Sugarcane expansion scenarios and their impacts on land use and food production in Brazil: exercises based on a computable general equilibrium model

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Abstract:

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Acknowledegment:

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Keyword (s): Sugarcane; land use, food, computable general equilibrium

JEL: Q24; Q21; D58

1. INTRODUCTION

There are several factors that trigger the recent increase in interest in the production of biofuels. Among them, it is worth mentioning the instability of the price of a barrel of oil and the global interest in adopting clean energy sources in order to reduce greenhouse gas emissions in the transportation sector. Brazil is considered a world leader in the production of sugarcane ethanol, whose industry has one of the lowest production costs in the world. In the south-central region of the country, ethanol production reached 28.2 billion liters, in the 2015/2016 harvest, against 4.6 billion liters in the 1982/1983 harvest. Accompanying the evolution of the sector, there is the sugar cane production in the last decades. In the harvest of 2015/2016, production reached 666 million tons. The growth of production is accompanied by a strong expansion of the area harvested from sugarcane. In the period between 2000 and 2015, the Brazilian territory presented an expansion of 126% of area destined to the cultivation of the commodity.

The rapid expansion of the area reserved for the production of sugar cane causes some questions and concerns about the socio-environmental and economic impacts. One issue that has been widely discussed in the literature is the availability of arable land that can harbor the expansion of sugarcane cultivation. Due to the fact that land use is an intensive activity, direct and indirect threats to land use can generate serious environmental consequences through the reduction of forest areas, for example. Or, it may have consequences for the economically vulnerable population, through rising food prices, (FAO, 2013).

Underlying this discussion is the question of the direct and indirect effects of changes in land use (LUC and ILUC). As Brazil is a country with a large stock of land with conversion capacity for agricultural use, besides being a major producer and exporter of biofuels, the discussion on LUC and ILUC derived from the expansion of energy inputs becomes an important schedule among researchers . As noted by Babcock (2009), "the debate over whether biofuels is a good thing now focuses squarely on whether they use too much conversion on natural lands to crop and livestock production around the world."

In this context, these factors express the relevance of investigating the impacts of the expansion of sugarcane in Brazil, indirect land use and agricultural production of food. Understanding the dynamics that involve the substitution of agricultural products and the conversion of land into their different uses, both directly and indirectly, assist public policy makers in decisions involving both economic and environmental issues. Thus, the main objective of this research was to project the impact of the increase of ethanol production derived from sugarcane on land use and on food production in Brazil. To achieve this objective, the Projeto de Análise de Equilíbrio Geral - PAEG (translation General Equilibrium Analysis Project) was used as methodology, with some improvements needed to make the analysis feasible. One of the modifications in the model was the incorporation of a land use module capable of capturing LUC and ILUC. A conversion cost between different types of soils was explicitly approached, considering the idea of land scarcity according to David Ricardo

So, in addition to this introduction, this article is divided into four more sections. The next one describes the methodology, presenting the PAEG model and its closure. The third section presents the modifications made in the original model, such as the incorporation of land rent, supply and demand, and land conversion costs. The fourth section describes the scenarios and simulations. In the fifth section we have the results of the simulations. And, finally, we construct the final considerations and conclusions.

2 METHODOLOGY

The economic model used was the General Equilibrium Analysis Project (PAEG). This type of modeling is adequate to answer the problems of the research in question, since it is able to represent the economies of the great Brazilian regions and partner countries, considering the interrelationships of the different sectors, markets and agents of the economies. In addition, this modeling allows to obtain the total variation in the level of economic activity in response to production shocks. The PAEG model is static, multiregional and multisectoral. The five Brazilian macro-regions are individually represented, which allows us to capture the specificities related to the production of sugarcane, other agricultural products and the area of natural vegetation available for conversion, making it possible to examine the direct and indirect effects generated by an increase in supply and demand for sugarcane.

The PAEG reference model is the Global Trade Analysis Project - GTAP model (HERTEL, 1997; GTAP, 2001). The programming of the PAEG model follows the basic structure of the GTAPinGAMS model (Rutherford and Paltsev, 2000; Rutherford, 2005), which uses the GTAP model database, but is elaborated as a nonlinear complementarity problem in the programming language GAMS (General Algebraic Modeling System, Brooke et al., 1998). Therefore, the PAEG follows the American "tradition" of modeling. In addition to allowing the model to be solved as a non-linear complementarity problem, the GTAP version in GAMS also allows the aggregation of the database in different formats and sizes and the modification or imposition of alternative data in the domestic economies.

The PAEG 4.0 model uses the GTAP 9.0 database, representing the economic environment of 2011, composed of data from 140 regions of the world and 57 goods / productive sectors. Sectors and regions are aggregated according to the objectives of the research, in order to concentrate the economic representation in those regions and sectors of interest, and to avoid computational problems related to the dimension of the model. In the present study, the original aggregation of the PAEG will be maintained a priori. To represent the five macro regions of Brazil. GTAP data for the Brazilian region were replaced by data from the input-output matrices of the five macro-regions.

3 MODIFICATIONS OF THE ORIGINAL MODEL

In order to respond to the proposed research problem, it is necessary to explicitly represent the possibility of competition for the use of agricultural land by different cultures, as well as the capacity of the expansion of the agricultural frontier. In the literature we observe different forms and approaches of land use representation in applied models of general equilibrium (GTAP-AEZ by HERTEL et al., 2010; EPPA by GURGEL et al., 2008. For Brazil TERM-BR by Domingues et al., 2008; BLUE by Faria, 2012; REGIA by Carvalho, 2014, among others).

