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Evidences on Sugarcane Expansion and Agricultural Land Use Changes in Brazil

Report

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June 12th, 2013

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Executive Summary

The debate on land use changes caused by the expansion of food-based biofuels is still ongoing in academic circles, in the private sector, and in the policymaking arena. The European Commission (EC) took the most recent initiative to tackle this issue and published a new Directive proposal in the fall of 2012. Although still under scrutiny by the European Parliament and the Council, the amendments proposed to the RED and FQD Directives indicate that the EC makes no distinction among feedstock that can also be used to produce food. Therefore, any biofuel produced from food crops, such as cereals and other starch rich crops, sugars, and oil crops is considered as a conventional biofuel and its participation to the EU 2020 renewable energy target in transport is limited to 5% because it creates additional demand for land. The intention of the EU authorities is to stimulate the growth of biofuels which production do not require agricultural land or may use land that is not suitable for producing food. They are named low-ILUC advanced biofuels, in opposition to the conventional ones.

The objective of this paper is to present a set of evidences demonstrating that sugarcane ethanol produced in Brazil should not be considered as a conventional biofuel and, therefore, its use to achieve the RED and FQD targets should not be capped. The evidences presented in this study demonstrate that sugarcane ethanol produced in Brazil is a low-ILUC raw material, and its production is more energy and land efficient than any other food feedstock.

Measuring the impacts of indirect land use changes (ILUC) is still an issue far from being solved. There is a broad consensus within the scientific community, as well as among policymakers, that the expansion of any agricultural activity, being it feedstock for biofuel or for food, will cause indirect effects associated with land use change. There is also a common view that it is necessary to continue investing in research to improve the methodologies to measure ILUC. Nevertheless, economic models used to measure ILUC are improving and consequently results are converging.

In recent studies using global models as the main tool to assess ILUC, ILUC factors for sugarcane ethanol range from 4 to 13 gCO2/MJ. These values are much lower than the numbers published in 2008 when this discussion started and caught the attention of the scientific community. Measured differently, results are also converging in ILUC per hectare of expansion, 0.2 to 0.24 ha, and ILUC in ha per 1,000 liters of ethanol produced, 0.23 to 0.38. Even with the recent improvements, the uncertainty about the results of modeling exercises raises diverse concerns among policymakers concerning indirect effects associated to biofuel policies. Therefore, although we know that ILUC is a reality, its magnitude is still subject to uncertainties.

The results of quantitative studies also show that different feedstocks have different ILUC factors. Sugarcane ethanol has been pointed out as a biofuel with a low ILUC factor. The EC proposal to amend the RED and the FQD, however, is assuming that all food crops are at high ILUC risk.

This paper presents several evidences supporting the argument that sugarcane ethanol is a low ILUC risk biofuel. The first evidence this paper put forward is that Brazilian agriculture is undergoing a process of intensification and efficiency gains that reduces the need for converting new land to accommodate crops that are expanding (Figures 2, 3, 4, 5, 6, 9 and Table 1).

The second evidence discussed in this paper is that sugarcane is predominantly expanding over pastures used for cattle production, and pasture-fed cattle is the production system that is increasing productivity faster in the Brazilian agricultural sector. Leakage and cascading effects, therefore, cannot be assumed as a significant source of ILUC. In sugarcane expansion regions, cattle are facing cane-induced intensification (Figure 11).

The third evidence is that the development of integrated production systems aiming to maximize the efficiency is already happening in Brazil. Double cropping systems are growing fast allowing corn production to expand without any impact on land use change (Figure 7). Food production in sugarcane renovation areas is neglected by all models, which ignore the relevant land use credit that sugarcane ethanol ought to be receiving (Figures 10 and 12).

The fourth evidence is that sugarcane ethanol expansion has no impact on food prices. This is true not only because the sugar market has not suffered prices peaks because more cane has been used for ethanol, but also because historical data shows that sugarcane shortage leads to adjustments in the ethanol market and not in the sugar market (Figures 13, 14 and 15).

Sugarcane ethanol produced in Brazil is a low-ILUC feedstock, it is energy efficient, and it also uses residues more than any other feedstock (Table 2). Therefore, if cane is a food crop as well as a low-ILUC risk feedstock, the EC should introduce an intermediary category between conventional and advanced biofuels in its proposal for amending RED and FQD.

1. Introduction

The debate on land use changes caused by the expansion of food-based biofuels is still ongoing in academic circles, the private sector and in the policymaking arena. The European Commission (EC) took the most recent initiative to tackle this issue and published a new Directive proposal in the fall of 2012. Although still under scrutiny by the European Parliament and the Council, the amendments proposed to RED and FQD Directives indicate that the EC makes no distinction among feedstock that can also be used to produce food. Therefore, any biofuel produced from food crops, such as cereals and other starch rich crops, sugars, and oil crops is considered as a conventional biofuel and its participation to the EU 2020 renewable energy target in transport is limited to 5% because it creates additional demand for land. The intention of the EU authorities is to stimulate the growth of biofuels which production do not require agricultural land or may use land that is not suitable for producing food. They are named low-ILUC advanced biofuels, in opposition to the conventional ones.

Differently from the EC, the US Environmental Protection Agency (EPA), another government body agency that has also adopted measures to account for the emissions resulting from land use changes, distinguishes between conventional and advanced feedstock based on total emissions, including ILUC, and not based on land demand criteria. For EPA, thus, food-based biofuels might either be conventional or advanced depending on the level of total emissions reduction (direct and indirect) they promote. Sugarcane ethanol is considered as an advanced biofuels according to EPA, but it is conventional according to the EC. EPA, however, like the EC, is also seeking to promote the development of cellulosic biofuels as more a sustainable alternative.

Unlike the EC and EPA, the California Air Resource Board (CARB) does not distinguish between conventional and advanced biofuels. For CARB, biofuels are only differentiated according to their total GHG reduction capacity, explicitly accounting both direct and indirect emissions.

All of these agencies recognize that ILUC is directly associated to the potential intensification of current production. If the room for intensification is large, the displacement of feedstock for food, feed or fibers by biofuels will stimulate more intensification generating, therefore, less ILUC than if the intensification potential is low.

Besides yields increase, the EC, EPA and CARB have considered land use intensification in the sense that the quantitative analysis used to estimate ILUC values show pastureland being converted into crop land, which reduces the demand for land occupied with native vegetation (mainly primary forest, savannah and natural grasslands).Therefore, total emissions estimated by the EC, EPA and CARB include results from biofuels-stimulated land use intensification.

Although there are differences within the EC and EPA approaches to estimate land use emissions[1], it is almost inevitable to compare their assumptions and the ILUC factors they come up with. The ILUC values proposed by the EC are much higher than the ones adopted by EPA. In the case of sugarcane ethanol, according to our calculation, the ILUC factor

[1] There are several other differences between the EC and EPA approaches to estimate LCA (direct and ILUC emissions), especially in the case of ILUC, that are not the subject of this paper.

adopted by EPA is 4.1 gCO2/MJ, while the EC's value is 13 gCO2/MJ. Intensification is key to explain the differences in ILUC emissions magnitude. CARB is also revising its ILUC estimations. The preliminary ILUC factor released in 2009 was 46 gCO2/MJ. The interim report indicates that original numbers would fall by 71%[2,3].

The differences in the magnitude of ILUC estimates, however, are not the most relevant fact. The EC proposal to limit the use of so-called conventional biofuels without considering a low-ILUC risk food crop category discriminates directly biofuels made from feedstock that are more efficient in direct emission savings and that have a very positive energy balance, which is the case of sugarcane. In the opposite direction, although EPA has also considered emissions from ILUC in total emissions savings, the agency has rewarded sugarcane as the most efficient feedstock considering it advanced rather than conventional. Not coincidently, EPA considers sugarcane ethanol as an advanced biofuel. Even considering initial ILUC results for sugarcane (and not the most recent figures), sugarcane ethanol is the main biofuel foreseen by CARB to fulfill the Low Carbon Fuel Standard objectives.

RED typical values for direct emissions savings clearly show that sugarcane ethanol (71% emissions savings) is more efficient than any other food crops. The only pathway with similar values is wheat ethanol when a Combined Heat and Power (CHP) plant runs with straw (69% emissions savings). Those are the only pathways combining the utilization of a food crop to produce biofuel and the use of its residue to generate energy destined to the refining process. Why a process using food crop residues (straw for wheat and bagasse for sugarcane) as an energy source should be treated differently from a process that produces biofuel directly from residues, such as used cooking oil or municipal organic waste? According to the EC, this distinction is justified since food crop necessarily causes ILUC effects.

The purpose of this paper is to present a set of evidences demonstrating that sugarcane ethanol produced in Brazil should not be considered as a conventional biofuel and, therefore, it should not be limited to achieve the RED targets. The evidences discussed here demonstrate that sugarcane ethanol produced in Brazil is a low-ILUC feedstock and its production is more energy and land efficient than any other food feedstock. The evidences are associated to the following topics: intensification and efficiency gains in the Brazilian agriculture; availability of land in Brazil; land use changes caused by the expansion of sugarcane ethanol; integrated production systems utilizing sugarcane energy content, and no impact on food prices.

2. Intensification and efficiency gains in the Brazilian agriculture

Brazil is one of the few countries combining availability of agricultural land not occupied with natural landscapes (notably pastures), large amount of protected native vegetation (tropical forest and savannahs), strong conservation laws based on "command-control" enforcement,

[2] Given that CARB is also revising the methodology to estimate emissions factors, the interim report brings results in hectares/1000 gallons rather than gCO2/MJ. The ILUC factor in ha/1000 gallons in the interim report is 0.16, being 0.55 the original value.

[3] Tyner, Wallace E. Calculation of indirect land use change (iluc) values for low carbon fuel standard (lcfs) fuel pathways. Interim Report. CARB contract 10-408. September 2011.

and an agricultural sector with high productivity levels[4]. This unique combination, probably not shared by any other developing country, has several implications on the ILUC discussion.

For a given land demand necessary to meet an additional agricultural-based biofuel production, the size of the ILUC effect, measured in hectares of land, will depend on four variables:

(i) The level of land intensification that is taking place in the country where the biofuel production is expanding. Biofuel expanding in countries presenting higher levels of intensification, induced or not by biofuel feedstock, can reduce the overall ILUC effects.
(ii) The availability of land in the country where the biofuel is expanding. Countries with more available land for agriculture will respond faster and more strongly to higher prices than regions with less available land. The rationality here is that in regions with more available land, land prices are lower and land supply is higher. It can be expected, therefore, that the indirect effect caused by the expansion of biofuel in a region with land availability will be likely located in the same region.
(iii) The level of yields in the regions where the indirect effect will take place. If ILUC takes place in a low yield region compared to the yield in a region where biofuel is expanding, more land will need to be converted to off-set the displacement caused by biofuels expansion.
(iv) The type of agricultural activity the biofuel feedstock is directly displacing. If an annual crop is displaced for a given historical yield growth and yield regional level, a proportional amount of land tends to be brought into production (it can come from pastureland or native vegetation displacement, depending on the case). However, if pastureland is displaced, given the high potential for cattle intensification presented in some countries, much less land will be necessary to off-set the biofuel expansion.

