Institute for International Trade Negotiations

Report to the U.S. Environmental Protection Agency regarding the Proposed Changes to the Renewable Fuel Standard Program

Impacts on Land Use and GHG Emissions from a Shock on Brazilian Sugarcane Ethanol Exports to the United States using the Brazilian Land Use Model (BLUM)

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EXECUTIVE SUMMARY

Greenhouse gas (GHG) emissions published in the proposed changes to the Renewable Fuel Standard program (RFS-2)'s Draft Regulatory Impact Analysis (DRIA) as a result of an increasing demand for sugarcane ethanol overstate the emissions associated to direct and indirect land use changes. This document shows that a more accurate land use model for Brazil derives new per hectare CO_2-e emissions factors and, as a consequence, the reduction of GHG emissions of sugarcane ethanol compared to gasoline should be higher than the results presented by the draft analysis. Rather than 44 percent reduction for 100 year with 2% discount and 26 percent for 30y years with 0% discount as published in RFS-2's DRIA, our analysis indicates 69 percent for 100 year with 2% discount and 60 percent for 30 year with 0% discount. We strongly urge the U.S. Environmental Protection Agency (EPA) to revise its calculations, taking into account the methodology and the results presented in this document.

There are several differences between the analysis presented in this document and the analysis published in the RFS-2 DRIA. The most relevant is that a specific economic land use model for Brazil has been used (BLUM – Brazilian Land Use Model). The model projects land use change at six Brazilian regions, while the analysis published in the DRIA only brings calculation of land allocation for the entire Brazilian territory. In this regard, BLUM is similar to the FASOM model, which divides the United States in ten regions. The second major difference, which is associated to the regionalization of land allocation within the country, is that the model not only calculates land allocation for the different productive uses (soybean, corn, cotton, dry beans, rice, sugarcane and pastures), but also land use changes due to the substitution within agricultural uses and between agricultural and natural vegetation uses. Land use change, therefore, is an output of BLUM, which is obtained due to regularity conditions (homogeneity, symmetry and adding up) imposed over regional elasticities matrices. This discussion is detailed in sections 2 and 3 below.

In order to analyze and discuss the results for ethanol CO_2-e emissions associated to land use changes (LUC) due to the increase in sugarcane production, we replicated two RFS-2 DRIA scenarios in BLUM: "Imports Only" (Baseline) and "Control Case" (Shock). These scenarios permitted us to isolate the effect of the increase in sugarcane production in Brazil and the emissions related to land use change due to a shock on ethanol demand.

In the "Baseline" scenario, the demand for ethanol is 0.6 billion gallons, while in the "Shock" scenario it has been increased by 2.5 billion reaching 3.1 billion gallons. We considered that all additional demand would be produced and supplied by Brazil, as done in the results published in the RFS-2 DRIA. Also, we used the Brazilian net exports published in the "Imports Only" scenario for both scenarios for all products, except for ethanol. This procedure is important to guarantee that all LUC effects would take place within Brazil, not internationally, because the exports of all other activities were maintained fixed in the "Shock" scenario and equal to the "Imports Only". Fixing net trade for all activities and having all other demand and supply components variable and depending on prices or profitability, we ensure the model would find a vector of prices that solves all markets simultaneously.

According to RFS-2 DRIA report, only Brazil has ethanol excess of supply to support an additional demand of 2.5 billion gallons in the United States, as considered in the Shock scenario. However, the results found that only 56 percent of total indirect LUC associated to this increase would take place within Brazil, assuming that Brazil does not have enough land to accommodate all the increase in sugarcane production. However, geospatial data from AgLUE-BR database (discussed in section 2.2.2.1 below), used as input in BLUM, shows that there is a sufficient amount of land available for agricultural purposes in Brazil. Although we do not have information about land availability in other countries, the magnitude of the amount of land available and historical data showing that Brazilian agriculture responds to price and profitability changes expanding planted area, are strong evidences that any increase in sugarcane production in Brazil will not lead to reductions in the supply of other crops and cattle. Additionally, it can be said that not only Brazil has enough land available for agricultural expansion converting natural vegetation, but also and more important, due to yields improvements on pasture areas.

