CHAPTER 7

Implications of biofuel production on direct and indirect land use change: Evidence from Brazil

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Contents

1. Introduction

Land use change, its drivers, and its consequences have been discussed extensively. Drivers such as increases in human population with additional needs for food, changes in the types of food as wealth and urbanization rates increase, demand for energy and fiber, and enhanced transportation and the development of roads (among others) have all been cited as causes of deforestation. Biofuels have gained notoriety in driving land use change and have also been singled out as an important source of deforestation, as grains and oils traditionally used for food are diverted toward bioenergy, spurring the need to expand production to satisfy nutritional requirements. Additional production can be attained by increasing the amount of land used by obtaining higher yields per unit of land or by a combination of the two.

Biofuels, Bioenergy and Food Security
https://doi.org/10.1016/B978-0-12-803954-0.00007-3

Biofuels therefore have direct land use changes as well as indirect land use changes. While direct effects can be captured by knowing how much feedstocks are needed per unit of bioenergy produced and feedstock yields per unit of land, indirect land use changes are much more difficult to assess. They are highly dependent on the interactions of yields of different crops and locations as well as on possibilities for substitution on both the demand and supply sides. Early work recognized the importance of accounting for indirect land use change when assessing the environmental credentials of different types of biofuel pathways (Searchinger et al., 2008). While later softened, this well-cited paper raised the point that accounting for indirect (both at national and global levels) land use change as a result of biofuel expansion was needed because it had important impacts on both the level of greenhouse gas (GHG) emissions and other environmental metrics as well as on commodity prices and food markets. Recognizing its importance, regulators both in the United States and the European Union were tasked to conduct assessments that included direct and indirect land use change to define the types of biofuel pathways that were eligible for support and to be counted toward mandated consumption levels (USDA, 2017; CARB, 2015; Valin et al., 2015).

This chapter is organized as follows. A brief overview of the literature relating to direct and indirect land use change is provided, followed by consideration of land use change for policy implementation. Several factors relevant for the analysis of land use change are then illustrated using recent transitions in Brazil. Final remarks close the chapter.

2. Overview of direct versus indirect land use change

The literature on the impact of biofuels on land use and the environment has evolved over time. Initially, studies accounted for only the direct land use impacts of biofuel production in terms of increased acreage of agricultural feedstock for biofuels relative to the production of fuel from petroleum (Commission of the European Communities, 2006; Farrel et al., 2006; Macedo et al., 2004; Wang et al., 2007; Wang et al., 1999). At that time, the general consensus was that replacing fossil fuels with biofuels would lead to lower GHG emissions. Accounting for only direct land use impacts, producing ethanol from corn led to a saving of GHG emissions when compared to fossil fuels. Hill et al. (2006) estimated a 12% reduction in GHG emissions from the production and combustion of ethanol. Estimates by Wang et al. (2007) averaged higher, at about a 20% saving of GHG emissions relative to fossil fuels. However, studies that took into account indirect land use changes showed increased carbon emissions as land expansion included the clearing of rainforests and grasslands thus releasing carbon.

Subsequent studies, more prominently by Searchinger et al. (2008) and Fargione et al. (2008), found that indirect land use changes from biofuel production resulted in increased carbon emissions. Searchinger's study estimated that the production of corn-based ethanol, when including indirect land use changes, led to a doubling of GHG emissions over 30 years. Ethanol produced from sugarcane also increased emissions but by less than corn. Fargione et al. (2008) found that biofuels produced from food crops resulted in higher GHG emissions, while biofuels produced from biomass or from perennial crops would have no carbon debt and led to GHG savings.

While Searchinger's study highlighted the importance of considering indirect land use changes in the estimation of GHG impacts of biofuel production, the study was criticized for not taking into account the increase in land productivity induced by increased demand and prices, and the use of perennial energy crops on marginal land that did not require the conversion of natural lands to agricultural production (Wang and Haq, 2008; Mathews and Tan, 2009). The early analysis by Searchinger et al. (2008) and Fargione et al. (2008), and later analyses, which took into account land intensification (Hertel et al., 2010; Dumortier et al., 2011), have shown the critical role of land use change in determining lifecycle emission of biofuels.