Brazil has around 198 million ha of pastureland (Figure 1), of which, according to our calculations, 180 million ha is used for cattle production[5]. Almost one third of the 180 million ha is suitable for crops. Crop land is also around one third of pastureland. Differently from other agricultural producing regions, in which the stock of land for crops is concentrated in land occupied with native vegetation, stock of land in Brazil is also concentrated in pastures. While land covered with native vegetation only becomes productive, from an agricultural perspective, if converted, pastures will be intensified and become increasingly more productive.

Brazil has 554 million ha of native vegetation (Figure 1). Around 210 million ha are protected for conservation units and indigenous reserves purpose. The difference - 344 million ha - is native vegetation located in private properties. Around 274 million ha out of this 344 million ha are protected by law (riparian areas, high slopes areas, top of hills areas, and areas allocated to Legal Reserve[6]), and cannot be deforested or converted into productive use.

[4] Deininger, K; Byerlee, D.; Lindsay, J.; Norton, A.; Selod, H.; Stickler, M. 2011. Rising Global Interest In Farmland: Can It Yield Sustainable and Equitable Benefits? The World Bank, Washington. 266 p.

[5] According to Figure 1 pastures occupy 198 million ha. Figures 7 and 8 indicate 180,7 million ha. The difference is due to the source of data: in Figure 1 pastures were measured from satellite information, while figures 7 and 8 combine Agricultural Census data with satellite information. We consider the information in figures 7 and 8 more appropriated because it was calculated based on the concept of pastures utilized for production.

[6] Legal Reserve is a requirement of the National Forest Code. Producers are required to keep conserved and set aside 20%, or 35%, or 80% of the farm size. The Legal Reserve is additional to the Permanent Preservation

Therefore, 87% of the 554 million ha of native vegetation is protected by law, either in conservation units and indigenous reserves, or as mandatory permanent preservation areas and legal reserve.

Brazilian environmental regulations, however, do not protect 100% of the remaining native vegetation of the country. Around 13% of the native vegetation can be legally converted under certain conditions. The pace at which this area (70 million ha) will be converted depends on the growth for agricultural products demand and the capacity of producers to comply with all legal requirements to obtain deforestation permits. Considering the current deforestation rate – 1.1 million ha per year (Figure 2) -, the depletion of this stock of land would require 63 years. When combining pastures (198 million ha according to Figure 1) with native vegetation that can be legally converted, it becomes clear that land competition is not a major issue for Brazilian agriculture and biofuel production.

There are four key facts about Brazilian agriculture that must be emphasized as they have strong implications for the ILUC analysis:

(i) The expansion of biofuel is not undermining the expansion of food, feed and fiber crops;
(ii) Brazilian agriculture is intensifying: pasture productivity is growing, double cropping systems are expanding and sugarcane energy yields (MJ/ha) is increasing;
(iii) Indirect effects caused by the expansion of biofuel in Brazil must occur predominantly within Brazil.
(iv) Soil carbon balance resulting from the conversion of pastures into sugarcane must be accurately accessed.

While sugarcane area has increased by 92% in the last 10 years, annual crops and commercial forest have also undergone a very strong expansion in the same period (Sources: LAPIG/UFG, PRODES/INPE, SOS Mata Atlântica, Ministry of Environment.
Note: Official data for Savanna deforestation is available until 2010.

Areas-PPA (riparian areas, high slopes areas and top of hills areas) requirement. The different levels of requirement are determined according to the State and the Biome on which the farm is located. Unlike the PPAs, the legal reserve is not spatially located and, therefore, we refer to areas allocated to legal reserve rather than areas of legal reserve.

Figure 3). As expected, due to the strong growth of the ethanol market in Brazil, sugarcane area has expanded relatively more than other agricultural land use. This expansion, however, has not constrained annual crops and commercial forests to expand in order to meet the increasing demand for their products.

Brazil is one of the most efficient agricultural producers in the world. The total Factor Productivity (TFP) in the Brazilian agriculture has increased by 3.63% per year from 2000 to 2007, more than any other agricultural producing country or region (Figure 4)[7]. TFP annual increase rates for North and South Europe, for example, were 0.82 and 0.91%. Other Latin American countries, such as Argentina, Chile, Paraguay and Uruguay faced a 2.03% annual increase.

Yields by sector also show strong growth. In the beginning of the 80s, grains production and planted area were about the same level, around 40 million tons and hectares. Brazilian current levels are 166 million tons for crop production, but only 51 million hectares for planted area (

[7] Alston, J.M., B.A. Babcock, and P.G. Pardey eds (2010). The Shifting Patterns of Agricultural Productivity Worldwide, CARD-MATRIC Electronic Book, Center for Agricultural and Rural Development. The Midwest Agribusiness Trade Research and Information Center, Iowa State University, Ames, Iowa. Available at: www.matric.iastate.du/shifting_patterns.

Figure 5).

Sugarcane, sugar and ethanol also faced yields increase. Cane yield has increased 17 ton/ha since 1990 (29% from 1990 to 2010)[8]. Sugar and ethanol yields are measured by the total recoverable sugar (TRS) per ton of sugarcane. TRS might also be calculated per hectare. Increasing TRS per hectare is a combination of increasing cane yield and increasing energy extraction in the mills. While cane yield is used to measure the efficiency gain in the agricultural stage, TRS yield per ha reflects the efficiency gain in the industrial stage. TRS has increased approximately 39% from 1990 to 2012 (Figure 6). Another important measure to increase the efficiency gain is the generation of electricity surplus from cane bagasse. From 2005 to 2012 the electricity surplus jumped from 1 to 11 Twh/year, representing a 600% growth per ton of crushed cane.

Brazil is also the top country in commercial forests yields. Brazil's mean annual increment for eucalyptus and coniferous production is 40.1 and 36.9 cubic meters per year, much higher than any other world producer of commercial forests[9].

Although yields gains in grains and sugarcane are impressive, double cropping and productivity gains in grass-fed livestock are more relevant examples to illustrate the intensity of land intensification process happening in Brazilian agriculture.

Corn production in Brazil has grown 3.4 times from 1990 to 2013. There are two corn production systems in Brazil: summer corn (or first crop) and winter corn (second crop). Approximately 75% of the corn production expansion is explained by the second crop. Currently, the second crop represents more than 50% of the total production (

[8] It is worth mentioning that yields in the last two seasons (2011 and 2012) were negatively affected by weather problems and low investment in cane fields.

[9] ABRAF. 2012. Anuário estatístico da ABRAF 2012 ano base 2011. Associação Brasileira de Produtores de Florestas Plantadas. Available at www.abraflor.org.br/estatisticas.asp.

Figure 7). Without the double cropping technology development, which is, by the way, being adopted for cotton as well, summer corn area should be 7.1 million ha larger. Due to the growth of winter corn, summer corn area is starting to reduce.

Winter corn is usually planted after soy, in an integrated system, to take advantage of the short cycle of bean. By combining soy and winter corn yields, Brazilian regions that are able to adopt this production system are probably the most productive lands of grains in the world.

While winter corn saved 7.1 million since the double cropping systems was adopted (mostly 1990), pasture intensification saved 3.2 million ha from 2002 to 2012 (Figure 8). According to the Brazilian Agricultural Census, pasture area had increased in Brazil until 1985, reaching 179 million ha. Ten years later (1995-96), when the next Census was published, pasture area had reduced to 177 million ha. In the last Census (2006), total pasture area was 160 million ha, a 17 million ha reduction.

Pasture area reduction, however, does not guarantee livestock production intensification. Together with pasture reduction, production must grow in order to achieve intensification. From 2002 to 2012, although pasture area has been reduced by 3.2 million ha, beef production has increased from 38 kg/ha to 54 kg/ha (

Table 1)[10]. Therefore, pastures are not only freeing land for crops and planted forest, but they are also not constraining the increase of beef and milk production.

The strong process of intensification faced by Brazilian agriculture associated to the large stocks of land still available in the country explain why crop land in Brazil, even in the presence of increasing yields, is growing more than in other regions (Figure 9). Among the most important agricultural producing and exporting regions in the world, Brazil is the country with the largest crop land expansion in recent years. Oilseeds and grains area has increased more than 8 million ha in Brazil. For the same period, this area was reduced in the EU and Russia/Ukraine region, and has increased by 2 million in the US.

Area in China has increased in similar levels than Brazil, but it is well known that China has strong constraints in land availability. Sub-Saharan Africa area expansion was larger than Brazil, but the region is not integrated to the world market, which means that this expansion was mainly driven by domestic demand and not by world demand. Argentina is the only country with patterns comparable with the ones in Brazil.

The main conclusion underlying these figures is that if more land needs to be brought into crop/forest production due to the increasing demand for agricultural products, we can expect that: the majority of this land expansion will take place in Brazil, and a large share of land conversion within Brazil ought to be pasture.

Indirect effects caused by the expansion of biofuels in Brazil must occur predominantly within Brazil since Brazil responds, at the margin, faster than other agricultural exporting regions in terms of bringing new land for crops production. Given that the expansion of crops is converting more pastures than native vegetation, and that crop yields in new areas are very similar to consolidated areas, ILUC effects tend to be lower in Brazil than in other biofuel producing regions. Simulations with the objective to estimate land use changes confirm this logic[11]. This conclusion is reinforced if the biofuel production is expanding in Brazil. Therefore, it is reasonable to expect that the large majority of ILUC caused by the expansion of Brazilian sugarcane ethanol takes place within Brazil.

Although it is true that Brazil responds by bringing more land than many other producing regions in the world, it is a fact that this affirmation is not necessarily true for all agricultural sectors. Hypothetically, if palm oil is more competitive than soy oil, and soybean is displaced in Brazil by sugarcane, marginally a palm producer country should offset displacing Brazil in the vegetable oil market. But if sugarcane is displacing pastures, which accounts for 69.7% of the cane expansion from 2005 to 2009 in Brazil[12] (Adami et al., op. cit.), and livestock production is intensifying, there are no evidences supporting ILUC effects outside Brazil due to the expansion of sugarcane. In the case of pastures displacement in Brazil, given that beef

[10] As shown in Figure 8, beef production per hectare has been almost constant since 2007. This is due to a reduction in the numbers of female cattle, reducing the capacity of the herd to rebuild. Current numbers indicate that the herd rebuilding is happening, which will lead to an increase in beef production.

[11] Laborde, D. 2011. Assessing the Land Use Change Consequences of European Biofuel Policies: Final Report. ATLASS Consortium.
EPA. 2010. Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis. United States Environmental Protection Agency. EPA-420-R-10-006.

