Production | *Rio Grande do Sul* | Fallow land |
| Corn | Oil price | Slaughter | *Santa Catarina* | Pasture-used |
| Barley | Population | Imports | *Espírito Santo* | Pasture-degraded |
| Sorghum | Domestic GDP | Exports | *Rio de Janeiro* | Forest |
| Other coarse grains | Domestic CPI | Food | *São Paulo* | |
| Soybeans | Exchange rate | Feed | *Alagoas* | |
| Cotton | Interest rate | Industrial demand | *Ceará* | |
| Soybean meal | World commodity prices | Ending stocks | *Paraíba* | |
| Soybean oil | Policy variables (i.e., import tariffs, ethanol to gasoline blend rate) | Animal inventories | *Pernambuco* | |
| Other oilseeds | | Crush demand | *Rio Grande do Norte* | |
| Sugar | | Gasoline price | *Sergipe* | |
| Ethanol | | Ethanol price | Frontier region | |
| Biodiesel | | | *Bahia* | |
| Cattle | | | *Piauí* | |
| Beef | | | *Goiás* | |
| Pork | | | *Mato Grosso do Sul* | |
| Poultry | | | *Mato Grosso* | |
| Eggs | | | *Maranhão* | |
| Milk | | | *Minas Gerais* | |
| | | | *Acre* | |
| | | | *Amazonas* | |
| | | | *Amapá* | |
| | | | *Pará* | |
| | | | *Rondônia* | |
| | | | *Roraima* | |
| | | | *Tocantins* | |

Note: GDP=Gross domestic product. CPI=Consumer Price Index.
Source: USDA, Economic Research Service.

The primary data source for agricultural commodities is USDA's Production, Supply, and Distribution (PS&D) database. Macroeconomic data, including the international price of crude oil, Brazilian and industrial country exchange rates, gross domestic product (GDP) growth, and population growth, as well as commodity reference (international) prices, are from ERS data sets prepared for USDA's 10-year reference projections for major agricultural commodities. Data for Brazil's interest rates, inflation rates, minimum wages, and GDP deflator are from Brazil's Central Bank. Land-use data are from Brazil's Institute of Geography and Statistics (IBGE) and the United Nations Food and Agriculture Organization (FAO). State-level supply data for sugarcane and individual commodities competing with sugarcane for land area (soybeans, corn, cattle ranching, and forest products) are from IBGE. Producer and consumer prices are from Brazil's Ministry of Agriculture (MAPA) and São Paulo's Institute for Applied Economics (IEA), while unit production values are from IBGE. Consumer retail prices are from IEA and from the Sugar and Alcohol Millers Association of São Paulo State (UNICA). Data for cost of production, input use, and prices are from CONAB and IBGE. Data for hydrous and anhydrous ethanol production, consumption, exports, and prices are from Brazil's National Petroleum, Natural Gas, and Biofuels Agency (ANP). Flex-fuel vehicle statistics are from the National Association of Automobile Manufacturers (ANFAVEA). Data for sugar and ethanol shares of sugarcane production and the blending rate for ethanol in gasoline production are from UNICA.