A review of more recent studies has continued to account for indirect land use changes although there has been a wide range in results based on modeling assumptions (Finkbeiner, 2014; Ahlgren and Di Lucia, 2014). Taheripour and Tyner (2013) found that, in assessing the global impacts of US ethanol expansion, model modifications capturing more recent data resulted in less expansion of cropland, less conversion of forestland, and a decline in land use emissions by 18%.[1] More recent studies have emphasized the importance of land intensification in terms of double cropping and increases in technology-driven and market-driven (price-response) land productivity in assessing land use change (Taheripour et al., 2017a,b; Byerlee et al., 2014). Results showed lower global land use change and emission values from biofuel expansion (Taheripour et al., 2017b).

3. Land use change considerations for biofuel policy implementation

Changes in relative prices between commodities in general and as a result of the expansion of biofuel demand lead to land use change. In particular, higher prices provide incentives for producers to bring more land into agricultural production, and to reallocate land among different agricultural activities. Higher prices are observed not only in countries that increase their feedstock needs because of higher biofuel production and/or consumption but also globally. These global changes in land use may have nontrivial implications for carbon release, posing challenges for policy implementation and fueling the policy debate. In this line, regulations on biofuels require reporting of GHG emission

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[1] The authors modified the Global Trade Analysis Project model to account for regional responses in terms of the extent and location of land use change as well as updating rates of land conversion to forestland and pasture (Taheripour and Tyner, 2013).

reductions related to feedstock-specific biofuels (Panichelli and Gnansounou, 2015; Warner et al., 2014; Khanna et al., 2017).

Land use changes both direct and indirect are important. Policies such as the USA's Energy Independence and Security Act of 2007 and the European Renewable Fuels Directives indicate that biofuels need to achieve certain targets in terms of lifecycle GHG emission reductions (Hennecke et al., 2013).

There is a large variation in terms of results of lifecycle analysis from different models and methods. Differences at the cultivation and production stages are evident across analyses because a given feedstock can be produced through very distinct practices by producers even within a country (Hennecke et al., 2013). Cross-country differences are even larger in terms of practices, yields achieved on agricultural and newly converted lands, and land uses being displaced (e.g., unused cropland vs. natural forests or peatlands) (Edwards et al., 2010; Babcock, 2015; Plevin et al., 2015).

Some authors conclude that there is a need for harmonization in the calculation of GHG emissions from biofuels (Hennecke et al., 2013; Warner et al., 2014). As indicated, agricultural production, land use needed for a given amount of feedstock, intensity of land use (e.g., possibility for double cropping), and land uses displaced are location specific and can result in very different calculated emission levels. This is important because a regulatory gap is created that needs to be considered for correct implementation of policies, leveling the field, and creating correct incentives to improve the GHG credentials of different biofuels.

4. Evidence from Brazil

To properly assess direct and indirect land use changes resulting from biofuels, it is important to reflect on how agricultural production has responded to price increases from increased demand for biofuel feedstock. This section provides an illustration from Brazil, namely, agricultural production trends, observed land use change based on land intensification (double cropping, increased yields), and extensification (land expansion) in response to price signals.

4.1 Agriculture intensification: The case of double cropping and soybean expansion

Double cropping means planting several crops in the same area and in the same crop year so that the same land is used to generate more than one crop per year. In Brazilian agriculture, double cropping is practiced for maize, peanuts, potatoes, and beans. In some regions, such as Southeast and Northeast Cerrado (MATOPIBA[2]), potatoes and beans

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[2] Confluence of the States of Maranhão, Tocantins, Piauí, and Bahia. The MATOPIBA is the new agricultural frontier in Brazil.

may even have some areas with a third crop in the same crop year. However, double cropping in maize production represents the most important double cropping in the country. Over the past 10 years, planting summer soybeans (rainy season) with a winter crop of maize has become well established in some regions—South (Paraná State) and Center-West (Mato Grosso)—and is therefore a key driver in the expansion of maize production.

There are two main determinants for such dynamics: the no-till practice for soybean production, which has decreased the time between the harvest of summer soybeans and the planting of maize, and the development of herbicide resistance varieties of maize, high-quality inputs, and technical improvements, which have made it easier to plant the crop directly after soybeans. As presented in Fig. 7.1, the result is an increase in double cropping area in response to higher agricultural prices, thus increasing total production of maize without increasing land use or land use conversion.