[12] Adami, M.; Rudorff, B. F. T.; Freitas, R. M.; Aguiar, D. A.; Sugawara, L. M.; Mello, M. P. (2012). Remote Sensing Time Series to Evaluate Direct Land Use Change of Recent Expanded Sugarcane Crop in Brazil. Sustainability 2012, 4, 574-585 (doi:10.3390/su4040574).

production growth and the reduction of pasture are taking place simultaneously, none or very small ILUC effect shall be expected. And if there is some ILUC, that effect should be located within Brazil.

According to the 2006 Agricultural Census, Brazil had in 2006 9.9 million ha of degraded planted pastures. Although expressive, there are indications that this number is underestimated. A more precise indication of the amount of pastures under degraded conditions is the Federal Government ABC Plan[13]. The ABC Plan, launched in 2010, is committed to stimulate the recovery of 15 million ha of degraded pastures. We believe that this figure is more accurate and represents the reality of the planted pastures in degraded conditions.

It is essential to note that degraded pastures have much lower soil carbon stocks than improved pastures. Although pastures, depending on how they are managed, soil types and some specific conditions have potential to be a carbon sink when displacing native savannas, the majority of studies taking in consideration Brazilian conditions show that pastureland has carbon stocks per hectare that are 85% lower than forests, in average, and 45% lower than savanna (Maia et al., 2009 and Lisboa et al., 2011).[14]

Additionally, studies in Brazil are showing that soil carbon stocks in improved planted pastures, especially in the regions where sugarcane has been expanding, have similar magnitude than sugarcane (Amaral et al., 2008; Galdos et al., 2010, Joaquim et al., 2011)[15].

3. Cane ethanol and land use

This section discusses the following topics:

(i) Direct effect of sugarcane expansion in Brazil.
(ii) Contribution of the area under renovation to increase food crops production.
(iii) Brazilian policies in place to manage the sugarcane expansion (zoning system).
(iv) Options to integrating sugarcane and cattle production.

[13] MAPA; MDA (2011). Plano Setorial de Mitigação e de Adaptação às Mudanças Climáticas para a Consolidação de uma Economia de Baixa Emissão de Carbono na Agricultura: Plano ABC (Agricultura de Baixa Emissão de Carbono). Ministério da Agricultura, Pecuária e Abastecimento; Ministério do Desenvolvimento Agrário (available at http://www.mma.gov.br/clima/politica-nacional-sobre-mudanca-do-clima/planos-setoriais-de-mitigacao-e-adaptacao).

[14] Maia S. M. F.; Ogle S. F.; Cerri C. E. P. et al. (2009) Effect of grassland management on soil carbon sequestration in Rondonia and Mato Grosso states, Brazil. Geoderma, 149, 84–91.
Lisboa, C. C.; Butterbach-Bahl, K.; Mauder, M.; Kiese, R. (2011). Bioethanol production from sugarcane and emissions of greenhouse gases – known and unknowns. GCB Bioenergy (doi: 10.1111/j.1757-1707.2011.01095.x).

[15] Amaral, W. A. N.; Marinho, J. P.; Tarasantchi, R.; Beber, A.; Guiliani, E. (2008). Environmental sustainability of sugarcane ethanol in Brazil. In: Zuurbier and Vooren (coord.), Sugarcane ethanol: contributions to climate change mitigation and the environment. Wageningen: Wageningen Academic Publishers.
Galdos, M. V.; Cerri, C. C.; Lal, R.; Bernoux, M.; Feigl, B.; Cerri, C. E. P. Net greenhouse gas fluxes in Brazilian ethanol production Systems. GCB Bioenergy (2010) 2, 37–44, doi: 10.1111/j.1757---1707.2010.01037.
Joaquim, A. C.; Bertolani, F. C.; Donzelli, J. L.; Boddey, R. M. (2011). Organic Carbon Stocks in Soils Planted to Sugarcane in the Mid-South Region of Brazil: A Summary of CTC´s Data, 1990-2009. Centro de Tecnologia Canavieira [Centre for Sugarcane Technology]. Technical Report, Piracicaba, São Paulo, 2011. Available at: http://www.unica.com.br/download.php?idSecao=17&id=18105453

The South-Central region of Brazil, where 87% of total sugarcane is grown, is monitored with remote sensing since 2003[16] by the Canasat Project. Areas of expansion, renovation, where pre-harvest burning is used and direct land use change are measured annually. Total sugarcane area in the South-Central region has increased 4.3 million ha from 2005 to 2012 (

[16] See http://www.dsr.inpe.br/laf/canasat/en/. Sugarcane data in Brazil are usually presented in market year. The year 2003 is equivalent to the market 2003/04, e.g., cane harvested in 2003 for the South-Central region and harvested in the end of 2003 and beginning of 2004 for the Northeast region.

Figure 10). Cultivated areas include areas under renovation (950 thousand ha in 2012). The majority of the expansion occurred from 2005 to 2009 (860 thousand ha a year on average).

A critical issue in sugarcane expansion dynamic is which types of land use cane is displacing directly. Analyzing cane expansion from 2005 to 2009 in the State of Sao Paulo and from 2007 to 2009 in other South-Central states (totalizing 3.2 million ha), one may observe that by 2000, 69.7% of this area was pasture and 25.0% was annual crop, with both accounting for 94.7% of Direct LUC due to sugarcane expansion (Figure 11). Out of the 69.7% pasture conversion, 35% was pasture converted to annual crops before being converted to sugarcane, and 65% was pasture converted directly to sugarcane. This transition from pasture to annual crops and then to sugarcane is a management practice commonly adopted to improve the physic-chemical soil characteristics of degraded pastureland (Adami et al., op. cit.).

As it is the case of double cropping (discussed in the previous section), sugarcane area under renovation is a topic not explicitly cited in the discussion as well as in the models simulations to assess impacts on food prices and ILUC. Cane area under renovation, however, is expressive (950 thousand ha in 2012,

Figure 12). The cane ratoon is renovated after 5 or 6 years of harvesting in Brazil. The main objective of this renovation is to recover yields and to promote crop rotation.

Roughly speaking, there are two types of cane seedling: year and a half (it requires one year and a half to become mature for harvesting); one-year cane and winter cane (they require one year to become mature for harvesting). The year and a half cane is planted in the beginning of the harvesting season and harvested by the end of the season after the next. One common practice is to plant leguminous crop (such as soybean, peanuts or kidney beans) in the year and a half renewal area of cane during summer. The renewal of sugarcane, therefore, increases food production and helps to mitigate the food versus fuel concerns[17].

The sugarcane area under renovation should be treated in the same way as DDGS for corn and wheat, and beet pulp for sugarbeet since it also promotes the production of food and feed crops, and reduces ILUC. This contribution of the area under renovation (1/6 of sugarcane area), however, is not included in models such as MIRAGE and GTAP, and it is not considered by policymakers when assessing the ILUC of sugarcane ethanol.

Unlike corn, wheat and sugarbeet that receive credit for avoided ILUC associated to the feed co-product, agricultural products produced in cane area under renovation are counted in the total production of the product, but are not considered in association with sugarcane. In its 2011 study, David Laborde says: “Therefore, sugar cane is not benefiting from a LUC reduction for its co-product in our framework[18]”. Sugarcane has no ILUC credit because the co-product is not from sugarcane, but from the renovation sugarcane area. Additionally, given that models are projecting sugarcane allocated area including renovation area, the renovation area is counted twice: in cane area and in other agricultural product area.

The agricultural production in the area under renovation, nevertheless, should be taken as sugarcane ILUC credit. An intuitive way to think about this credit is the following: the sugarcane ethanol ILUC should be reduced by 1/6 of the sugarcane expansion area. Another way is to keep in mind that each hectare of sugarcane brings together 1/6 of food production.

In 2008, the state of Sao Paulo, responsible for 68% of sugarcane harvested area at the time, launched the agro-environmental zooning for sugarcane[19]. The cane zoning had been incorporated in the state regulations for licensing new sugar and ethanol plants and cane plantations[20]. In 2009 the Federal Government, through the Ministry of Agriculture, also undertook a similar initiative and launched the national agro-environmental zooning for

[17] In the case of the one year cane and winter sugarcane, seedlings planting take place in the same crop year of the harvesting and, therefore, the area under renovation is occupied only with sugarcane. In general, one year sugarcane is planted in the beginning of the raining season (in the ending of the cane season) and harvested in the next season. It is important to note that Canasat data on area under renovation capture only one and a half year sugarcane.

[18] Laborde, D. (2011, op. cit.).

[19] All information (reports, methodologies, maps, regulations, etc.) regarding the State of São Paulo sugarcane zooning is available at http://www.ambiente.sp.gov.br/etanolverde/zoneamento-agroambiental/.

[20] Resolução SMA-088 de 19 dezembro de 2008 (available at http://www.ambiente.sp.gov.br/wp-content/uploads/resolucao/2008/Resolucao_SMA_88_2008.pdf).

sugarcane[21]. The logic behind the zoning initiatives is the same: to classify areas according to their agronomic suitability for sugarcane cultivation, subject to environmental limitations and constraints (no go areas) with the purpose of managing the expansion.

In the state of Sao Paulo zoning, the main environmental limitations are related to areas with medium priority for protecting biodiversity corridors and areas under critical watersheds. Areas with imposed constraints are those within conservation units, with high conservation value areas and areas with high vulnerability for groundwater conservation.

Environmental constraints imposed by the federal zoning define the following categories as no go areas: Amazon and Pantanal biome, forest remnants, conservation units, indigenous reserves and permanent preservation areas. Meanwhile, zoning in areas suitable for cultivation divides them according to their current use (crop, crop/pasture and pasture) and level of agronomic suitability (high, medium and low).

The development of cane-cattle integration systems is another alternative to promote cane-induced food production and zero ILUC risk. In a cane-cattle integration system, cane bagasse, hydrolyzed cane bagasse, molasses and yeasts, plus soybean and corn produced in the area under renovation, are used to feed beef cattle in feedlots finishing systems[22]. This integration system would deepen the intensification process that is already happening in areas where sugarcane and grains are expanding through pastureland conversion.

Although it is possible to build a business case, several conditions must be met to allow cane-cattle integration systems to develop: there must be availability of young animals (heifers and steers) in the region to finish them in a feedlot system; the ethanol/sugar mill must have surplus of bagasse, which happens only if the steam production system is highly efficient; there must be feed availability in the region, specially soy crushers to supply soy meal from the soy produced in the rotation area. Therefore, although the cane-cattle integration systems have been often quoted as an ideal solution to mitigate any ILUC risk, the conditions for implementing these integration systems in large scale in Brazil do not prevail yet.

Additionally it is also important to mention that energy yields are much higher in the CHP process than in the bagasse to feed process. An efficient CHP plant has a yield of 40% to 50%, which means that 2 to 2.5 energy units of bagasse generate 1 unit of steam and electricity. On the other hand, this relation is 40 to 1 when bagasse is used as one ingredient of feed in confined system for finishing cattle[23].