3.1 The remuneration of agricultural and natural land

The first step in the process of land endogenization was to disaggregate agricultural and natural land rent from capital rent into the Input-Output Matrix, used in the PAEG. For the disaggregation of the agricultural land rent was calculated the remuneration of the agricultural land for all the Brazilian regions. Subsequently, the proportion of this land rent from the Value of Agricultural Production was found. One way of calculating land rent is considered payment received by the land owner in a lease process. The data on the leased land were taken from the 2006 Agricultural Census, in "Expenses incurred by establishments - Land leasing" and "Land legal status".

The calculation of natural land remuneration was based on the series of land prices collected by FGV / IBRE. Based on data from the FGV / IBRE, deflated by the IGP-DI index, based on the year 2006, the ratio between the sales prices of forests and fields and between the sale prices of crops and pastures was calculated in order to to establich a link between agricultural and natural land prices. Subsequently, these averages of price were extrapolated to the regions of natural lands that can be converted. In this way, obtains the natural land rent. The values found for the ratio between agricultural and natural land prices, agricultural and natural land rent are shown in Table 1.

Table 1: Values of agricultural and natural land incomes

Brazil and Macroregions	Proportion of agricultural and natural land prices	Agricultural land rent (R$/ha)	Natural land rent (R$/ha)
North	0.362	50.62	18.34
Northeast	0.544	107.28	58.39
Southeast	0.630	300.64	189.50
Midwest	0.546	121.40	66.34
South	0.638	215.97	137.71
Brazil	0.411	214.15	87.939

Source: Search Results

The results found for P_{it} indicate that in Brazil, about 41% of the agricultural land rent comes from natural land rent. The more land available for conversion there is in the region, the lower the P_{it} ratio and the lower the land yield. The North region, for example, abundant in land suitable for conversion, owns 36% of the agricultural land rent derived from the natural land rent. natural land rent is only $ 18.34 per hectare, well below the natural land rent of regions with little available land, suCH as the Southeast, whose natural land rent is $ 189.50 per hectare.

3.2 Supply, demand and the cost of land conversion

The second step in the process of endogenization of land was to represent the supply and demand of land and, explicitly, the cost of transformation of natural areas in agricultural areas, in the framework of general equilibrium.The representation of the demand and supply of productive lands and vegetation were incorporated into the PAEG model, following, in general lines, the procedure adopted by Gurgel et al, (2008), with some adaptations. And the conversion process is represented by the increasing costs of land conversion, according to the formulation of Gouel & Hertel (2006).

On the supply side, a CES function will be used, representing the substitution between natural land and agricultural land (crops, pastures, forestry and forests), with subsequent disaggregation of the different crops in another CET function (the same representation is used in GTAP models, GTAPinGAMS, GTAP-AEZ, TERM, BLUE, REGIA, among others cited in this paper). Figure 1 shows the supply-side representation of agricultural land adopted in the PAEG model. The land can be used for cultivation of crops and pastures, represented by L_i, L_j e L_n.

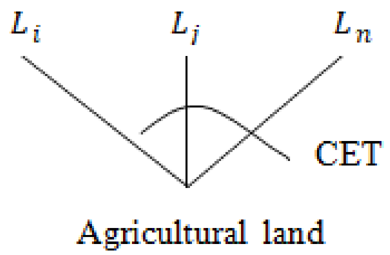

Figure 1: Land structure incorporated in the PAEG model

Figure 2 represents the structure of the land transformation function, incorporated in the PAEG model. A CES function can transform one hectare of land, of any kind, into a hectare of another type, or even transform a natural area into an agricultural area using production inputs. The inputs are: natural area ("fixed factor"), capital, labor and intermediate inputs, and the product is the agricultural area. The natural area is an input used in a constant proportion to the others. The substitution between these inputs is specified by a Cobb-Douglas function. The conversion process is represented by the land conversion cost function which will be detailed later. This conversion cost is nothing more than the sum of the expenses with the inputs used in the conversion. The elasticity between the "fixed factor" and other inputs is intended to capture the curvature of the conversion cost curve. Similar procedure is found in Gurgel et al. (2008), Gurgel et al. (2011), Gurgel et al., (2016).

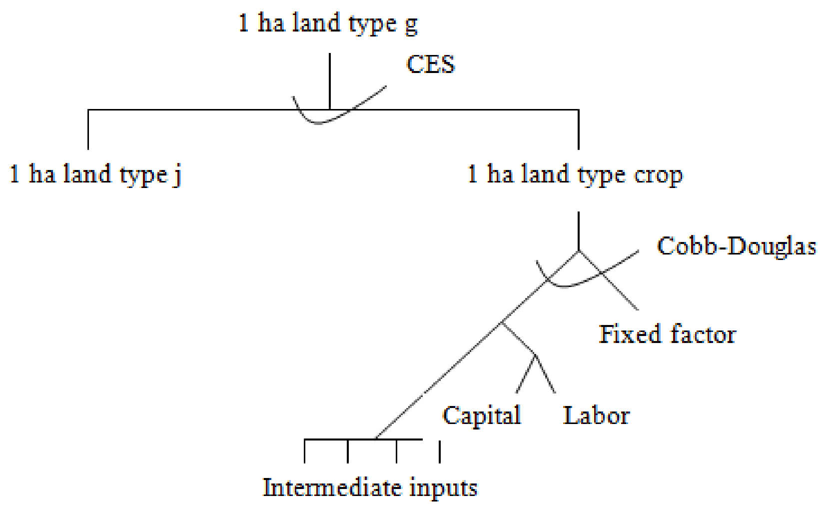

Figure 2: Structure of the land transformation function
Source: Self elaboration based on Gurgel et al, (2016)