Even though the shorter planting period for maize represents more risk compared to traditional maize systems, this process has been increasing significantly across different regions in Brazil. Table 7.1 shows that in the last 20 years, the annual growth rates of planted area of first and second crops of maize were −4.0% and 9.5%, respectively. In the Center-West (Cerrado) and North (Amazon) regions, the annual growth rate reaches 12.8% and 14.9%, respectively. The production growth of the second crop of maize more than compensates for the decline in the first crop as shown in Table 7.1. The second crop of maize is very sensitive to price and profitability, markets, and land use changes.

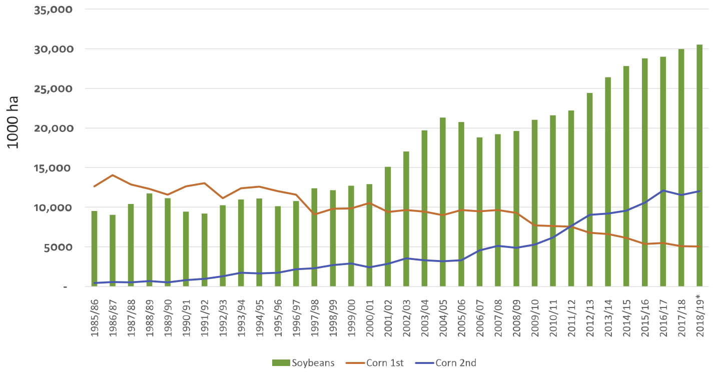

Fig. 7.1 Planted area of maize (first and second crops) and soybeans in Brazil (1985/86–2015/16). *(From Companhia Nacional de Abastecimento (CONAB)—Série Histórica das Safras, 2017. Available at: https://www.conab.gov.br/info-agro/safras/serie-historica-das-safras?start=20).*

Table 7.1 Growth rates of planted area and volume of production of maize (first and second crops) and soybeans (1996–2016)

	Maize				Soybean	
	Planted area		Volume of production			
	First crop (%)	Second crop (%)	First crop (%)	Second crop (%)	Planted area (%)	Volume of production (%)
Brazil	−4.0	9.5	−0.6	13.1	5.2	6.8
South	−5.2	7.0	−0.3	11.1	4.0	6.0
Southeast	−3.0	4.0	0.5	5.5	3.9	6.2
Center-West	−6.8	12.8	−3.8	16.3	6.0	7.5
North	−4.5	14.9	−2.2	19.5	34.8	35.5
MATOPIBA[a]	−1.2	3.8	3.4	5.5	10.2	10.4
Northeast	−3.9	–	−8.9	–	–	–

[a] The MATOPIBA region is made up of the acronyms of Maranhão (MA), Piauí (PI), Tocantins (TO), and Bahia (BA), which is considered the new agricultural frontier in Brazil.

From Companhia Nacional de Abastecimento (CONAB)—Série Histórica das Safras, 2017. Available at: https://www.conab.gov.br/info-agro/safras/serie-historica-das-safras?start=20.

In terms of soybean planted area and volume of production, the annual growth rates between the 1995/96 and 2015/16 crop years were 5.2% and 6.8%, respectively. These rates are lower than the rates for maize. However, the recent expansion of soybeans, especially in the Cerrado biome, allows for the expansion of the second crop of maize, as shown in Table 7.1. Additionally, soybeans represent 90% (15.6 million hectares [Mha]) of all agriculture in the Cerrado, and in the last crop year more than half (52%) of the soybeans produced in Brazil were concentrated in the Cerrado.

If a particular biofuel crop requires more land, the maize producers would be willing to reduce the area of the first crop of maize and expand the second crop area to adjust land market fluctuations and increase profitability. Increasing double cropping area is one of the farmers' first responses to changes in crop prices. As in Brazil, double cropping in the United States involves soybean production.

A recent comprehensive study on the Cerrado biome and soybean production has shown that there is a potential for Brazilian agriculture to expand soybean production to areas previously occupied by pastures without the need of further deforestation (Filho and Costa, 2016). In the last decade, the agricultural area of Cerrado expanded 87%, and around 70% of the agricultural expansion occurred in pasture or areas with other agricultural crops. The exception is the MATOPIBA region, which has had the greatest expansion over native vegetation areas.

The research also highlights that 33.4 Mha of anthropized areas (areas with high, medium, and low suitability for agriculture without altitude and slope restrictions) would be suitable for conversion into grain production, and 4.2 Mha of this total area are in the MATOPIBA region. Additionally, sustainable cattle ranching intensification initiatives are extremely relevant and strategic to accommodating market changes without losses to the remaining vegetation. This process is already under way in the consolidated agricultural frontier (outside MATOPIBA). As a result, the region has great potential to promote the transition between cattle and soybeans over pasture areas.