Box: Comments on the 2011 IFPRI Study[24]

[21] All information (reports, methodologies, maps, etc.) regarding the national sugarcane zooning is available at http://www.cnps.embrapa.br/zoneamento_cana_de_acucar/.

[22] CGEE (2010). Estudo de Sustentabilidade da Produção de Etanol de Cana-de-Açúcar – Fase II: Relatório Técnico Final. Centro de Gestão e Estudos Estratégicos. 395 p.

[23] The typical system in Brazil is to finish a steer confined 90 days in a feedlot. The feed conversion in this 90 days period is around 9.8 kg of feed per 1 kg of meat (carcass weight equivalent, with 55% carcass yield). Given that bagasse has 2.25 more heating power than bovine meat, the conversion is 40 units of energy of bagasse per 1 unit of energy in meat. On the other hand, even with this low feed conversion, bagasse monetary value is almost the double when it is used for feed rather than for generating steam and electricity. This is due to the fact that the market value for the energy in the meat is much higher than the market value for electricity.

[24] Laborde, D. (2011, op. cit.).

The 2011 version of the IFPRI study has brought several and important improvements if compared to the 2010 study[25]. The improvements related to land use dynamics in Brazil are noteworthy and are aligned with our concerns expressed in the 2010 EU Public Consultation on Indirect Land Use Change[26]. However, four aspects of the MIRAGE model should still be improved:

- The double cropping system with the integration of soy and corn is not represented accurately in Mirage. Indirectly, the high yields scenario simulated could be justified based on the double cropping, but this system is not discussed in the report;
- The sugarcane area under renovation is not explicitly modeled and, therefore, cane ethanol is not receiving any credit for the food produced within the renovation area;
- The study assumes that new areas have lower yields if compared with traditional ones. This assumption makes sense in regions that will incorporate marginal and low suitable agricultural land. This is not the case in Brazil where new areas, after a few years of cultivation, have very similar yields to traditional areas;
- The degree of pasture intensification obtained by IFPRI in the simulations indicates that in the future it will be lower than the historical trends of intensification. In this sense, the parameters driving competition for land between cane and pastures ought to be revised.
- Elasticity of land extensification, which are linked to the previous topic, shall be considered too high compared to the decreasing rate of deforestation observed in Brazil since 2004.

4. Cane ethanol: co-products and food market

Land use changes, although very important, are not the only topic that must be addressed in order to understand the sustainability of agricultural feedstock used in biofuel production. It is also necessary to evaluate the feedstock capacity to generate co-products and to what extent the food market is affected by the use of biofuel feedstock. Specifically in the case of sugarcane produced in Brazil, there are two main evidences that make cane ethanol unique with respect to other biofuel produced from food crops:

(i) Sugarcane crop is very efficient in terms of energy production, more than any other agricultural feedstock currently used in biofuel production. Consequently, although ethanol is produced using energy from cane fermentable sugars (e.g. the main product of cane), cane residues (bagasse and molasses) are integrally used in the industrial process.

(ii) Contrary to other food crops, in which biofuels can compete with food in the market, the sugar market has supported ethanol expansion in Brazil. In the case of cane ethanol, market evidences show that without sugar, ethanol would not be produced competitively. Additionally, if the supply of sugarcane is short, demand´s adjustments usually occur in the ethanol market rather than in the sugar market.

Among the main food crops used for biofuel production, sugarcane has the highest energy content per hectare (Table 2): 444 GJ/ha, much higher than sugarbeet and palm (fresh fruit bunches), and almost 6 times higher than wheat and rapeseed.

[25] Al-Riffai, P; Dimaranan, B, Laborde, D. (2010). Global Trade and Environmental Impact Study of the EU Biofuels Mandate: Final Report. Atlass Consortium.

[26] Nassar, A. M; Gurgel, A. C.; Harfuch, L. et al. (2010). European Commission Public Consultation on Indirect Land Use Change: Responses to the Consultation Document. Document submitted to the European Commission.

Differently than the other feedstocks, sugarcane, already very efficient in energy yield per hectare, will increase even more its energy yield when bagasse and straw start to be used for producing ethanol. Although current biofuel production uses more than 50% of the energy content of sugarbeet, wheat, corn, rapeseed and palm, they have already achieved their limit in biofuel production since the remaining energy contained in the feedstock is delivered to the food market. That is why sugarbeet, corn and wheat receive avoided ILUC credits (as discussed in section 2).

Sugarcane potential to produce biofuels and bioenergy (including other products than bioliquids) is much higher than other feedstocks. This difference in potential may be measured comparing energy balances. While sugarcane ethanol generates 12 units of renewable energy for each unit of fossil energy consumed, other feedstock and process do not exceed 3.5 (the only exception in Table 2 is wheat ethanol with straw being used in CHP plant). The two main reasons for this difference in energy balance are: (i) due to the high energy yield per ha, energy consumed per ton of sugarcane in the agricultural production is much lower; (ii) even more important is the integral use of sugarcane bagasse in the CHP plant generating all steam and electricity required by the sugar/ethanol plant.

Sugarcane ethanol produced in a refining process integrated to a cogeneration plant, which is the standard system in Brazil, has 40% of its energy coming from bagasse, even if fermentable sugar is the main feedstock[27]. Additionally, up to 15% of total ethanol volume produced comes from sugar residues (the molasses). No other food crop uses this amount of residues to produce biofuel as sugarcane does. Therefore, although sugarcane ethanol is not a biofuel entirely produced from residues, cane feedstock ought to be treated distinctively from sugarbeet, starch and oilseeds processes because of the high relevance of residues in its refining process.

The relationship between cane ethanol and sugar also presents specific features that make the issue of food versus fuel almost irrelevant when related to the case of sugarcane in Brazil. The main evidences supporting this argument are the following:

(i) Sugar prices have traditionally been higher than ethanol prices (Figure 13), which lead sugar/ethanol producers to divert cane to the sugar market. Given that sugar has been more profitable than ethanol, producers will aggregate more value to sugarcane if it is converted into sugar rather than ethanol. This is true even considering that costs to produce sugar are higher than ethanol in a sugar mill integrated with a distillery facility. Since ethanol blending into gasoline is mandatory in Brazil (between 18% and 25%), the flexibility to divert sugarcane to sugar is constrained but, as it is shown in the next topics, supply adjustments are always made in the ethanol market and not in the sugar market.
(ii) A common market practice in Brazil is to name the marketing years as maximum sugar or maximum ethanol. If sugar prices, in the same basis, are higher than ethanol, producers seek to maximize sugar production, even if it leads to larger idle capacity in fermentation facilities and distilleries. In the opposite case, they maximize ethanol

[27] Assuming 50% efficiency in the CHP plant.

production. From 2005 to 2012, 6 years were maximum sugar and only 2 were maximum ethanol.

(iii) Besides sugarcane, sugar and ethanol share industrial and logistics costs: cane transportation, crushing and juice treatment and concentration. The economy of scale of cost-sharing brings benefits to both sugar and ethanol. In general, sugar/ethanol mills in Brazil have higher crushing capacity than other sugar producing regions due to this cost-sharing. There are also synergies, such as cogeneration system: due to the large capacity on sugarcane crushing, boilers also need to have large capacity to process the bagasse. Larger scales, therefore, justify higher investments in CHP system. The possibility to produce two products from sugarcane makes the processing system more efficient. On top of that, given that sugar prices have been higher than ethanol prices, sugar maximization strategy reduces ethanol costs, although it also reduces ethanol supply.

(iv) Higher prices for sugar than for ethanol could lead to an opposite analysis: sugar prices are higher because of the ethanol market, which has inelastic demand due to mandatory blend; it is consuming more sugarcane, and reducing its availability. This analysis is accurate only for regions without E100[28] market in conjunction to flexible fuel vehicles (FFV). The existing situation in Brazil, especially after the penetration of FFV, is that market adjustment occurs in the hydrous[29] supply and demand, and not in sugar supply and demand. This results from the high flexibility of the Brazilian ethanol market due to flex cars and E100 availability.

Market adjustments might be observed in moments with short supply of sugarcane (Figure 14 and

[28] Flex fuels cars can run with 100% hydrous ethanol and fill their tanks in dedicated pumps available at all service stations in Brazil.

[29] Hydrous ethanol is used in FFV, while anhydrous ethanol is blended with gasoline.

(v) Figure 15). The last three seasons in Brazil (2010, 2011 and 2012) were short in sugarcane supply. Sugar production, nevertheless, has grown. Anhydrous ethanol production, because of the almost fixed blend, did not change substantially. The production of hydrous ethanol, however, decreased substancially, with ethanol share dropping deeply on the Otto´s cycle market to the profit of gasoline.
(vi) In an opposite situation, when sugarcane crushing was expanding (2005 to 2010), hydrous ethanol faced strong expansion. This expansion, however, has not jeopardized sugar production, which was also able to grow during that period.

5. Conclusions and Recommendations

Measuring the impacts of ILUC is still an issue far from being solved. There is a strong level of consensus in the scientific community, as well as among policymakers, that any increase in demand for agricultural feedstock, being it for biofuel or for food, will cause indirect effects associated to land use change. The view that it is necessary to continue investing in research to improve methodologies to measure ILUC is also shared. Nevertheless, economic models used to measure ILUC are being improved and, consequently, results are converging more and more.

ILUC factors, from recent studies using global models as the main tool to assess ILUC, range from 4 to 13 gCO2/MJ. They are much lower than the numbers published in 2008 when the ILUC discussion started to receive attention from the scientific community. Measured differently, results are also converging in ILUC per hectare of expansion, from 0.2 to 0.24 ha, and ILUC in ha per 1,000 liters of ethanol produced, from 0.23 to 0.38. Even with these improvements, there are still uncertainties about the results of the models leading policymakers to react differently to the concerns regarding indirect effects associated to biofuels policies. Therefore, although we know that ILUC is a reality, its magnitude is still subject to uncertainties.

Results from quantitative studies are also showing that different feedstock have different ILUC factors. Sugarcane ethanol has been pointed out as a biofuel in the lower range of ILUC factor. The EC proposal to amend the RED and the FQD, however, is assuming that all biofuels made from food crops have high ILUC risks.

This paper has presented several evidences supporting the argument that sugarcane ethanol is a biofuel with a low ILUC risk. The first evidence is that Brazilian agriculture is going through an intensification and efficiency gains process that reduces the need for new land conversion to accommodate crops that are expanding.

The second evidence discussed in this paper is that sugarcane is predominantly expanding over pastures used for cattle production, and pasture-fed cattle is the type of production system that is increasing productivity the faster in the Brazilian agricultural sector. Leakage and cascading effects, therefore, cannot be assumed as a large source of ILUC. In regions where sugarcane is expanding, cattle is facing a cane-induced intensification.