The calculation of the conversion cost of the five Brazilian macro-regions was based on Gouel & Hertel (2006). The first step was the survey of the hectares of land in their different uses, including lands with conversion potential and the survey of hectares of deforested land. The second step was the survey of the average prices of agricultural and natural land. The hypothesis is that, in the initial period, the first hectare of deforested land, among those hectares of lands subject to conversion, will generate a conversion cost equal to the natural land price in that initial period. This hypothesis is useful for calibration purposes, since it implies equality between natural land price (observed variable) and cost of conversion (variable not observed), which is consistent with the zero profit condition required to represent the sectoral equilibrium in a general equilibrium model.

According to Gouel & Hertel (2006), the natural land price is determined by the net present value (NPV) of the expected income stream of natural land. Thus, the NPV of future yields can be expressed as follows:

$$PTnat_t^i = RTnat_t^i \frac{1+ROR_t^i}{ROR_t^i} \quad (1)$$

Where $PTnat_t^i$ is the average price of one hectare of natural land in region i, in period t; $RTnat_t^i$ is the land rent per hectare and ROR_t^i is the net expected rate of return in the region where deforestation is occurring.

If we consider that deforested land will bring future benefits in the same way as an investment asset, then the conversion cost will not be equal to the natural land price, but it will be the present value of the natural land price in the next period. The conversion cost CC_t^i will be given by, according to Gouel & Hertel (2006):

$$CC_t^i = \frac{PTnat_{t+1}}{1+ROR_t^i} \quad (2)$$

Considering that the expectations are static, we have:

$$CC_t^i = \frac{PTnat_t}{1+ROR_t^i} \quad (3)$$

Making the necessary substitutions:

$$CC_t^i = \frac{RTnat_t^i}{ROR_t^i} \quad (4)$$

Table 2, below, shows the values of natural land rent, the rate of return and the conversion cost of new areas. The rate of return was calculated according to equation (1), using the average natural land price and natural land rent. The average price of natural land, by region, was determined by data from the series of sale prices of forest and field lands, from 1977 to 2006, collected by the FGV / IBRE and deflated by the IGP-DI index, considering The conversion cost was calculated using equation (4), which simply involves the division between the land rents and the rates of return. The calculation of the cost of conversion to the northeast region was based only on information from the States of Maranhão, Piauí and Bahia (MAPIBA), since the other States do not have great conversion capacity.

Table 2: Land conversion cost

Brazil and Macroregions	RTnat (R$/ha)	PTnat (R$/ha)	ROR	CC ($/ha)
North	18.34	388	0.05	369.46
Northeast	58.39	657	0.10	598.75
Southeast	189.50	1 810	0.12	1620.36
Midwest	66.34	1 389	0.05	1322.48
South	137.71	3 908	0.04	3770.22
Brazil	87.93	1 224	0.07	1136.34

Source: Search Results

For the survey of the hectares of land in their different uses and of the lands subject to conversion, the data of the Systematic Mapping of Land Use of IBGE, used in the project "Changes in Coverage and Land Use of Brazil"[1]. The hectares of land destined to environmental conservation were subtracted from the natural areas according to art. 12 of Law no. 12,651, arriving, finally, in the areas considered suitable for the conversion. The survey of means of annual deforestation was done through the data provided by the Brazilian Biome Deforestation Monitoring Project (PMDBBSO).[2] The final value of the areas of each land use incorporated in the model, as well as the annual deforestation, is shown in Table 3.

Table 3: Areas of different land uses (millions of hectares)

Brazil and Macroregions	Agricultural	Pasture	Silviculture	Legal reserve	Area available for conversion	Annual deforestation
North	4,5	38,4	0,3	257,9	64,4	0,7
Northeast	10,3	27,7	0,8	7,7	14,3	0,4
Southeast	16,7	32,3	3,7	7,1	28,6	0,1
Midwest	21,1	53,7	0,8	28,1	52,3	0,4
South	17,8	11,5	2,8	4,3	17,2	0,05
Brazil	73,9	173,0	8,6	307,7	181,4	1,8

Source: Self elaboration, based on the data of the project "Changes in Coverage and Land Use of Brazil" - IBGE and Project to Monitor Deforestation of Brazilian Biomes by Satellite – MMA

The cost of conversion changes as new areas are cleared. As the conversion cost function is convex, as deforestation increases, the conversion cost of an additional hectare rises. This implication is consistent with the Ricardian theory that the lands exploited first are those with greater ease of access. Thus, we assume that conversion costs become infinite as they approach deforestation of the last hectare of available land, which means that the latter hectare becomes economically inaccessible. Several functional forms may represent such a situation. The one chosen for this research was the one used by Gouel & Hertel (2006) and Chakravorty et al, (2012):

$$CC_t^i = -\alpha \ln\left(\frac{\bar{h} - h}{\bar{h}}\right) + \beta \tag{5}$$

Where $\bar{h}$ is the total land available, that is, the total land subject to conversion, including the area already converted and in use. h represents the area currently in use. Note that $\bar{h} - h$ is the area available for conversion, subject to deforestation. And that $\left(\frac{\bar{h} - h}{\bar{h}}\right)$ is bounded by zero and one, so that ln is bounded by [-∞, 0]. The parameters α and β are positive in the model and vary by region. α is the slope parameter and β is the level parameter, implicitly representing the conversion cost of the first hectare of deforested land, it represents, implicitly, the conversion costs when $h = 0$. The parameter β will tell us the point at which this cost function begins: whether it starts from a higher or lower point of the curve, representing the heterogeneity of the land in each region. That is, β is directly related to the land characteristics of each region, (Gouel & Hertel, 2006).