Historical data show that grazing yields are improving at the same time that both sugarcane and grains areas are increasing overtime and, as a result, it can be empirically proved that grains and sugarcane directly displacing pasture area. BLUM results reflect exactly that dynamic: *sugarcane increases over other crops and pasture; crops displace pasture, and pasture displaces natural vegetation* (see sections 3 to 4 and Annex 1).

In terms of CO_2-e emissions associated to LUC, calculated *ex post* based on BLUM results, the total displacement caused by the increase in sugarcane production is the total amount of pasture converted to crops (sugarcane plus grains), summed to natural vegetation converted to pastures. For each region, these types of land conversion were transformed in coefficients. These coefficients represent the percentage of each type of conversion in the region, considering the weight of each region in the total land displaced in Brazil. These factors are used directly to calculate the average emission associated to each category in each region, differently from the two steps approach used in RFS-2 DRIA (see section 4 for more details).

The results for land use and GHG emissions calculations are summarized in the file attached "ICONE_BLUM_EPA.xls" (all results are described in section 5). The file comprises thirteen spreadsheets with all formulas, calculations and results for land use change and GHG emissions. More important, the "Land Use Change" spreadsheet presents the results on land use change that are used as the base for the calculation of per hectare CO_2-e emission factors. The results on life cycle and GHG emissions are presented in the "Results_2022" spreadsheet.[1]

In comparison with RFS-2 DRIA results for the reduction on ethanol emissions related to gasoline, our results show a decrease on the emissions levels by 25-34 percentage points, respectively for 100 years with 2% discount and 30 years with 0% discount scenarios. These are materially and significant changes that must be considered prior to the final rule. <u>Our analysis demonstrates that while there are some emissions associated to LUC in Brazil effect is marginal for the case of sugarcane ethanol.</u> Considering the methodological advantages in using BLUM for the analysis proposed, we urge EPA to incorporate these results in the final RFS-2 regulations.

[1] Sheets of "ICONE_BLUM_EPA.xls" spreadsheet are blocked. The password to unblock the sheets is available upon request to the authors.

1. INTRODUCTION

The Energy Independence and Security Act (EISA) established new specific volumes and requirements for cellulosic biofuel, advanced biofuel, and total renewable fuels that must be used in transportation fuel in the United States. The requirements include greenhouse gas emission thresholds for renewable fuels, including direct emissions from the production cycle and emissions associated to land use changes.[2]

As described by the U.S. Environmental Protection Agency, "the term 'lifecycle greenhouse gas emissions' means the aggregate quantity of greenhouse gas emissions (including direct emissions and significant indirect emissions such as significant emissions from land use changes), as determined by the Administrator, related to the full fuel lifecycle, including all stages of fuel and feedstock production and distribution, from feedstock generation or extraction through the distribution and delivery and use of the finished fuel to the ultimate consumer, where the mass values for all greenhouse gases are adjusted to account for their relative global warming potential." [3]

EPA, as part of proposed revisions of the Renewable Fuel Standard program, as mandated by EISA, published a preliminary version of the results on full lifecycle analysis for renewable fuels. According to EPA, the analysis aims to verify if renewable fuels produced will meet the GHG emissions requirements established by EISA mandates introducing both direct and indirect emissions, thus also including the emissions from international land use – changes (herein referred to as "LUC").

Considering that LUC represents the majority of the total agricultural emissions worldwide and the fact that the impacts on land use change, and its related carbon emissions, predominately take place in Brazil, according to the results published in the RFS-2 DRIA, it is necessary to analyze and verify the calculations and assumptions considered in the simulated scenarios.

This document argues that the results presented in the RFS-2 DRIA with respect to carbon emissions associated to LUC overstate the impacts of LUC emissions due to the increase in sugarcane production as a result of an increasing demand for Brazilian ethanol as

[2] Based on U.S. Environmental Protection Agency's Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program. Washington DC: Federal Register, vol. 74, n. 99, May, 2009. Available at: http://www.epa.gov/fedrgstr/EPA-AIR/2009/May/Day-26/a10978a.htm

[3] Based on U.S. Environmental Protection Agency's Draft Regulatory Impact Analysis: Changes to Renewable Fuel Standard Program. Washington DC: Office of Transportation and Air Quality, document EPA-EPA-420-D-09-001, p.278, May 2009. Available at: http://www.epa.gov/OMS/renewablefuels/420d09001.pdf

a consequence of higher imports from U.S. This report presents new results with respect to land use change and related carbon emissions that are more accurate than current global models and suggests an alternative methodology based on an economic model specifically developed for Brazil, heretofore referred to as the Brazilian Land Use Model (BLUM).[4] In order to guarantee consistency with the scenarios used in the RFS-2 DRIA, and make the results comparable for analysis by EPA, we inputted into BLUM the same data for all activities, except sugarcane, used in the published scenarios.