The third evidence is that integrated production systems aiming at maximizing land use efficiency is already a reality in Brazil. Double cropping systems are growing fast allowing the expansion of corn production without any impact on land use change. The food production in areas under sugarcane renovation is neglected by all models, which ignore the relevant land use credit that sugarcane ethanol ought to be receiving.

The fourth evidence is that sugarcane ethanol expansion has no impact on food prices. This is true not only because the sugar market has not suffered prices peaks since more cane has been used for ethanol, but also because historical data show that a shortage of sugarcane leads to adjustments in ethanol market and not in sugar market.

Sugarcane ethanol produced in Brazil is a low-ILUC biofuel, it is energy efficient and it also uses residues in a much larger amount than any other feedstock. Therefore, in order to accomodate food-based biofuels with a low ILUC risk, we suggest that the European Commission considers an intermediary category between conventional and advanced biofuels in the proposal for amending the RED and FQD.

Figure 1. Land Use in Brazil 2011

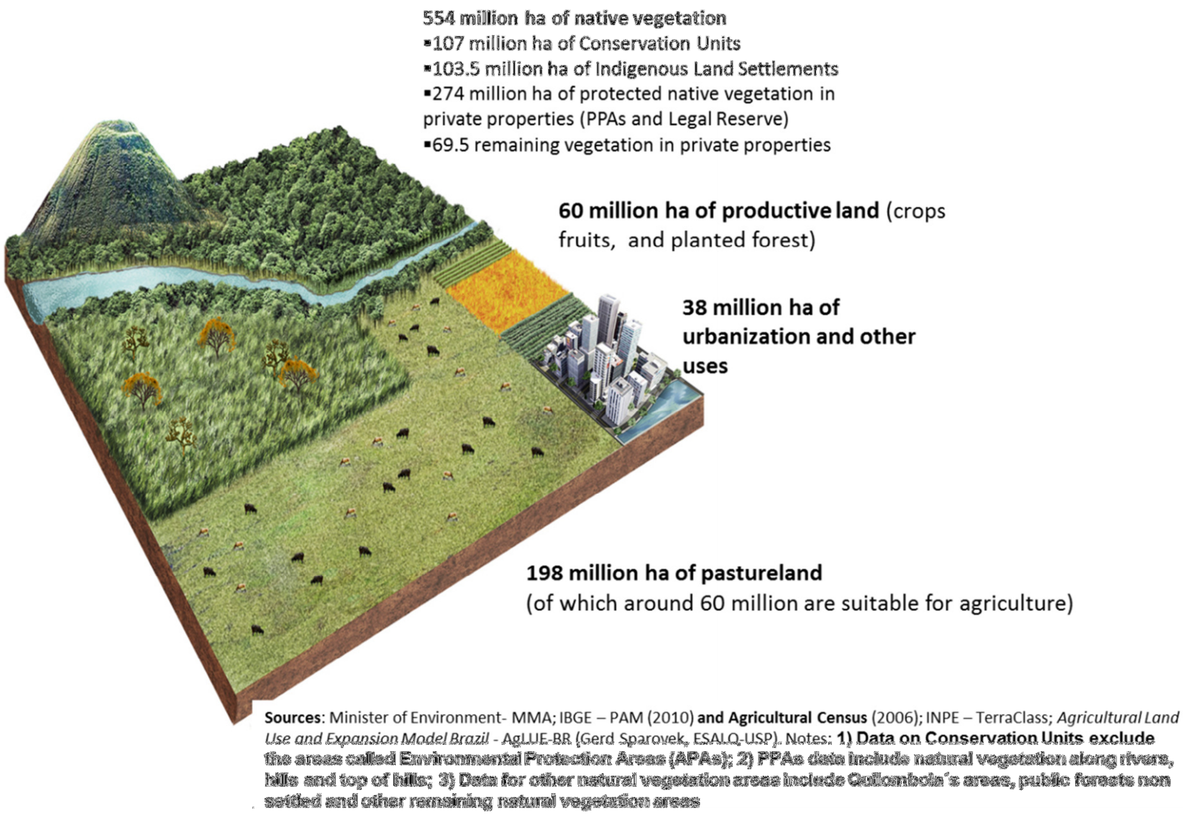
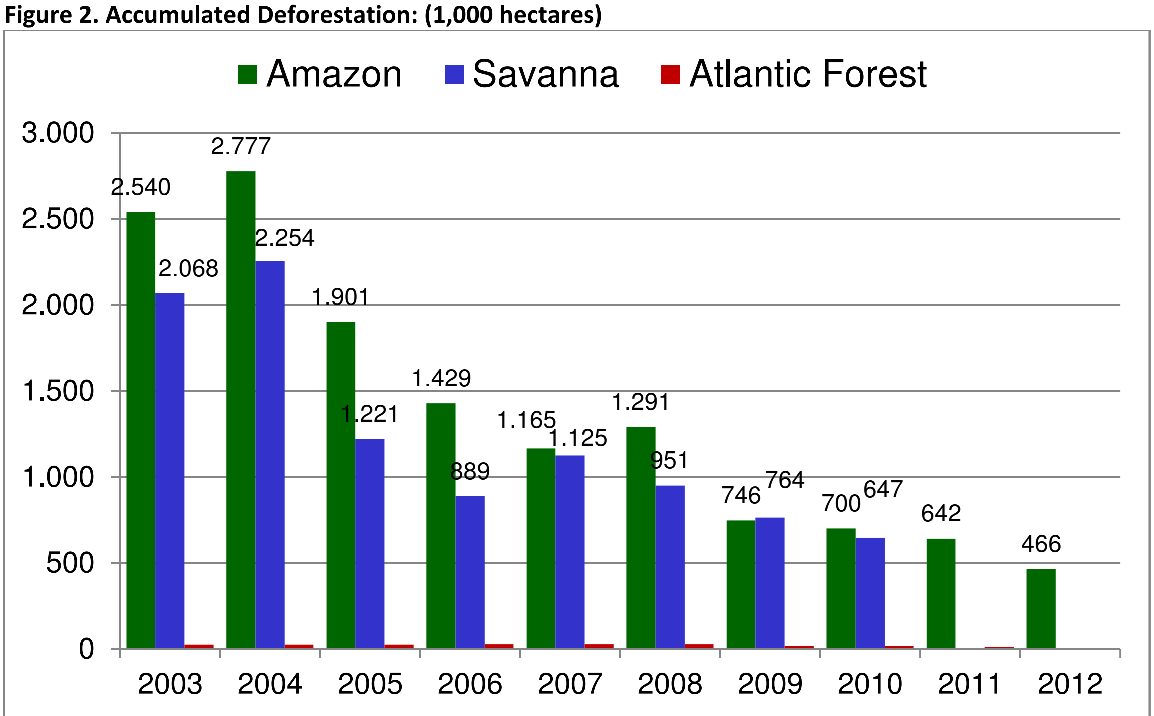
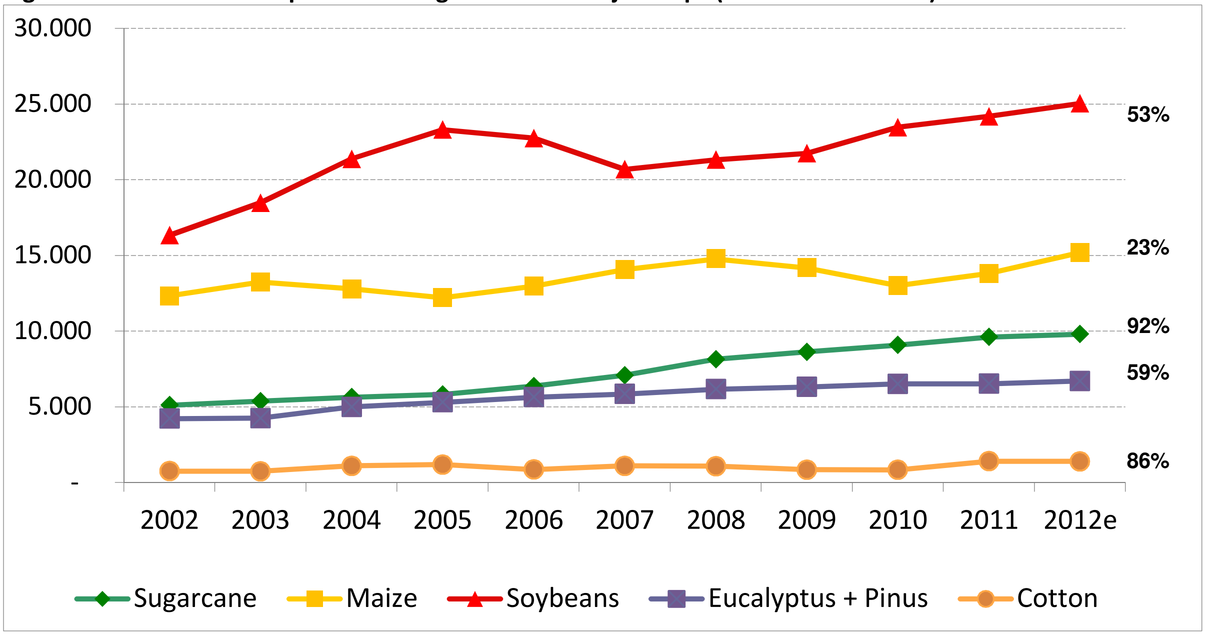


Figure 2. Accumulated Deforestation: (1,000 hectares)



Sources: LAPIG/UFG, PRODES/INPE, SOS Mata Atlântica, Ministry of Environment.
Note: Official data for Savanna deforestation is available until 2010.