The calibration problem consists in choosing α and β that combine information on the cost of conversion and the elasticity of the conversion cost with respect to the land used. The intersection parameter, β, is calculated by means of the conversion costs function itself, after finding the value of α. The parameter α, which is the slope parameter, can be calculated from the elasticity σ, according to Gouel & Hertel (2006):

[1] http://www.ibge.gov.br/home/geociencias/recursosnaturais/usodaterra/default.shtm

[2] Developed by the Ministry of Environment - SBF/MMA - http://siscom.ibama.gov.br/monitora_biomas/

$$\sigma = \frac{\alpha}{CC} \cdot \frac{1}{\bar{h}/h - 1}$$

$$\frac{\partial \sigma}{\partial h} = \frac{\alpha \bar{h}}{CC(\bar{h} - h)^2} \cdot \left(1 - \frac{\alpha h}{CC\bar{h}}\right) > 0 \qquad (6)$$

However, an important limitation is the absence of data or information on the elasticity of the cost of conversion of each Brazilian state and macro-regions. Therefore, a simple approach was adopted, as in Gouel & Hertel (2006), to determine this elasticity. It is considered that the fewer the convertible areas in a region, the greater the elasticity of the conversion cost. In contrast, the larger the area of forest available for deforestation, the lower the elasticity. This approach ensures that the less land there is for deforestation, the more expensive the conversion will be. Thus, after determining the values of the elasticities in each region, it becomes possible to calculate the parameters. The values are shown in Table 4 below:

Table 4: Elasticities and parameters of the conversion cost function

Brazil and Macroregions	σ	α	β
North	0.450	248	242
Northeast	1.181	260	257
Southeast	0.901	791	794
Midwest	0.770	704	693
South	0.903	1824	1849
Brazil	0.724	663	602

Source: Search Results

The conversion cost equation is negative because it is a cost. As more land is being converted, h increases and the numerator decreases, increasing the cost of conversion, since the denominator of equation (5) is constant. Over time, marginal lands are being used and the cost of conversion is increasing. What you want to capture with this approach is exactly the rate of increase in conversion cost, that is, the ratio and the rate at which the increase occurs. The cost will always increase in greater proportions than deforestation. As land is scarce and its level of scarcity is measured in terms of opportunity costs, the cost of conversion becomes a good proxy, representing opportunity costs of land use.

4 SCENARIOS AND SIMULATIONS

All of the model's shocks were based on the scenarios of expansion and stagnation projected by the Sugarcane Industry Union (UNICA) and presented at the "Public Hearing at the Joint Commission on Climate Change: The Role of Ethanol for Climate" in November The scenarios are defined below. Given the scenarios of expansion and stagnation, 5 different shocks were simulated in order to investigate the general and specific objectives of this research. The shocks and their descriptions are shown in Table 5.

Table 5: Description of the shocks used in the research

Shocks	Description
CH 1: National increase in demand for sugarcane in an expansion scenario	An increase in the hypothetical national demand for sugarcane for ethanol was simulated, in order to generate an increase in sugarcane supply equivalent to the expansion scenario.
CH 2: National increase in demand for sugarcane	An hypothetical national demand increase from

in a scenario of stagnation	sugarcane to ethanol was simulated, in order to generate an increase in sugarcane supply equivalent to the scenario of stagnation.
CH 3: Regional increase in demand for sugarcane in a scenario of expansion	An hypothetical regional demand increase was simulated from sugarcane to ethanol, in order to generate an increase in sugarcane supply equivalent to the expansion scenario.
CH 4: Regional increase in demand for sugarcane in a scenario of stagnation	An hypothetical regional demand increase was simulated from sugarcane to ethanol, in order to generate an increase in cane supply equivalent to the scenario of stagnation.
CH 5: Increased productivity of land for the production of sugar cane	An exogenous productivity increase of 2% of the land destined to the production of sugar cane was simulated. Demand and supply of sugarcane remains unchanged.

According to UNICA projections, in the scenario of stagnation, the national production of sugarcane will be 731 million tons, and, in the scenario of expansion, 1.015 million tons. The national consumption of fuel ethanol will be 21.6 billion liters in the scenario of stagnation and 50.9 billion liters in the scenario of expansion. The hectares of cane harvested area will be 7.7 million in the stagnation scenario and 10.7 million in the expansion scenario. In order to regionalize these projections according to Brazilian macroregions, the quantity of sugarcane destined for ethanol in each macroregion was calculated according to the state data of "Total Sugar Cane Production" and "Sugar Cane ethanol "in the 2015/2016 harvest, provided by the National Supply Company (Conab) [3]. These ratios were extrapolated to the expansion and stagnation scenarios projected for 2030 and follow in Table 5.