The main motivation behind BLUM development was to create a land use economic model that was able to represent at a regional level the dynamics of the Brazilian agricultural sectors, capturing cause-effect relations that are not caught by international or nationwide models. One of the most important advantages of BLUM for the RFS-2 regulations is that the model measures not only land allocation but also land use changes. Having the results on land use change estimated through an economic model, carbon emissions can be more accurately calculated by multiplying the LUC for the regions covered in the model by regional CO_2-e emissions factors. Therefore, this document not only presents new results for LUC, but also suggests an alternative methodology for calculating carbon emissions, using the same CO_2-e emissions factors presented in the RFS-2 DRIA.

After describing the model, the assumptions and datasets used, this document presents the results on land use change due to sugarcane ethanol demand expansion projected by BLUM, according to the EPA scenarios presented in the RFS-2 DRIA. The results generated from these scenarios were used as the base for CO_2-e emissions calculations. The main objective is to compare these results with the ones published by EPA in the proposed rule, showing that EPA should revise the results in order to reflect a more realistic assessment for sugarcane ethanol in Brazil.

The present paper is divided in four more sections. The second section gives a brief description of the BLUM structure and assumptions. The third section describes how we used the model for getting results on land use change due to an increase on sugarcane ethanol area and, consequently, the associated carbon emissions. The fourth section summarizes the

[4] BLUM was developed in a joint project between ICONE and CARD/FAPRI. BLUM is fully integrated to world FAPRI models. For the results presented in this document, BLUM was run independently of the world models but with the same parameters of the version that is integrated to the world models. Therefore the results presented here are under ICONE´s responsibility, without direct participation of CARD/FAPRI.

results on land use change and carbon emissions and analyzes them in light of the EISA goals. The last section has some final considerations.

2. BRIEF DESCRIPTION OF THE BRAZILIAN LAND USE MODEL

The Institute for International Trade Negotiations (ICONE) in partnership with the Food and Agricultural Policy Research Institute (FAPRI)[5] developed an economic model named Brazilian Land Use Model (BLUM) that aims to analyze and project the dynamic of the main agricultural sectors in Brazil.

BLUM structure differs from the one used by CARD/FAPRI for EPA analysis. The FAPRI world models produce results in terms of allocated area for each activity. BLUM also projects land use changes. CO_2-e emissions factors can thus be directly (*ex post*) connected to the respective land use changes. This is an important differential since it makes the calculation simpler and more accurate than the two-step approach developed by Winrock International for the RFS-2 DRIA.

2.1. SCOPE OF THE MODEL

The model comprises the following products: soybeans, corn (first and second crop), cotton, rice, dry beans (first and second crop), sugarcane, dairy, and livestock sectors (beef, broiler, eggs and pork). Commercial forests are considered as exogenous projections.[6] In conjunction, these activities were responsible for 95 percent of total area used for agricultural production in 2008.[7] Although second and winter crops, such as dry beans and corn, do not generate additional need for land (they are smaller and planted in the same place of first season crops), their production is accounted in the national supply.