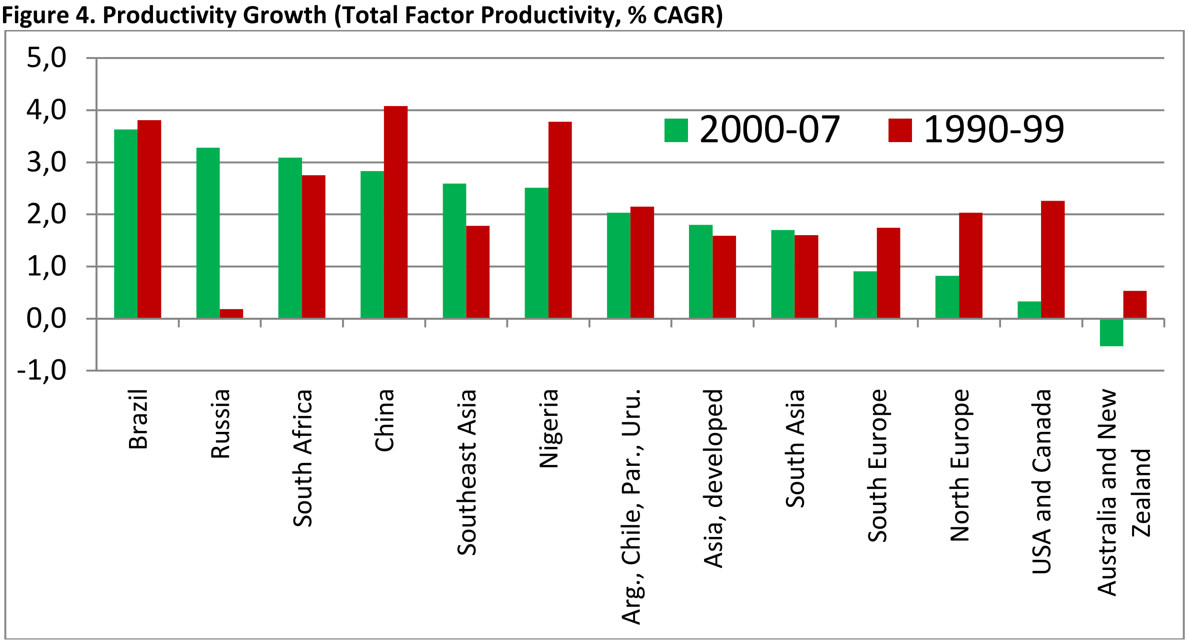
Figure 3. Simultaneous expansion of sugarcane and major crops (thousand hectares)



Sources: IBGE, ABRAF, UNICA

Note: Numbers on the right indicate relative growth from 2002 to 2012.

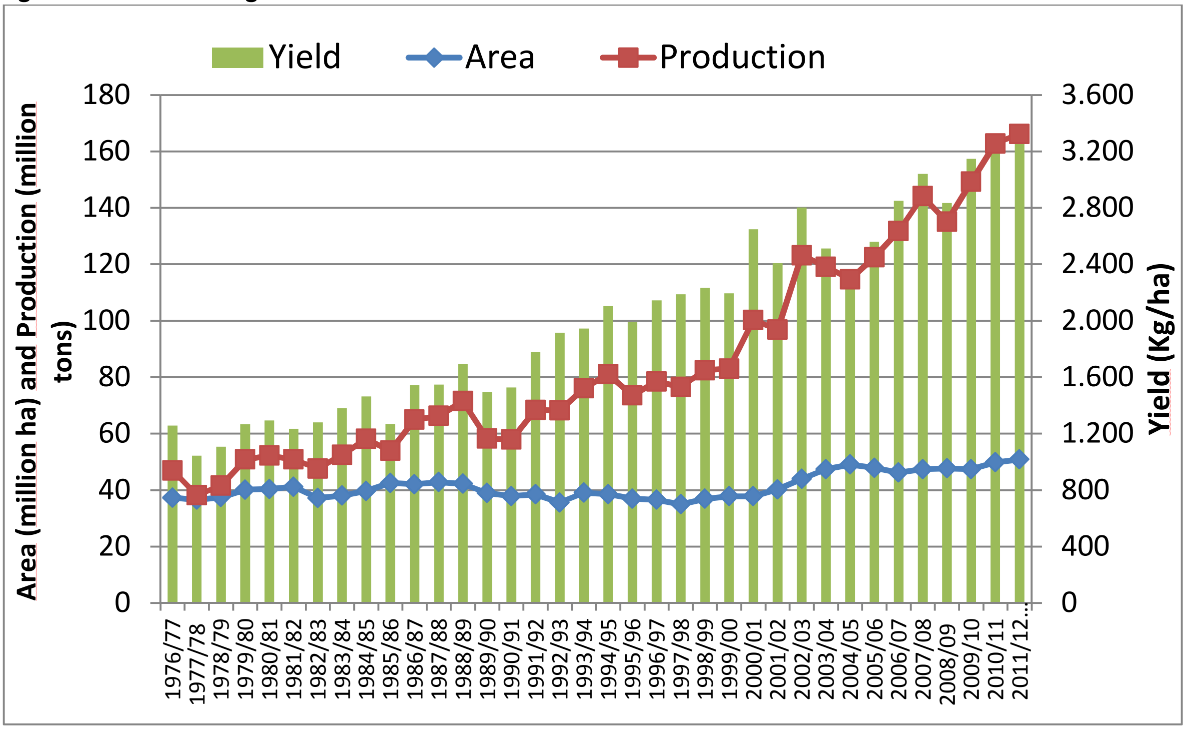
Figure 4. Productivity Growth (Total Factor Productivity, % CAGR)



Source: Alston et al. (2010, op. cit.).

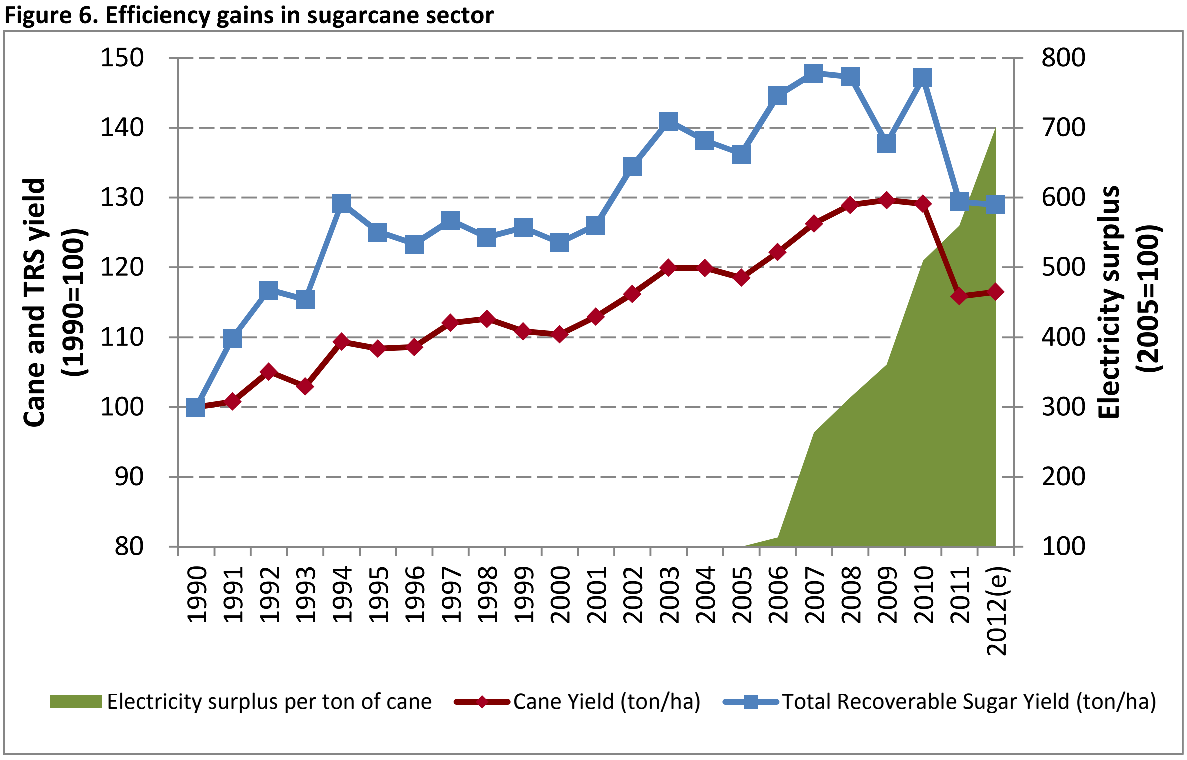
Note: TFP (total factor productivity): represents resources efficiency (labor, capital and land). Higher TFP, higher production efficiency.

Figure 5. Grains: Strong Yield and Production Increase



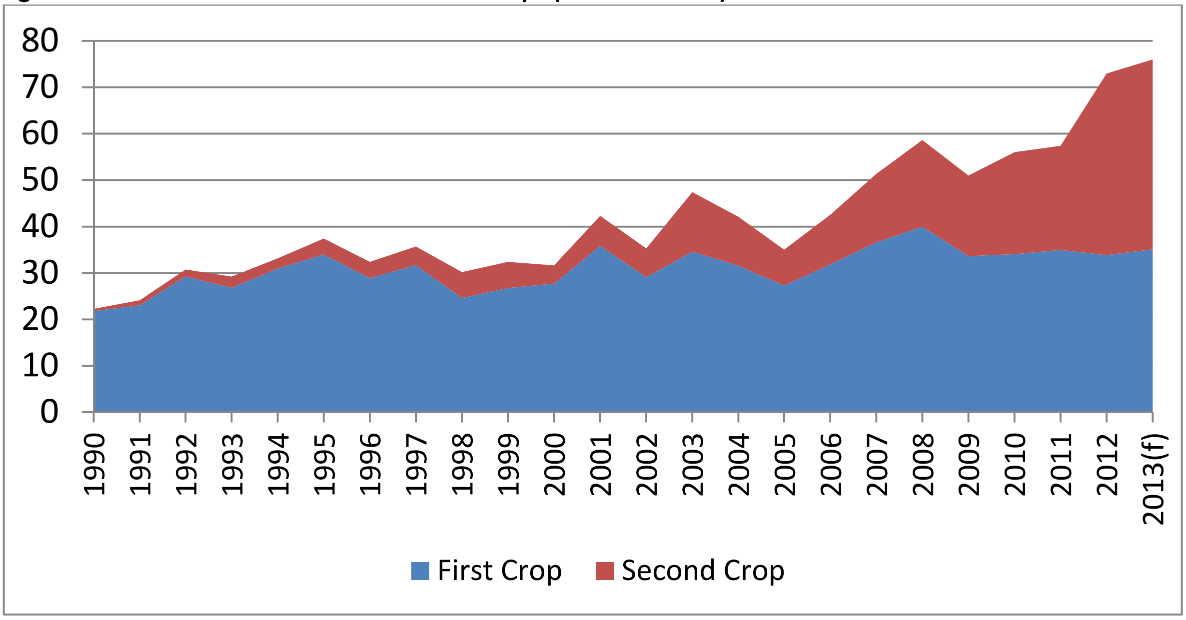
Source: CONAB.