4.2 Livestock intensification: Pastureland and integrated systems

Pastureland is around 170 Mha according to the Image Processing and Geoprocessing Lab, Federal University of Goiás (LAPIG–UFG), representing 70% of Brazilian agricultural area. However, the proportions of natural and planted pastureland have changed dramatically over time. Natural pasture was replaced by more profitable planted pasture areas. Planted pasture reached its peak in 1985 (179 Mha), after which pastureland areas declined due to abandonment or shifts to croplands. During the period between 1985 and 2010, planted pasture expanded in the North region following the main rivers and roads (Dias et al., 2016).

In response to market forces, livestock yields increased 129% between 1996 and 2016 (GTPS, 2017). This improvement allowed pastureland areas to decrease by about 20.6 Mha, while, at the same time, meat production increased (Fig. 7.2). Brazilian livestock systems have demonstrated a high endogenous potential to intensify production and absorb any marginal increase in crop area (Nepstad et al., 2014; Latawiec et al., 2014; Strassburg et al., 2014; Dias et al., 2016), which could come from biofuels.

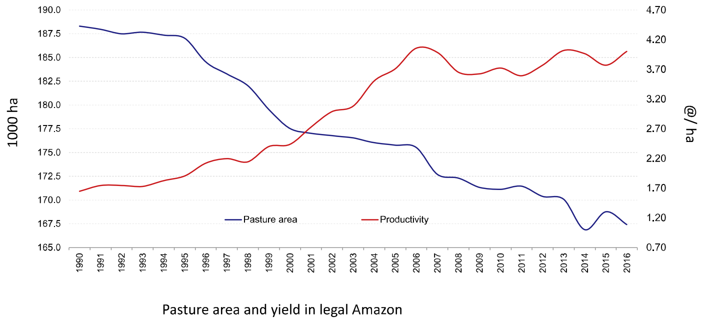

Fig. 7.2 Pasture area (Mha) and livestock productivity (@/ha) (approximately 15 kg per hectare) in Brazil (1990–2016). *(Adapted from Grupo de Trabalho da Pecuária Sustentável (GTPS). Brazil: Agro-Environmental Potency Challenges of the Planet and Mankind. Available at http://gtps.org.br/biblioteca/). Used with permission from Athenagro Consultoria.*

There are around 30 Mha of pastureland with some level of degradation in Brazil. Although this number is far from being a consensus in the literature due to different definitions of degradation levels and livestock productivity, it is evident that there is a large amount of degraded pastures that could be converted to more efficient use.

Recovered pastureland reduces carbon dioxide (CO_2) emissions by at least 60% in a production system and increases biomass production (Kurihara et al., 1999). Nutrient replacement in the pasture improves animal diet quality. This reduces the time of slaughter and the emissions of methane gas (CH_4) by enteric fermentation (Assad, 2015), which is not currently accounted for in land use change estimation. It also reduces the pressure to convert natural areas into pasture. When compared to degraded pasture, recovered areas provide a higher carbon stock to the system, since there is an accumulation of organic matter in the soil, as well as lower CO_2 losses (32.3 kg CO_2 equivalent per live weight gain for degraded pasture, and 9.8 kg CO_2 equivalent per live weight gain for recovered areas) to the atmosphere. This estimation includes land use change and agricultural emissions factors.

Several studies have shown that policy-driven intensification could reduce pasture areas in Brazil promoting land sparing and reducing the pressure on natural forests and natural areas (Cohn et al., 2014; Strassburg et al., 2014; Silva et al., 2017; Harfuch et al., 2016). The importance of agriculture in mitigating GHG emissions was reinforced in the Brazilian Nationally Determined Contribution (NDC), which additionally aims to recover 15 Mha of degraded pasture, and increase the adoption of integrated systems (ISs) by 5 Mha between 2020 and 2030.

The expansion of soybean production, the degradation of large areas due to livestock ranching, and low livestock productivity in Brazil provide the catalyst for the development of new agricultural practices to intensify agricultural yield, especially in the livestock sector (Salton et al., 2014). Agricultural systems that integrate grain production and livestock ranching could be advantageous to both farmers and the environment. ISs could make it possible to recover pasture productivity and increase crop stability at the same time (Moraes et al., 2014; Sá et al., 2017).