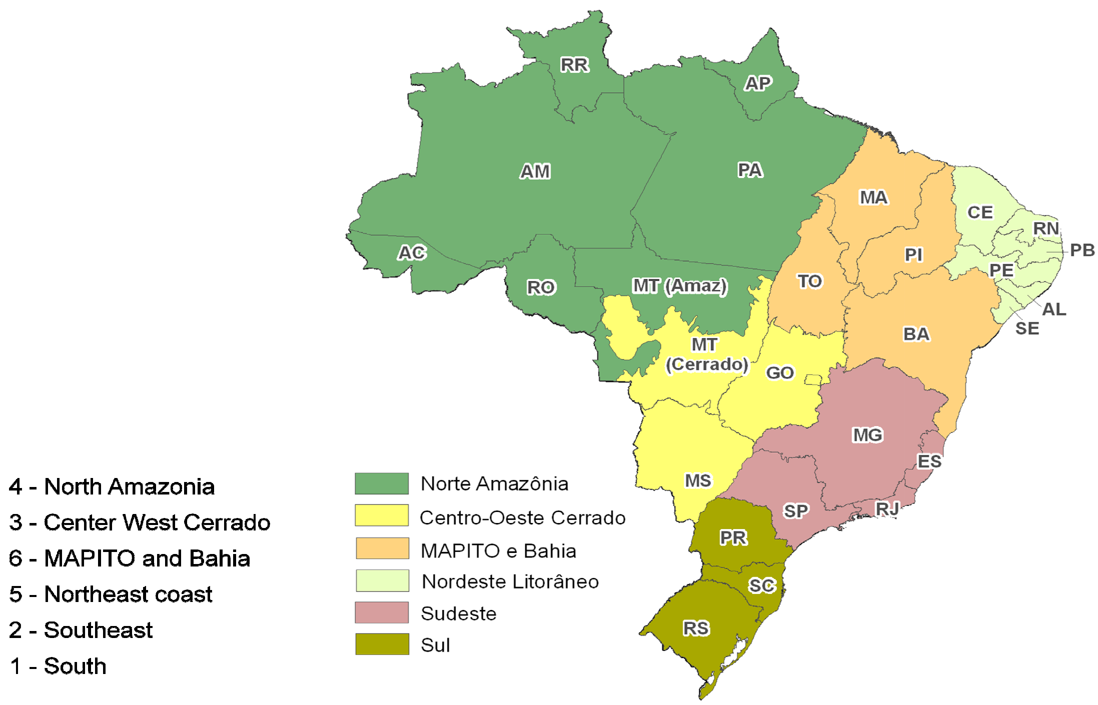
Land allocation for agricultural and livestock is calculated for six regions,[8] as showed in Figure 1:

- Region 1: South (states of Paraná, Santa Catarina, Rio Grande do Sul);

[5] FAPRI is a joint effort of Iowa State University's Center for Agricultural and Rural Development (CARD) and the University of Missouri-Columbia. For purposes of the work in this report, ICONE worked with the CARD/FAPRI team at Iowa State University.
[6] The projections come from the Brazilian government Programa Nacional de Energia (PNE) and from the private sector as the Brazilian Producers on Planted Forests Association – ABRAF.
[7] When we refer to agricultural area, we consider crops and livestock.
[8] The main criteria to divide the regions were agricultural production homogeneity and individualization of biomes with especial relevance for conservation.

- Region 2: Southeast (states of São Paulo, Rio de Janeiro, Espírito Santo, Minas Gerais);
- Region 3: Center-West Cerrado (states of Mato Grosso do Sul, Goiás and part of the state of Mato Grosso inside the biomes Cerrado and Pantanal);
- Region 4: North Amazon (part of the state of Mato Grosso inside the Amazon biome, Amazonas, Pará, Acre, Amapá, Rondônia, and Roraima);
- Region 5: Northeast Coast (Alagoas, Ceará, Paraíba, Pernambuco, Rio Grande do Norte, and Sergipe);
- Region 6: MAPITO and Bahia (Maranhão, Piauí, Tocantins, and Bahia).

Figure 1 – Map of the *Brazilian Land Use Model* – BLUM regions



Source: Based on Instituto Brasileiro de Geografia e Estatística (IBGE)'s analysis. Developed by ICONE and the Federal University of Minas Gerais (UFMG).

2.2. MODEL STRUCTURE

BLUM is a multi-market, partial equilibrium economic model and comprises two general sections*: supply and demand* and *land use*. These sections are interdependent through national production of each activity and are described on the two following sub-sections. The third sub-section explains how the model is solved and what kind of results is generated.

2.2.1. SUPPLY AND DEMAND SECTION

In the supply and demand section, the demand is projected in a national level and is formed by domestic demand, net trade (exports minus imports) and final stocks (which is not considered for dairy and livestock sectors and sugarcane),[9] which respond to prices and to exogenous variables such as gross domestic product (GDP), population and exchange rate. The supply is formed by national production (which is regionally projected) and initial stocks (again considered only for grains and final products of sugarcane) and responds to expected profitability of each commodity, which depends on costs, prices and yields.