Figure 6. Efficiency gains in sugarcane sector



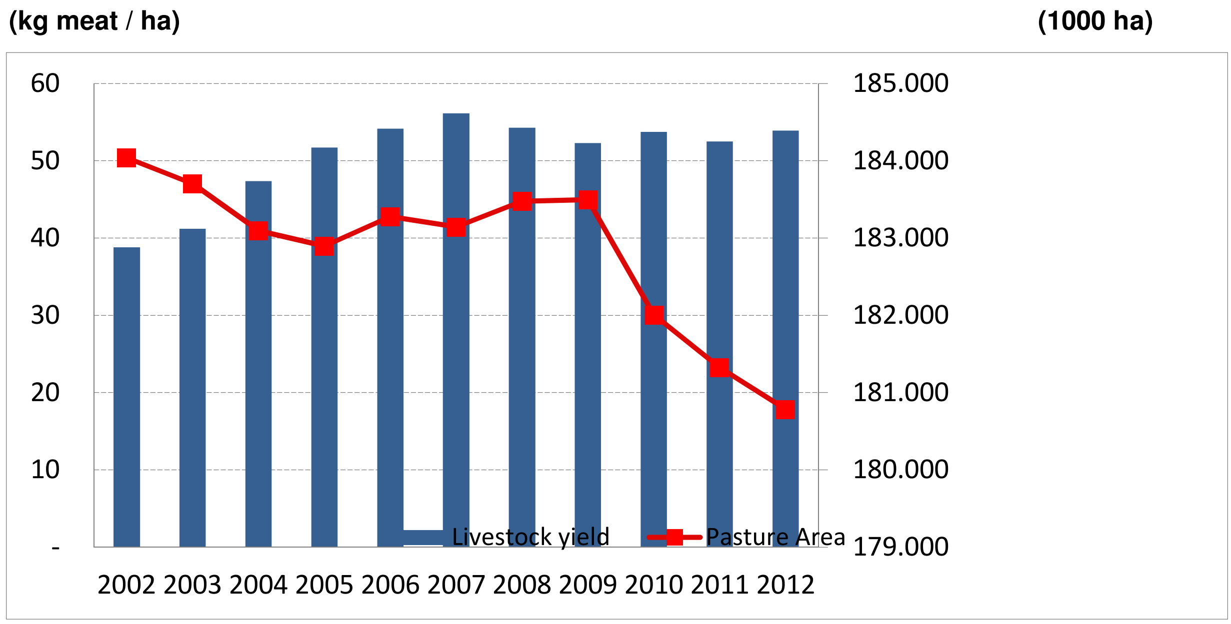
Sources: UNICA; IBGE; CONAB.

Figure 7. Corn Production: First and Second Crops (million tonnes)



Source: CONAB.

Figure 8. Livestock yield and pasture area



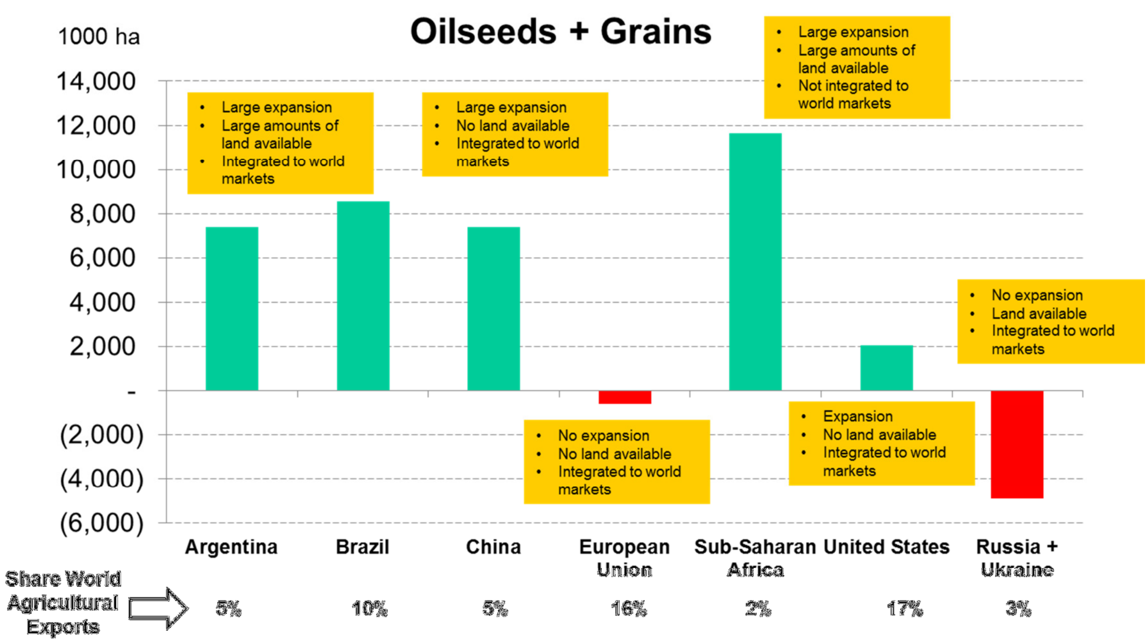
Sources: IBGE; UFMG; INPE; BIGMA Consulting; ICONE.

Table 1. Livestock yield and Production

	2002	2012	Variation	CAGR (%)
Pasture area (1000 ha)	184,037	180,785	-3,252	-0.14%
Herd (1000 Head)	185,349	213,239	27,890	0.98%
Meat production (1000 MT)	7,139	9,748	2,609	2.64%
Livestock yield (kg of meat/ha)	39	54	15	2.78%
Milk production (1000 liters)	24,172	33,996	9.824	3.6%
Milk production per cow (liters/cow)	1,286	1,479	193	1.4%

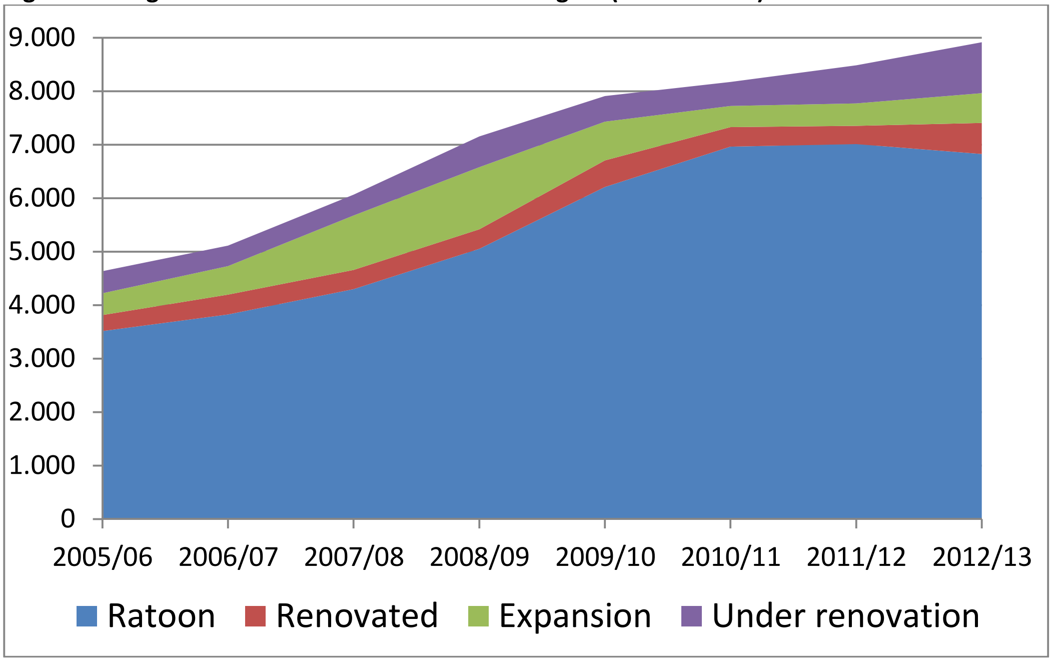
Sources: IBGE; UFMG; INPE; BIGMA Consulting; ICONE.

Figure 9. Harvested Area: Absolute Variation from 2004-06 to 2010-12



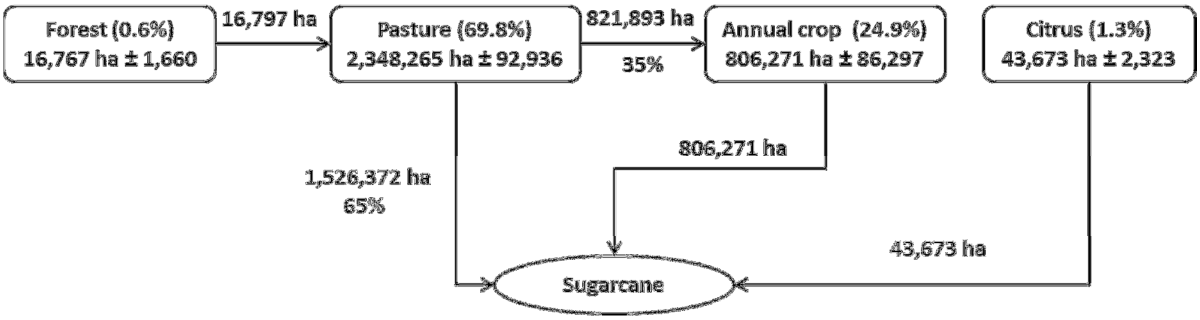
Sources: USDA/PSD Online; CONTRADE/WITS.
Note: The choice to compare the variation from 2004-06 to 2010-12 was due to the fact that this was a period with increasing world agricultural prices, whose effect should be to stimulate strong area expansion.

Figure 10. Sugarcane Area in the South-Central Region (thousand ha)



Source: CANASAT/INPE.

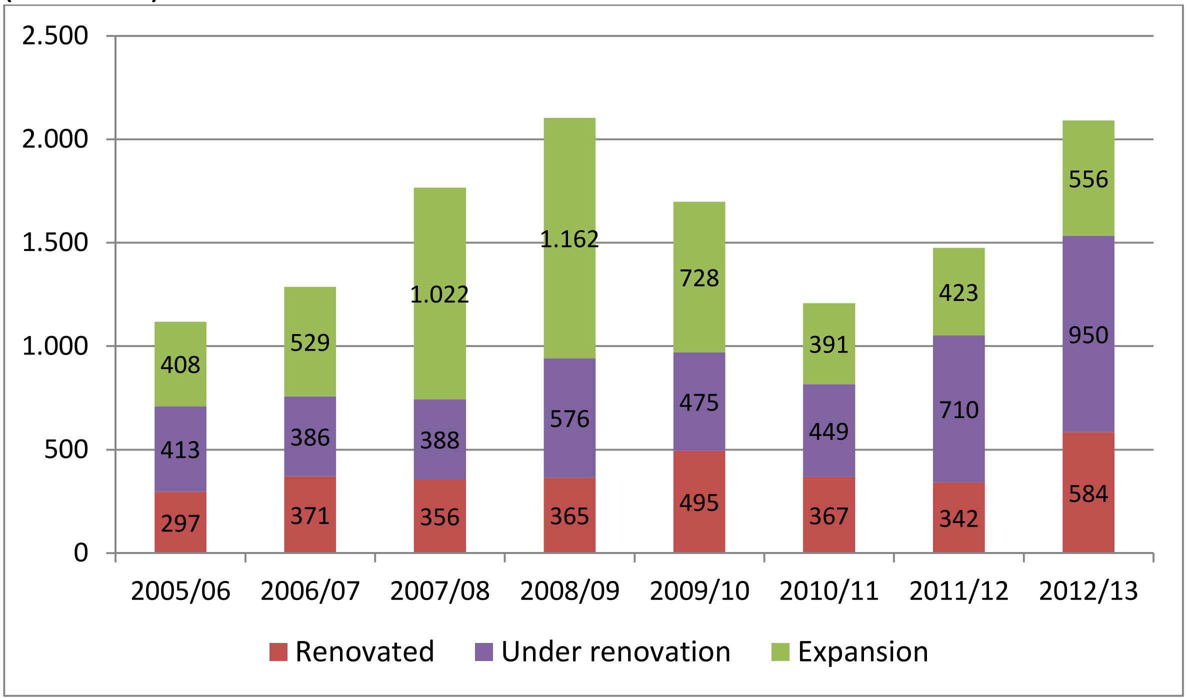
Figure 11. Direct land use change dynamics for sugarcane expansion in the South-Central region of Brazil over the period of 2000 to 2009



Source: Adami et al. (op. cit.)