Due to its economic and ecological advantages, ISs have been proposed as a strategy to contain agricultural expansion, the degradation of pastures, and the reduction of deforestation (Lima, 2017). Each type of IS—crop-livestock and/or crop-livestock-forestry—brings its combination of benefits to agriculture. ISs are key among sustainable technologies to overcome the problems arising from decades of using farming practices with high environmental impacts. ISs have the potential to mitigate GHG emissions, reduce erosion and fertility losses, reduce the silting of watercourses, and prevent soil and water pollution, among others. The IS can guarantee the sustainable intensification of agriculture, promoting increased production of foods, fibers, and energy associated with the promotion of ecosystem services (Moraes et al., 2017).

Recent research suggests that there are 11.5 Mha with ISs in Brazil (Rede de Fomento ILPF, 2016). Around 8000 grain (soybean and/or maize) and livestock producers were interviewed. The crop-livestock system with the integration of soybean/maize and livestock is well known by both grain and livestock producers, reaching 99% and 82% of adoption rates in each farmer group, respectively. Other important results are the determinants of IS adoption. In general, farmers are adopting IS because of the yield increases per hectare, higher profitability, recovery of pasture capacity, and reduction of environmental impacts. This information supports the role of livestock intensification progress in Brazil, as well as the mitigation potential of pasture recovery and IS technologies. Consequently, both technologies should be considered for a correct and complete policy assessment in Brazil since livestock intensification directly affects the indirect land use change factor.

4.3 Sugarcane yield and area expansion

Sugarcane is the most promising crop in Brazil to meet additional ethanol demand. It is therefore important to show recent sugarcane yields and regional area expansions. Brazil has already reached a yield of 80 tons per hectare (tons/ha) in the Center-South region—the main Brazilian sugarcane producing area, representing in the 2015/16 crop year about 93% of total production (CONAB, 2017). Several projections for Brazilian agriculture have shown that the yield in 2024/25 would be between 74 and 82 tons/ha (OECD/FAO, 2018; FIESP, 2016). The recent observed yield suggests that Brazil has reached these numbers earlier than projected.

Additional sugarcane production will require area expansion. However, the use of marginal land with lower yields for Brazilian sugarcane seems to underestimate the observed yield trends, especially in the Center-West (Cerrado) region. Logistic cost is the main restriction for sugarcane expansion in the region. Technical assistance and planting techniques adapted to regional characteristics are now broadly available in the "new regions" (Center-West). Table 7.2 shows the recent area expansion of sugarcane in Brazil. There is also evidence that sugarcane expansion creates positive spillovers and increases grain productivity as measured in yield per hectare (Assunção et al., 2016).

Another important point arises from the sugarcane agronomy and management decisions that lead to strong yield/price elasticity. Different from annual crops, sugarcane yield is very sensitive to investments in replanting. After replanting, sugarcane yield reaches the highest yield value and then declines in each successive ratoon. Although replanting is very expensive, sugarcane yield from the first cut is almost double that of the fifth cut, as shown in Table 7.3.

Since this decision combines significant investments and huge improvements in yield, agricultural managers always consider the expected prices for their products (e.g., sugar and ethanol) to determine how much of the area should be renewed each year. If prices

Table 7.2 Sugarcane area expansion in Brazil between 2009/10 and 2016/17 (1000 ha)

Regions	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	(2016/17–2009/10)
North	17	20	35	42	46	48	51	52	35
Northeast	1083	1113	1115	1083	1030	979	917	866	−216
Center-West	940	1203	1379	1504	1711	1748	1715	1811	871
Southeast	4833	5137	5221	5243	5436	5593	5455	5700	868
South	537	584	613	612	588	636	517	619	82
Brazil	7410	8056	8363	8485	8811	9004	8655	9049	1640

(From Companhia Nacional de Abastecimento (CONAB)—Série Histórica das Safras, 2017. Available at: https://www.conab.gov.br/info-agro/safras/serie-historica-das-safras?start=20).

Table 7.3 Sugarcane yield per year of cutting (ton/ha)

Crop-year	First cut	Second cut	Third cut	Fourth cut	Fifth cut
2007/08	102	90	79	71	66
2008/09	102	86	76	70	65
2009/10	106	91	78	71	65
2010/11	105	89	77	68	64
2011/12	91	78	69	63	59
2012/13	n.a.	n.a.	n.a.	n.a.	n.a.
2013/14	73	86	77	68	64
2014/15	96	87	76	69	64
Average	96	87	76	69	64

n.a., not available.