Annual productions in each region, comes from the product of land allocated and yields. The national production is the sum of all regions production, in addition with initial stocks. This relationship guarantees the interaction between the sections of *land use* and *supply and demand* in the model, considering that the following identity must be satisfied:

$$\textit{Beginning stock} + \textit{Production} + \textit{Imports} = \textit{Ending Stock} + \textit{Domestic Consumption} + \textit{Exports}$$

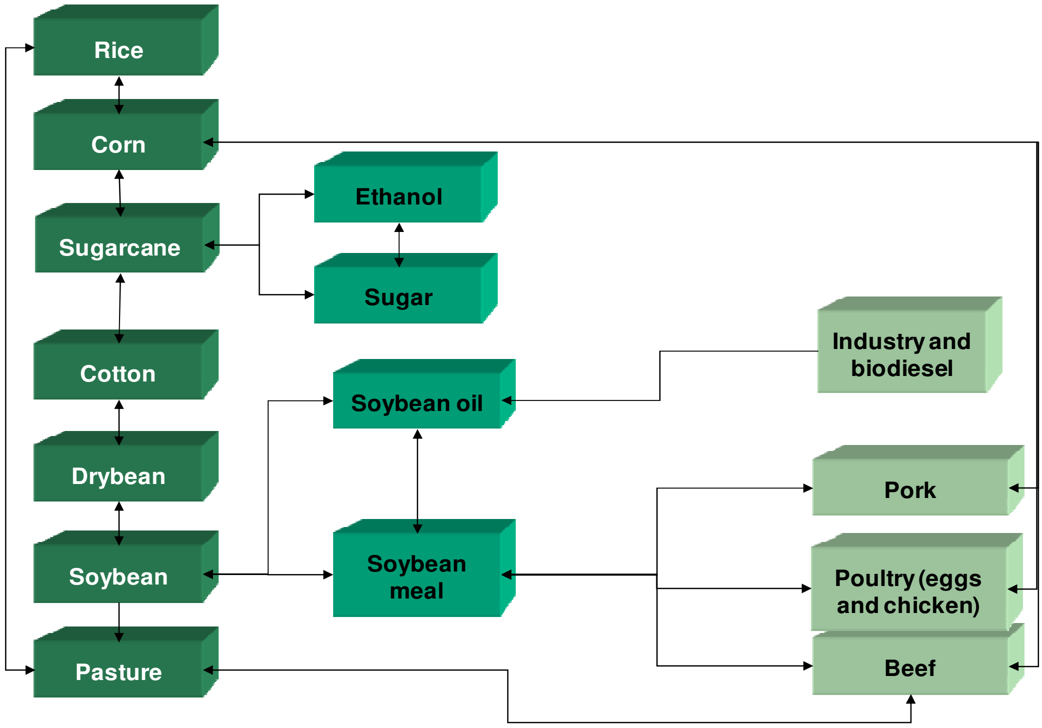
or, considering that *Net Trade = Exports - Imports:*

$$\textit{Beginning stock} + \textit{Production} = \textit{Ending Stock} + \textit{Domestic Consumption} + \textit{Net Trade}$$

BLUM also takes into account interactions among the analyzed sectors, and among one product and its sub-products. For example, the interaction between grains and livestock sectors is the feed consumption (basically corn and soybean meal) that comes from the supply of meat, milk and eggs, which is one component of the domestic demand of corn and soybeans. In the case of soybean complex, soybean meal and soybean oil are components of the domestic demand of soybeans and are determined by crush demand. Similarly, ethanol and sugar are the components of sugarcane demand. This dynamic can be visualized in Figure 2 below.

[9] In the case of sugarcane, stocks are only for its final products, sugar and ethanol. The model does not include, as a source of income for the sugarcane, other various byproducts of sugarcane production such as bagasse (whether used for electricity generation or animal feed).

Figure 2 – Interactions among BLUM sectors



Source: ICONE

2.2.2. LAND USE DYNAMICS[10]

The land use dynamics is divided in two effects: *competition* and *scale*. Intuitively, competition effect represents how the different activities compete for land for a given amount of available land, and the scale effect refers to the way that the competition among different activities generates the need for additional land allocation. This need is accommodated by the expansion of total agricultural area over natural vegetation.