Table 5: Production of total sugarcane destined for ethanol in the 2015/5016 crop and in the 2030 scenario (billion tons)

Brazil and Macroregions	Total sugarcane production 2015/2016	Sugarcane destined for ethanol 2015/2016	Sugarcane destined for ethanol-stagnation scenario 2030	Sugarcane destined for ethanol-expansion scenario 2030
North	3.5	3.3	3.6	4.9
Northeast	45.3	23.4	25.7	35.7
Southeast	436.4	238.4	261.8	363.5
Midwest	139.1	111.2	122.2	169.6
South	41.3	20.2	22.2	30.9
Brazil	665.6	396.5	435.5	604.7

Source: Self elaboration based on data from the Brazilian Sugarcane Harvest Monitoring (CONAB).

5 ANALYSIS AND DISCUSSION OF RESULTS

[3] http://www.conab.gov.br/OlalaCMS/uploads/arquivos/15_12_17_09_03_29_boletim_cana_portugues_-_3o_lev_-_15-16.pdf

5.1 Result of land use changes

Table 6 shows the values of the lands destined to the crops in each macro-region in the base year, as well as the values after the implementation of each shock. It is worth noting that changes in land use are only a consequence of the simulated shocks of increases in sugarcane production for ethanol, that is, they do not capture any other effect or trend observed in the economies of the regions in recent years. This means that the results obtained here are isolated from the effects of deforestation, expansion of the agricultural frontier, or even the regeneration of areas of natural vegetation that may be occurring as a consequence of other socioeconomic phenomena, as in Gurgel (2011).

Therefore, Table 6 shows an increase in hectares destined for crops. This increase in cultivated areas is slightly higher in the expansion scenarios than in stagnation scenarios and occurs more markedly in the Northeast. It should be noted that the study in question considers that area expansions in this region are possible only in the states of Maranhão, Piauí and Bahia (MAPIBA). For Brazil, in general, the increase of hectares for crops in the optimistic scenarios, CH 1 and CH 3, were 1.12 million hectares and 910 thousand hectares, respectively. These results show that an increase in sugarcane production, to satisfy a demand increase, national or regional, causes an expansion of the cultivated areas, in order to accommodate the need to expand the area planted with sugarcane.

The shock of increasing productivity (CH 5) was the only one that caused falls in the areas destined for crops. For Brazil, the decrease was 300 thousand hectares, more sharply in the Northeast. Therefore, a small increase in the productivity of the land used in the production of sugarcane is capable of accommodating the shock of expansion of the production of sugarcane, as well as provoking a saving effect. That is, less land is needed to produce the same amount of crops and sugarcane, which indicates that gains in productivity on the land destined for sugarcane could accommodate the scenario of expansion without pressure for land competition

Table 6: Area of land intended for crops, values in the base year and after shocks (millions of hectares)

Brazil and Macroregions	Base year	CH 1	CH 2	CH 3	CH 4	CH 5
North	4.84	4.95	4.86	4.90	4.85	4.83
Northeast	11.15	11.64	11.25	11.59	11.24	10.98
Southeast	20.50	20.64	20.53	20.73	20.55	20.45
Midwest	21.85	22.16	21.91	21.99	21.88	21.81
South	20.68	20.75	20.70	20.72	20.69	20.65
Brazil	79.01	80.13	79.24	79.92	79.20	78.71

Source: Search Results

In relation to the areas destined to pastures in the base year and after the shocks, Table 7 shows a decrease of pastures in all the scenarios and almost all the regions. In other words, the increase in sugarcane production or the productivity of sugarcane land causes a decrease in pasture in almost all Brazilian macro regions, except for the northern region in CH 3, which presented a slight increase in pasture areas , and South and Center-West regions in CH 5, which did not present significant alterations. The decrease in pastures is more pronounced in the shocks that represent optimistic scenarios, CH 1 and CH 3. For Brazil, for example, 990 thousand hectares and 790 thousand hectares decreased, respectively. This shrinkage is felt mainly in the Midwest, Northeast and Southeast regions.

These regions are traditionally known as abundant in pastures and their decreases may be related to the direct and indirect conversion of land use in favor of increased sugarcane production. As observed in Nassar et al. (2010), in the periods between 2005 and 2008, sugarcane expanded in the vast majority of pasture areas, in the Southeast, Center-West, and Northeast. The increase in the productivity of the land used in sugarcane production would also be an incentive to convert pastures into sugarcane plantations, especially in States with an abundance of pasture and a climate conducive to the planting of sugarcane. The results of the research in question are also in agreement with the results of the second scenario of biofuels expansion of Gurgel (2011), according to which there is a significant loss of the Brazilian Cerrado (whose territorial extension covers a good part of the Central-West region and MAPIBA) in favor of the increase of crop areas.

In the shock represented by the expansion of the supply of sugarcane regionally (CH 3), the North region presented a slight increase in the area destined to the pasture of 30 thousand hectares, which can be justified by the decrease of the pastures in the other regions. Since demands for food, such as milk and meat, are not changed in the application of the shock, it is expected that competition for land use will occur between different uses, with possible indirect land-use conversion, differentiated between regions, order to accommodate food needs, which change only due to changes in relative prices. The increase of pastures in some regions and decrease in others reflects this competition, since the regions with greater competitiveness in cane allocate lands to this crop at the expense of pastures, negatively impacting the livestock production, which in turn expands in regions with less response to the expansion of sugarcane.