(From MAPA, 2012. Ministry of Agriculture, Livestock and Food Supply. Sugarcane Productivity Evolution by Cut. Available at: http://www.agricultura.gov.br/arq_editor/file/Desenvolvimento_Sustentavel/Agroenergia/estatisticas/producao/SETEMBRO_2012/evolucao%20podutividade%20cana.pdf. CONAB, 2014. National Company of Food Supply. Conab—Levantamento: Agosto/2014—2° Levantamento da Safra 2014/15. Available at: http://www.agricultura.gov.br/arq_editor/file/camaras_setoriais/Acucar_e_alcool/27RO/App_Safra_27RO_Alcool.pdf).

are high, producers are willing to invest and expect a higher return. This relationship is clear and statistically significant, as shown in Fig. 7.3.

If the price is high, the producer tends to renew a greater share of the sugarcane area earlier, leading to a higher agricultural yield. Therefore the yield increase should be considered as an important way to achieve the additional sugarcane production required in both sugarcane pathways. Similarly, for crop yields, improvements in industrial performance are another aspect that must be accounted for in indirect land use change assessments.

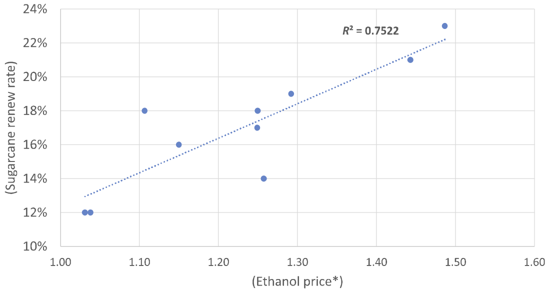

Fig. 7.3 Correlation between ethanol price and sugarcane renew rate. *Real/L (2014 real values). *(Based on the sources UNICA (2016). The Brazilian Sugarcane Industry Association. Coletiva de imprensa—Estimativa Safra 2016/2017. Available at: http://unica.com.br/download.php?idSecao=17&id=10968146. CEPEA, 2016. Center for Advanced Studies on Applied Economics. Available at: http://cepea.esalq.usp.br/etanol/#), accessed in 2016.*

4.4 Land use polices

In the last two decades, Brazil has established and reinforced a set of land use public and private policies, as well as control mechanisms. Nepstad et al. (2014) showed how enforcement of laws and interventions in soybean and beef supply chains, restrictions on access to credit, and expansion of protected areas appear to have contributed to the large decline in Amazon deforestation rates. Among the more significant policies and commitments established in Brazil are Sugarcane and Palm Oil Zoning (ZAE-Cana and ZAE-Palma, respectively), the Low Carbon Agricultural Plan (ABC Plan, in its Portuguese acronym), the voluntary commitment on reducing deforestation, the revision of the Forest Code (including Cadastro Ambiental Rural, CAR, in Portuguese), the Soybean Moratorium, and the commitment on eliminating illegal deforestation.

As part of the National Plan on Climate Change, the Plan for the Protection and Control of Deforestation in the Amazon (PPCDAm) and the Plan for the Protection and Control of Deforestation in the Cerrado (PPCerrado) commit to significant reductions in deforestation rates in the legal Amazon and Cerrado biome (80% and 40% reduction, respectively). Additionally, the government has put in place a set of strategies, such as the creation of new protection areas (with different restriction levels), better interactions between governmental bodies, as well as satellite vigilance to monitor and target specific deforestation focus, with effective results (Nepstad et al., 2014; Assunção et al., 2013). These measures have contributed to lower deforestation rates (Fig. 7.4).