The competition effect follows the methodology proposed by Holt (1999), and consists on a system of equations that allocates a share of agricultural area to each crop and pasture in each region as a function of its own and cross price-profitability. It establishes that, for a given amount of agricultural land, an increase of the own profitability of one activity will increase the share of area dedicated to this activity. On the other hand, an increase on profitability of a competing activity reduces the share of area of the first activity. In Holt (1999), total agricultural area is exogenously determined, while in the BLUM it is endogenously determined in the scale effect, as will be explored later on. The regularity conditions (homogeneity, symmetry and adding up) are imposed so that the elasticity

[10] The structure of the land use section of BLUM was initially proposed by CARD/FAPRI and was implemented in the model with joint work between ICONE´s staff and Miguel Carriquiry, Bruce Babcok and Jacinto Fabiosa from CARD/FAPRI.

matrices (and associated coefficients) are theoretically consistent. For any set of these coefficients we calculate own and cross impacts and competition among activities. Results of BLUM then allow us to calculate not only land allocation but also land use changes. In other words, the conditions allow the identification of the area exchanged, activity by activity, considering the amount of allocated total agricultural area.[11]

In order to guarantee coherence on the cited conditions, pasture area is regionally and endogenously determined but modeled as the residual of total agricultural area minus crops area. In the context of the Brazilian agriculture, it is particularly relevant to project pasture both endogenously and regionally. First, total pasture area in Brazil was around 204 million hectares in 2008 and has a huge potential to release area through yields improvements (see Annex 1). Further, it is very important to distinguish the regional dynamics of pasture area due to the difference on carbon stocks related to different types of natural vegetation (such as savanna, grassland, forests and others).

Although the competition among activities may represent the situation of regions where agricultural area is stable and near to its available potential, this is an insufficient analysis for Brazil. Recent Brazilian agricultural history showed that crops, commercial forests and pasture in conjunction respond to market incentives by contributing to an expansion of total area allocated to agriculture. This effect is captured in the scale section in the BLUM. This methodological improvement is essential to adjust the model skills to the specific reality of Brazilian agricultural land use dynamic, and thus an major advance comparing to the available models and the one used in the EPA analysis.

The *scale effect* refers to equations that define how the returns of agricultural activities determine the total land allocated to agricultural production. More precisely, total land allocated to agriculture is a share of total area available to agriculture, and this share responds to changes in average return of agriculture. For each region, total land allocated to agricultural production is projected as:

$$Agland = f\left(Avg\ \mathrm{Re}turn\right) * A,$$

where $Agland$ is total land allocated to agricultural production, $Avg\ \mathrm{Re}turn$ is the average agricultural return of the region, A is the total available land (that was estimated geospatial

[11] Section 2.2.2.1 explores total land availability in Brazil used in the BLUM.

information), $f(.)$ is a constant elasticity function with results in the interval [0,1] for reasonable values of average return.

Scale and competition effects are not independent, though. In conjunction, they are the two components of the own return elasticities of each activity. Considering a *ceteris paribus* condition, the increase on profitability of one activity has three effects: increases total agricultural area (through average return), increases its own share of agricultural area and, thereby, reduces the share of agricultural area of other activities. For competing crops, cross effects of profitability on area are negative.

As mentioned, the own elasticities of each crop are the sum of competition and scale elasticities. At the same time, regional elasticity of land use with respect to total agricultural returns (total *Agland* elasticity) is the sum of scale elasticities of each activity. So, competition elasticities can be directly calculated after total *Agland* elasticity and total own elasticities were obtained through econometric analysis and literature review. The option to estimate area response to return, instead of price, is supported by several studies.[12] The process to obtain proper elasticities was comprehensively discussed between ICONE and CARD/FAPRI staffs until the final values were agreed.

Own return elasticity was mainly estimated by time series econometric analysis, using official data for area, namely from Brazil's Agriculture Ministry's National Supply Agency (CONAB) and the Brazilian Institute of Geography and Statistics (IBGE), and annual profitability calculated by ICONE. Literature review and experts were also consulted for qualitative ranking of elasticities. Table 1 reports the own area-return elasticities (averaged by area) used in BLUM for this paper for crops and pasture. In the second row of the table, the elasticities used for Brazil in FAPRI international model are also reported, for comparison.[13]

[12] See BRIDGES & TENKORANG (2009).
[13] Elasticities used in FAPRI international model are available at: http://www.fapri.iastate.edu/tools/elasticity.aspx

Table 1: Average own return elasticities for Brazil used for first crops and pasture