Table 7: Areas of land for pasture, values in the base year and after shocks (millions of hectares)

Brazil and Macroregions	Base year	CH 1	CH 2	CH 3	CH 4	CH 5
North	38.41	38.40	38.41	38.44	38.41	38.41
Northeast	27.79	27.38	27.71	27.43	27.72	27.77
Southeast	32.37	32.20	32.34	32.09	32.32	32.36
Midwest	53.73	53.40	53.67	53.59	53.71	53.73
South	11.58	11.51	11.56	11.54	11.57	11.58
Brazil	163.87	162.88	163.69	163.08	163.73	163.86

Source: Search Results

Table 8 shows the values of deforestation in the base year and after the shocks. Brazil, as a whole, shows an increase in deforestation in all shocks, with more significant values in terms of magnitude in those expansion scenarios (CH 1 and CH 3). However, such variations can be considered small given the country's history of deforestation. In the CH 1 shock, for example, in Brazil, there was an increase of 130 thousand hectares, more significantly in the North and Northeast regions. In the stagnation scenarios (CH 2 and CH 4), this increase was even more subtle. In the CH 2 shock, for example, Brazil's deforestation was 50,000 hectares.

In these shocks, the Southeast, Center-West and South regions did not show significant variations, leaving the North and Northeast to absorb all the impact on deforestation. This result is consistent with the assumption established in this research regarding the amount of land suitable for conversion. Therefore, regardless of the shock, there is evidence of competition between sugarcane and forest, with impacts that may be considered small over the regions with the greatest abundance of natural vegetation in the country, North and Northeast (MAPIBA). However, it is important to highlight that the model assumes the hypothesis of lack of productivity gains due to technological advances and that, therefore, the results of deforestation should be interpreted with caution.

These results are consistent with the Low Carbon Study for Brazil, prepared by the World Bank (GOUVELLO et al., 2010), which indicates the conversion of native vegetation into use for production in projections for 2030. Such vegetative conversion occurs mainly, in the border regions, in the Amazon Region; on a smaller scale, in Maranhão, Piauí, Tocantins and Bahia. Nassar et al. (2010) point out that about 180,000 hectares of native vegetation were converted indirectly between 2005 and 2008, in favor of sugarcane expansion, mainly in the Southeast and cerrado of the Midwest and Northeast, corroborating with the results of the research in question, which indicate an indirect deforestation in these regions, due to an expansion in the supply of sugarcane destined for ethanol.

In the scenario of increased productivity of land destined for sugarcane, there is a national decrease in deforestation of 310 thousand hectares, with improvement mainly in the Northeast region. This indicates that technological advances that allow gains in land productivity significantly reduce deforestation and act as a mitigator of direct land use emissions. It is worth remembering that generating productivity gains implies costs and that these costs are not treated in the modeling process. According to Gouvello et al. (2010), one way to eliminate the structural causes of deforestation would be to dramatically increase productivity per hectare of both crops and pastures. The results found in the research in question, therefore, are in line with the theory behind the Central Bank proposal.

Table 8: Area of deforested land, initial values and after shocks (millions of hectares)

Brazil and Macroregions	Base year	CH 1	CH 2	CH 3	CH 4	CH 5
North	0.72	0.82	0.74	0.81	0.74	0.71
Northeast	0.45	0.53	0.48	0.52	0.47	0.26
Southeast	0.08	0.07	0.08	0.04	0.08	0.04
Midwest	0.40	0.37	0.40	0.40	0.40	0.36
South	0.05	0.04	0.05	0.05	0.05	0.02
Brazil	1.70	1.83	1.75	1.83	1.75	1.39

Source: Search Results

One way of verifying whether sugarcane expansion actually occurs over crop areas is by analyzing the absolute variations of these areas after shocks. If the variation of the area of cane is greater than the variation of the areas of crops, we can assume a direct conversion of the land use. Thus, Table 10 shows the absolute variation of sugarcane areas and crop areas in all shocks applied in the research. It can be seen that, in fact, the expansions of the cane areas are larger than the crop areas, in all scenarios, except for the land productivity increase scenario (CH 5). In the optimistic scenarios (CH 1 and CH 3), the gap between the absolute variations is more significant than in the pessimistic scenarios (CH 2 and CH 4), mainly in the Southeast, Center-West and South regions. of sugarcane expansion over crop areas were small.

In the Southeast region, for example, in the CH 1 shock, an increase in the demand for sugarcane destined for ethanol causes an increase in the cultivated area of 0.15 million hectares and an increase in the area planted with sugarcane of 0.47 million hectares. By subtracting the area of sugarcane from the area of cultivation, we found a negative variation of -0.33 million hectares. This indicates that there was a conversion of 0.33 million hectares of land that would be destined to other crops, which started to be destined to the cultivation of sugar cane. It is interesting to observe this same region in the optimistic regional shock (CH 3), whose variation of the crop areas is 0.23 million hectares and the sugarcane areas are 0.69 million hectares, presenting the largest gap of all the regions and shocks of the model. This result, once again, is driven by the fact that the region is the largest producer of sugarcane and other crops in Brazil.