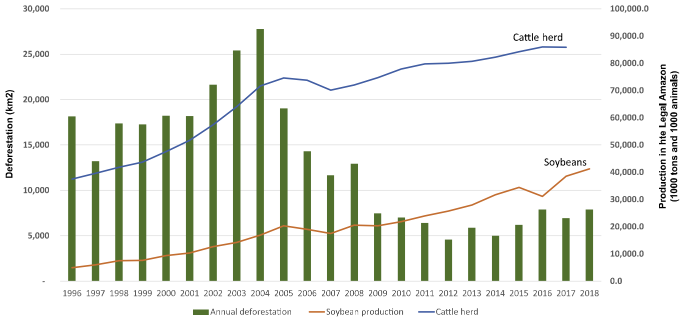

Fig. 7.4 Annual deforestation rate (1000 km^2), cattle herd (million animals), and soybean production (million metric tons) in the Legal Amazon between 1996 and 2016. *(From INPE, 2017. PRODES—Monitoramento da Floresta Amazônica Brasileira por Satélite. http://www.obt.inpe.br/OBT/assuntos/programas/amazonia/prodes. IBGE, 2017. Pesquisa Pecuária Municipal. Available at: https://www.ibge.gov.br).*

Launched in 2009, ZAE-Cana restricts the expansion of sugarcane over several land use classes, including areas covered by natural vegetation, the Upper Paraguay Basin Amazon and Pantanal Biomes, and indigenous areas, among others. According to the new criteria, 92.5% of the national territory is considered not suitable for sugarcane plantation having several restrictions for its expansion (EMBRAPA, 2009).

Launched in 2010, Palm Oil Zoning restricts palm oil expansion into native vegetation (EMBRAPA, 2010). To access official credit, oil palm producers should only use land deforested before 2008. Investors are required to adhere to the ZAE-Palma criteria and deforestation laws, which are being strictly monitored and enforced (Brandão and Schoneveld, 2015).

Launched in 2006 and with the participation of major trading companies, the Ministry of Environment, Brazilian Banks, and NGOs, the Soybean Moratorium restricted the purchase of soybeans from deforested areas of the Amazon biome after 2006. The cutoff date was postponed to 2008 to comply with the National Forestry Code. The moratorium has been recognized as an efficient tool to avoid deforestation, which should be maintained (Nepstad et al., 2014; Gibbs et al., 2015). In 2004, up to 30% of the planted soybeans came from recent deforestation in the Amazon. Today, this value is no higher than 1.25% (Greenpeace, 2016).

The Native Vegetation Protection Law No. 12.651/2012 (also known as the Forest Code) governs the use and protection of public and private lands in Brazil. It is a key policy instrument to promote restoration of natural vegetation, curb illegal deforestation, and regulate permitted conversion or legal deforestation. Key elements include the establishment of an Environmental Rural Registry (CAR) and Environmental Compliance Programmes (Programas de Regularização Ambiental, PRAs, in Portuguese), and obligations to keep and restore Permanent Preservation Areas (APPs) and Legal Reserves (LRs). According to Chiavari and Lopes (2017) it is one of the most important pieces of legislation with the potential to drive efficient land use in the country and become an effective tool against climate change.

Fig. 7.5 presents the best representation of land use in Brazil (left) and legal protection of natural vegetation (right). Even though native vegetation forests still account for 67% of the Brazilian territory (followed by pastures, 20%), only a share is not legally protected (28%). Considering the total remaining natural vegetation, around 28% is protected under conservation units or indigenous lands, and 34% is protected within private farmland.

Regarding private land, the Forest Code protects riparian areas (buffers vary from 5 to 500 m) and a percentage of private land native vegetation ranging from 20% to 80% must mandatorily be set aside. As shown in Fig. 7.6 the set-aside areas have a higher C stock, such as the Amazon biome.

It is important to mention that the current Forest Code was revised in 2012 seeking for effective implementation. A programmatic increase in formality of farms has been

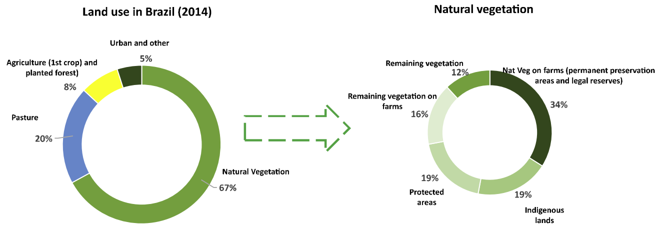

Fig. 7.5 Land use in Brazil and native vegetation. *(From Agroicone based on IBGE-PAM, 2014. Sparovek et al., 2015. A adicionalidade do mecanismo de compensação de reserva legal da lei no 12.651/2012: uma análise da oferta e demanda de cotas de reserva ambiental (Chap. 5). Availabel at: http://www.ipea.gov.br/agencia/images/stories/PDFs/livros/livros/160812_livro_mudancas_codigo_florestal_brasileiro_cap5.pdf).*

Fig. 7.6 Share of private properties that need to be set aside as Legal Reserves. *Note*: Calculations for all categories considered the best available data in 2014. *LR*, Legal Reserve. *(Used with permission from Agroicone.).*

established with special rules (compensation) for areas deforested before 2008. For the Atlantic Forest biome (tropical forest), restrictions are more stringent than the 20%, once typical forestry python-fisionomes (dense forests) are fully protected.