Activity	Corn 1st crop	Soybeans	Cotton	Rice	Dry beans 1st crop	Sugarcane	Pasture
BLUM elasticities	0.20	0.45	0.24	0.14	0.10	0.40	0.11
FAPRI elasticities	0.42	0.34	NA	0.07*	NA	0.20*	NA

(*) indicates production elasticity instead of area elasticity
Source: ICONE, based on ICONE and CARD/FAPRI joint work

One can verify that the values of own elasticities used in the BLUM can be considered high. The elasticities proposed are even higher than the ones used in FAPRI international model analysis, except for corn. However, differently from the FAPRI´s world models, corn area in BLUM is divided in first and second crops. As showed in the section B at Annex 1, the area of first crop of corn has been relatively stable while most of the demand growth has been supplied by the second crop.

The inference of regional total *Agland* elasticity was based on 1996 and 2006 Census data (with corrections on pasture area)[14] for area allocated to agriculture; geospatial data for land available, and estimated average return estimated by ICONE. Values of regional *Agland* elasticities are presented in Table 2 below.

Table 2: Estimated regional elasticity of land allocated to agriculture with respect to total agricultural returns

Region	South	Southeast	Center-West Cerrado	North Amazon	Northeast	MAPITO and Bahia	Brazil
Agland elasticity	0.06	0.07	0.18	0.25	0.01	0.10	0.13

Source: ICONE, based on ICONE and FAPRI joint work

Table 2 above reports some significant high values for *Agland* elasticities, especially for the North Amazon and Center-West Cerrado. For example, in the North Amazon region, a 50 percent increase on the average profitability (that may occur via price variation), leads to an increase on 12.5 percent of total area allocated to agriculture.

For comparison, the Global Trade Analysis Project (GTAP) model used in the "Proposed Regulation to Implement the Low Carbon Fuel Standard" (sugarcane and corn ethanol analysis), "elasticities of land transformation" inside the range of 0,10 and 0,20 in most of its analysis.[15]

[14] See Annex 1, section A.1
[15] See California Air Resources Board's Low Carbon Fuel Standard (2009).

2.2.2.1. ESTIMATES ON TOTAL POTENTIAL AVAILABLE LAND USED IN BLUM

Specific geospatial analysis was conducted in order to estimate total potential land available for agricultural production for each BLUM region, which enters as an input for the scale effect section in the model. This database was provided by the Agricultural Land Use and Expansion Model – Brazil (AgLUE-BR), which is under the coordination of Prof. Gerd Sparovek at University of São Paulo.[16] AgLUE-BR input database for land use considered compilation of latest available spatial maps. For restricting agricultural land use expansion physical (soil, climate and slope) and legal (environmental legislation applicable to private farmland and public conservation parks) were also spatially considered.

The first model step was the exclusion for agricultural expansion of all legally protected areas (conservation parks, Indian reservations, and Areas of Permanent Protection according to the Brazilian Forest Code) and urbanized areas. The remaining area was classified into anthropic (mainly used for agriculture and pasture) and natural vegetation classes, and aggregated by municipality.

The areas legally protected in private farmland represented by the Areas for Permanent Protection (APP) and Legal Reserve (LR), were also assessed. APP refers to riparian areas, generally along riverbanks, which were mapped and excluded for agricultural expansion. LR is more complex to estimate since it is a percentage of each farm that must be set-aside with natural vegetation, ranging from a maximum of 80 percent in Amazon biome to 20 percent outside the Legal Amazon Region, under Brazilian regulations. The LR calculations in the model were made at municipality level. Considering the natural vegetation area and the estimated area that should be used as LR, for each municipality, the deficit of LR or the natural vegetation that still could be used for agricultural purposes was calculated.

The results for natural vegetation that could be used for agriculture are different if LR is considered or not, especially in Amazon, where the LR is 80 percent of the properties' areas. Aiming to use conservative numbers, based on internal communication with CARD/FAPRI, we decided together to consider a partial compliance with LR, which means that the BLUM has been using an average of availability with and without LR requirements. Therefore, it is important to mention that we consider the used numbers overestimated,

[16] AgLUE-BR is in final stage of revision for publication. After publication the original databases used in the model will be made available for public access.

since environmental restrictions have been more stringently enforced lately, resulting in better compliance, especially for the future years.