Note: The values inside the boxes represent the estimated area of the land use classes in 2000 that were gradually converted to sugarcane until 2010.

Figure 12. Sugarcane Area in the South-Central Region: Renovated, Under Renovation and Expansion (thousand ha)



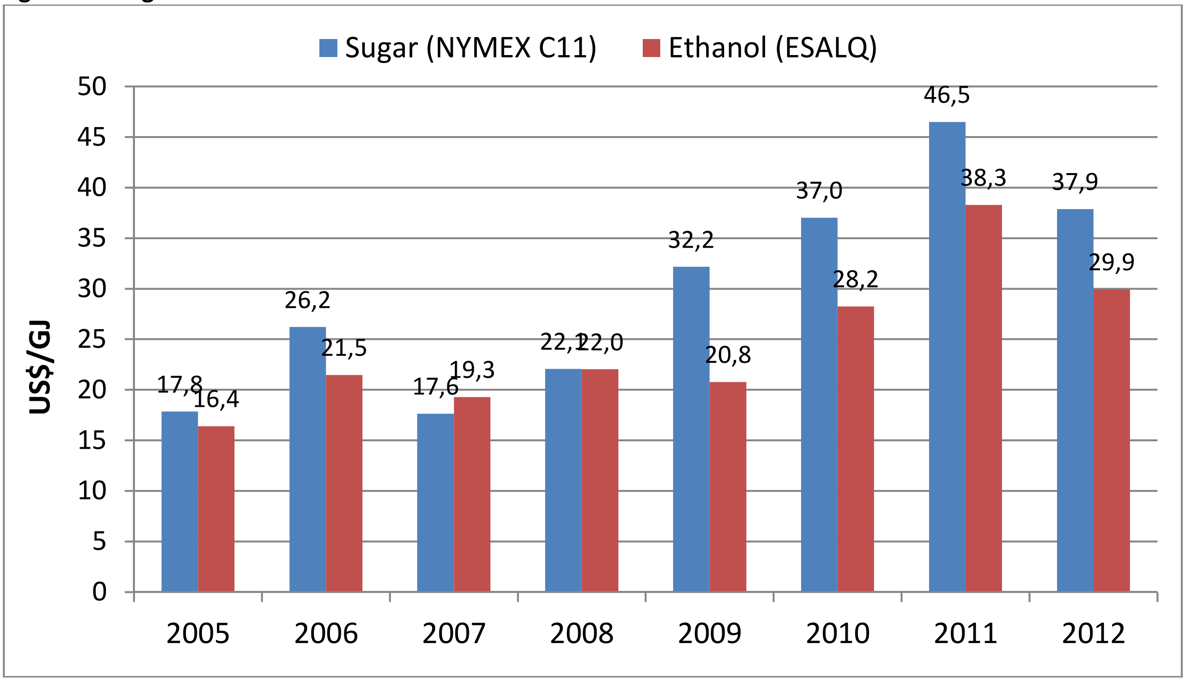
Source: CANASAT/INPE.

Table 2. Energy Indicators of Feedstock and Biofuel Refining Process

Feedstock / biofuel / Process	Yield (feedstock) kg ha-1	Total Energy MJ kg feedstock-1	Total Energy MJ ha-1 year-1	Biofuel Energy MJ ha-1 year-1	Energy Yield (biofuel/feedstock)	Energy Balance (biofuel/fossil)
Corn Ethanol	3,883.3	15.7	61,065.0	31,180.9	0.51	1.8
Palm Oil HVO	19,000.0	15.8	300,960.0	151,165.3	0.50	3.5
Palm Oil FAME	19,000.0	15.8	300,960.0	149,103.9	0.50	3.3
Rapeseed HVO	3,113.4	23.8	73,975.4	43,382.5	0.59	2.6
Rapeseed FAME	3,113.4	23.8	73,975.4	42,790.9	0.58	2.4
Soybean FAME	2,798.0	20.0	55,960.0	18,182.1	0.32	1.8
Sugar beet Ethanol	68,860.1	4.1	280,604.9	152,544.1	0.54	1.8
Sugarcane Ethanol	68,700.0	5.4	370,293.0	133,574.4	0.36	11.1
Sugarcane Ethanol	82,440.0	5.4	444,351.6	160,289.3	0.36	12.4
Waste vegetable or animal oil FAME		0.9			0.98	3.1
Wheat Ethanol (straw CHP)	5,208.2	14.7	76,586.8	40,688.0	0.53	5.4
Wheat Ethanol (natural gas CHP)	5,208.2	14.7	76,586.8	40,688.0	0.53	1.4

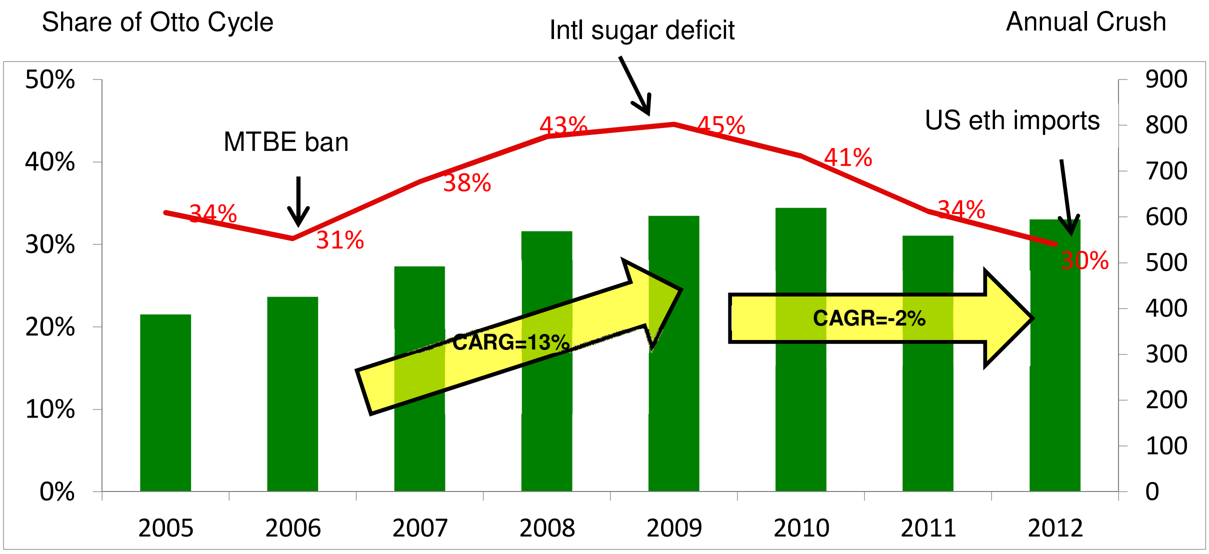
Source: adapted from BIOGRACE Biofuel Calculations Tool (Version 4b public).
Note: due to the area under renovation, some methodologies assume 5/6 of the current yield (5 years planted and harvested and 1 year planted). It is included in the table both the current yield and the 5/6 of the current yield.

Figure 13. Sugar and Ethanol Prices



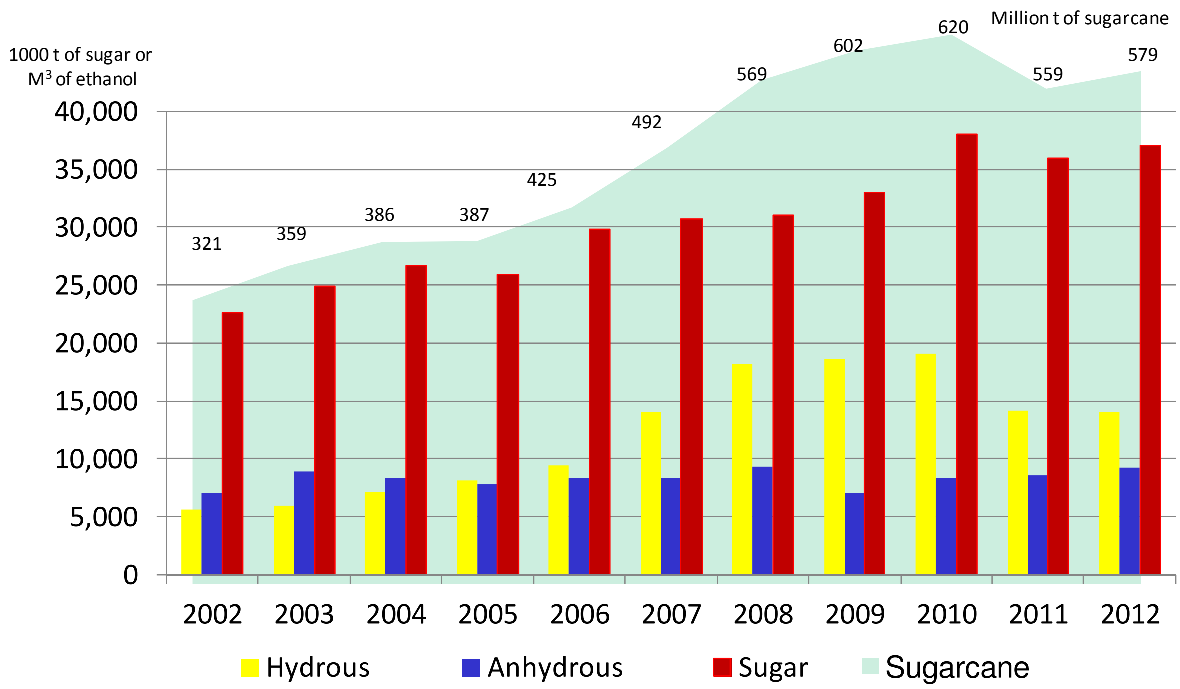
Sources: CME Group; ESALQ/CEPEA.

Figure 14. Share of Ethanol on the Otto cycle and Brazilian Sugarcane Crush



Sources: adapted from EPE; UNICA and USDA.

Figure 15. Evolution of Sugarcane, Ethanol and Sugar Production in Brazil



Source: adapted from UNICA.