Table 9: Absolute variation of sugarcane areas and crop areas (millions of hectares)

Brazil and Macroregions	CH 1		CH 2		CH 3		CH 4		CH 5	
	Crop	Sugar	Crop	Sugar	Crop	Sugar	Crop	Sugar	Crop	Sugar
North	0.11	0.14	0.02	0.03	0.06	0.08	0.01	0.02	-0.01	0.00
Northeast	0.49	0.63	0.10	0.13	0.44	0.56	0.09	0.11	-0.17	0.01
Southeast	0.15	0.47	0.03	0.09	0.23	0.69	0.05	0.13	-0.04	0.00
Midwest	0.31	0.54	0.06	0.10	0.15	0.28	0.03	0.05	-0.04	0.00
South	0.07	0.28	0.01	0.05	0.04	0.15	0.01	0.03	-0.03	0.00
Brazil	1.12	2.05	0.23	0.40	0.91	1.76	0.19	0.34	-0.30	0.01

Source: Search Results

The variation of the sugarcane area after an expansion shock may occur over the total area of crops, over pasture areas or even over native vegetation, intensifying deforestation. The model used in the research does not allow us to identify the land transition that actually occurred, but allows us to identify how many hectares of land were converted, as a consequence of the direct and indirect effects of the conversion process. Therefore, Table 11 shows the comparison between the absolute values of sugarcane expansion area, pasture conversion and deforestation. In the two main shocks of optimistic expansion of sugarcane destined for ethanol (CH 1 and CH 3), there is a decrease in areas destined for grazing in practically all regions of Brazil, except for North in the CH 3 regional scenario. In addition, there is a national increase in deforestation, with greater intensity in the North and Northeast.

For Brazil, for example, in the CH 1 shock, the expansion of the sugarcane area was 2.05 million hectares, with a sacrifice of 0.13 million hectares of native vegetation and conversion of pasture to the value of 0,99 million hectares. This sacrifice of native vegetation may have been due to the direct or indirect conversion of land use. As the sum of these conversions are not sufficient to accommodate the total expansion of sugarcane, we can conclude that part of the sugarcane growth occurs over the crop areas. In the same scenario, the Northeast region is the one with the largest absolute pasture fall and is the second region with the highest absolute rate of deforestation. This is due to the quantities of land set in the model. In other words, to accommodate an expansion of 0.63 million hectares of sugarcane, an increase in deforestation of 0.08 million hectares and a decrease in pasture of 0.41 million hectares was required. As the sum of converted hectares does not satisfy the expansion of sugarcane, we can conclude that part of the conversion in the Northeast region occurred on the crop areas, as verified for Brazil as a whole.

Tabela 10: Absolute variation of areas of sugarcane, pasture and deforestation, in the optimistic shocks, CH 1 and CH 3 (millions of hectares)

Brazil and Macroregions	CH 1			CH 3		
	Sugar	Pasture	Deforest.	Sugar	Pasture	Deforest.
North	0.14	-0.01	0.10	0.08	0.03	0.09
Northeast	0.63	-0.41	0.08	0.56	-0.36	0.07
Southeast	0.47	-0.16	-0.02	0.69	-0.28	-0.04
Midwest	0.54	-0.33	-0.02	0.28	-0.14	0.00
South	0.28	-0.07	-0.01	0.15	-0.04	0.00
Brazil	2.05	-0.99	0.13	1.76	-0.79	0.13

Source: Search Results

5.2 Results of changes in domestic commodity prices

One of the objectives of the research is to verify if the expansion of sugarcane affects the price of food by competition. Therefore, the variations of domestic commodity prices, from the main sectors, for the five Brazilian macro-regions, after the simulated shocks, were analyzed. Prices increase practically in all sectors and shocks of the model; however, this occurs in small magnitude. Therefore, the competition between sugar cane production and that of food inputs in Brazil is evident, but the reflection on the price of these inputs and, especially, on the price of the final food is relatively small. The variations are higher in the optimistic sugarcane expansion scenarios (CH 1 and CH 3), but in most sectors, they do not exceed 1% of price variation. In the pessimistic scenarios (CH 2 and CH 4) and increasing land productivity (CH 5), the variations are generally below 0.5%. The sector price changes, for each macro-region, in the scenarios CH 1 and CH 3 are shown below in Tables 12 and 13, respectively.

It can be observed in Table 12 that the Northeast and South regions showed the most significant variations in sectoral prices, in the face of a shock of national expansion of sugarcane destined for ethanol (CH 1). In the Northeast, price increases were higher than 1% in the following sectors: "Rice (pdr)"; "Maize and other cereals (gro)"; "Other agricultural products - wheat, fiber, fruits, vegetables etc. (agr) "and" Sugar cane, sugar beet, ind. sugar (c_b) ". The sector "Food products (foo)" presented the lowest variation, 0.13%. In the South, the sector with the highest price variation was the "c_b", with a 2.08% increase, followed by the "pdr", with 0.95%. The "foo" sector also had the lowest variation, 0.19% increase.