The Environmental Rural Registry (CAR) is one of the most important features of the new Forest Code. CAR is an electronic (geographical information system-based) national public registry mandatory for all rural properties with the purpose of integrating environmental information, and is composed of a database for control, monitoring, environmental and economic planning, and can also combat deforestation. Registration in the CAR is a mandatory condition for the exercise of several rights, such as obtaining authorization for the suppression of native vegetation and the maintenance of activities in consolidated areas, among others. In addition, all financial institutions will only grant agricultural credit to rural properties registered in the CAR (Silva et al., 2016). Until August 31, 2017, more than 4.3 million rural properties have been registered with a total area of 413 Mha inserted in the database (SFB, 2017), which represents more than 100% of the agricultural area.

Looking forward, the Brazilian NDC is heavily based on reinforcing land use policies jointly with biofuels expansion. Forestry Code implementation and the elimination of illegal deforestation are clearly established. In addition, the current legislation will reinforce its effectiveness.

Given the voluntary commitment made at COP-15,[3] in 2010 Brazil released the Low Carbon Agriculture Plan (ABC Plan, in Portuguese). The ABC Plan is a sectoral plan to mitigate GHG emissions in agriculture, improve efficiency in the use of natural resources, and increase the resilience of productive systems and rural communities, as well as enable the sector to adapt to climate change. The ABC Plan has several actions to be implemented by 2020, such as (1) recover 15 Mha of degraded pasture; (2) increase the adoption of ISs by 4 Mha; (3) increase the no-till system by 8 Mha; (4) increase biological nitrogen fixation by 5.5 Mha, substituting nitrogen fertilizers; (5) increase planted forests by 3 Mha; (6) expand the treatment of animal waste by 4.4 million cubic meters; and (7) encourage the implementation of adaptation actions to climate change, especially to those with GHG mitigation potential.

5. Final remarks

The expansion of biofuel production and consumption as a result of policies and market forces has led to the expansion of land used for agriculture as well as reallocation of land within crops and agricultural activities. This chapter provided a general overview of the implications of the expansion of biofuels and feedstock needs as a source of both direct and indirect land use changes. These changes can occur completely in the country in which the biofuel demand arises or could be exported either partially or in full to other countries around the world. The extent of the expansion and reallocation of land around the world, including the geographical zones affected, will depend on the biofuel pathway considered. Other sources of demand for biofuels feedstocks, as well as the possibilities of substitution in both the supply and demand sides, also affect the extent and location of land use change.

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[3] Brazil has committed to reduce GHG emissions by 37% below 2005 levels in 2025 and 43% in 2030.

Direct and indirect land use changes affect the environmental credentials of biofuels in terms of possible contamination of water and soil resources, and GHG emissions among other impacts. Market-mediated and price implications were also intensely analyzed as part of the food versus fuels debate. In short, it was argued that diverting commodities from food to fuel uses raises prices of grains, oils, and animal-based products, thus increasing the number of people that are food insecure.

The impacts just mentioned were recognized early and policies in several countries required that biofuels meet certain environmental criteria, most prevalently in terms of lifecycle reductions of GHG emissions relative to the fossil fuels that were displaced. Land use changes both direct and indirect were shown to be critical in the assessment of lifecycle GHG emissions of biofuels. This is also an area in which considerable scientific uncertainty remains with different modeling groups and approaches leading to widely diverging assessments as indicated here and highlighted in other chapters of the book (see, e.g., Dumortier, Elobeid, and Carriquiry).

A major difficulty in assessing land use change is the diversity of possibilities in which agricultural activities can be conducted, including production practices, climatic conditions, resource bases, etc. These are all highly specific, location dependent, and reflected and modulated by institutional and cultural aspects. The dynamics of agricultural expansion can also change in short periods of time as they respond to policy, technologies, and market forces. The recent evolution of agricultural activities in Brazil, including zoning restrictions, possibilities for double cropping, and stricter enforcement of policies, all illustrate the difficulties and the need to frequently evaluate and update land use change assessments.

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