Table 12: Variation of sectoral prices in each Brazilian macro-region after the implementation of shock CH 1 (%)

Sectors *	North	Northeast	Southeast	Midwest	South
Pdr	0.54	1.11	0.75	0.91	0.95
Gro	0.52	1.08	0.51	0.83	0.91
Osd	0.48	0.96	0.61	0.82	0.91
c_b	2.15	1.96	2.03	2.14	2.08
Oap	0.59	0.97	0.77	0.88	0.86
Rmk	0.56	0.71	0.83	0.83	0.85
Agr	0.43	1.16	0.62	0.80	0.92
Foo	0.05	0.13	0.16	0.12	0.19

Source: Search Results

* Rice (pdr); Maize and other grain cereals (gro); Soybeans and other oil seeds (osd); Sugar cane, sugar beet, ind. sugar (cb); Meat and live animals (oap); Milk and dairy products (rmk); Other agricultural products - wheat, fiber, fruits, vegetables etc. (agr); Food products - Other food products, beverages and tobacco. (foo);

Considering the changes in sectoral prices after the implementation of a sugarcane expansion shock for ethanol at the regional level (CH 3), we observed more significant increases in prices in the Southeast and Northeast regions. Table 13 shows the variations. In the Southeast, all sectors showed price increases above 1%, with the exception of the "osd" and "foo" sectors. The latter had the lowest variation. In the Northeast region, the "c_b", "agr", "pdr" and "gro" sectors were the ones with the highest price increases - the "foo" sector remained the lowest. As this shock does not capture the comparative advantage of the regions in the production of sugarcane, the Northeast and Southeast regions, which traditionally are the largest producers, tend to have a greater impact on sectoral prices, due to an increase in sugarcane production -of sugar.

Table 113: Variation of sectoral prices in each Brazilian macro-region after the implementation of shock CH 3 (%)

Sectors *	North	Northeast	Southeast	Midwest	South
Pdr	0.46	0.99	0.58	1.01	0.70
Gro	0.45	0.96	0.41	1.05	0.66
Osd	0.41	0.85	0.46	0.96	0.67
c_b	1.40	1.74	1.22	2.96	1.34
Oap	0.51	0.86	0.58	1.07	0.64
Rmk	0.50	0.64	0.64	1.06	0.63
Agr	0.37	1.04	0.49	1.02	0.68
Foo	0.04	0.12	0.12	0.13	0.14

Source: Search Results
* Rice (pdr); Maize and other grain cereals (gro); Soybeans and other oil seeds (osd); Sugar cane, sugar beet, ind. sugar (cb); Meat and live animals (oap); Milk and dairy products (rmk); Other agricultural products - wheat, fiber, fruits, vegetables etc. (agr); Food products - Other food products, beverages and tobacco. (foo);

Therefore, an increase in the supply of sugarcane destined for ethanol, in a scenario of optimistic expansion, both national and regional, in addition to increasing the price of the sugarcane sector for the production of sugar, increases the price other crops and agricultural products. However, this fact does not cause significant increases in the prices of the final food (sector "Food - Other food products, beverages and tobacco - foo"). This may be related to the fact that the prices of this sector absorb little increase in the price of their raw materials, since the final value of food is composed of several other inputs and value added, not just the agricultural input.

6 CONCLUSIONS

The main objective of this research was to project the impact of an increase in demand for sugarcane destined for ethanol on land use and food production in Brazil, in scenarios of expansion and stagnation of production. The results suggest that the large availability of lands suitable for conversion in Brazil, whether by the existence of extensive pasture areas or by the huge area of vegetation cover, allows to accommodate the growth of the sugarcane crop projected for the year 2030. This would occur at the expense of crop and pasture areas, mainly. The impact on deforestation is relatively small. The decrease of crop areas does not seem to significantly impact on the price of food inputs and on the final food price, as verified by Ferreira Filho and Horridge (2014). The production of food inputs would be accommodated between regions, that is, in some Brazilian regions there would be a decrease in the sectorial production of food and its inputs, but in other regions there would be an increase in the production of these sectors.

The results of the shock that simulates an increase in the productivity of the land destined for sugarcane indicate that a small increase in the productivity of the land used in the production of sugarcane causes a saving effect. This fact indicates that gains in productivity on land could accommodate the scenario of expansion without pressure for land competition. It was also concluded that technological advances that allow gains in land productivity reduce deforestation and act as a mitigator of direct land use emissions.

Finally, it is believed that a thorough analysis of patterns of land use change, and the ability to design such changes, is necessary for regional planning and for the formulation of land use development policies. The formulation developed here can serve as an instrument for representing the possibilities of expanding the sugarcane culture destined for ethanol among the Brazilian regions. In addition it follows the economic rationality of allowing the conversion first of the areas of smaller cost and easiness of access, according to the Ricardian idea of the use of the earth. In addition, it captures the different conversion costs of the Brazilian macro-regions and the prices of areas of agricultural use and natural vegetation.

However, the model does not take into account other factors that may affect the dynamics of changes in land use, such as sociocultural aspects, public policies and international pressures. Also, being the static model, there is no evolution in the production of the other agricultural inputs and productive factors. As observed by Gurgel (2007), in a dynamic economy, population growth, capital accumulation, and investment in expanding profitable sectors could mitigate or even reverse the decline in output in some agricultural sectors, increasing demand for the land factor and pressure on the expansion of the agricultural frontier. Furthermore, in a dynamic model it would be possible to consider the growth of land productivity, which could counterbalance the need for deforestation of native vegetation areas.

Thus, the suggestion for future studies is to add dynamic aspects of expansion of productive factors, increases in agricultural productivity and investment opportunities in the economies, and consider the increase in demand for other agricultural products, not only energy inputs. It is also important to be able to measure the effects of growth of energy inputs on changes in agriculture and land use, not only in Brazil, but also in other regions of the world. In addition, it is necessary to try to incorporate the use of the second generation biofuel inputs in the modeling process and the analyzes.

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