Furthermore, although AgLUE-BR is already prepared to provide data on land availability accounting for all criteria of physical suitability (soil, climate and slope), it is also important to mention that total area considered available for agriculture does not include suitability classification for agricultural activities, which would decrease total available area. The only suitability variable used in the scenarios presented in this document was slope (less than 12 percent). Thus, the total land available for agricultural expansion used by BLUM for this analysis (see Table 3) is likely overestimated.

Table 3 – Total land available for agricultural expansion (1,000 hectares), actual use (%) and main biomes for the Brazilian regions

	Remaining vegetation discounting legal restrictions	Remaining vegetation without discounting legal restrictions	Share of potential area used in the BLUM[a]	**Main biomes**
South	3,392	4,638	0.91	Atlantic Forest (60%) and Pampas (40%)
Southeast	6,755	13,211	0.89	Cerrado (57%) and Atlantic Forest (41%)
Center-West Cerrado	12,611	26,530	0.84	Cerrado (67%) and Pantanal (24%)
North Amazon	18,330	129,050	0.74	Amazon (98%) and Cerrado (2%)
Northeast Coast	4,944	195	0.76	Caatinga (98%) and Atlantic Forest (2%)
MAPITO and Bahia	25,053	40,013	0.61	Cerrado (60%) and Caatinga (33%)
Brazil	71,084	213,636	0.79	

[a] Refers to the share of potential agricultural area which has currently been used in the BLUM in the scale effect section, based on 2008.

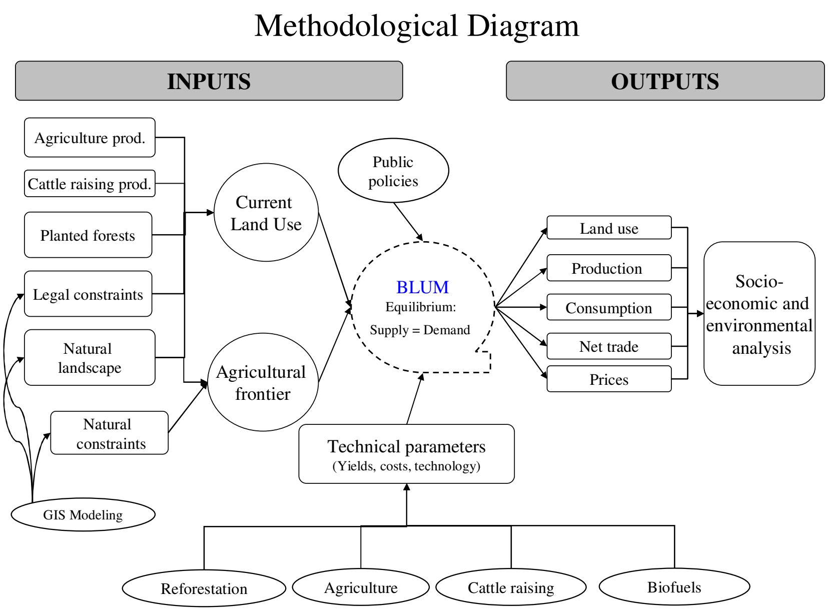
Source: AgLUE-BR. Elaboration by ICONE.

The predominant type of remaining vegetation in each region, as indicated in the last column in Table 3, in addition with the main biome which has currently been used for agricultural production in the BLUM were used for the projected land use change analysis. For the Center-West Cerrado region, for example, all the future expansion over natural vegetation was considered on cerrados, since it has the largest share on total remaining vegetation and, also, the largest share of current agricultural production.

2.2.3. MODEL SOLUTION AND ITS RESULTS

As explained earlier, national supply and demand and regional land use of each product respond to price. Consequently, for a given year, equilibrium is obtained by finding a vector of prices that solves all markets simultaneously. Year by year, a sequence of price vectors are found, which allows following the market trajectory along time. The outputs of the model are: regional land use and change, national production, prices, consumption and net trade. One of the main contributions of BLUM related to other simulation models is that, as explained before, it enables to identify LUC dynamics, instead of simple area allocation, including pasture area and its yields improvements. A synthesis of the model is described in Figure 3, below.

Figure 3 – Methodological diagram of the Brazilian Land Use Model (BLUM)



Source: ICONE

In Section 3, which follows, we describe how the BLUM can be used in order to have land use change results used to calculate (*ex post*) its related carbon emissions from sugarcane ethanol analysis.

3. BLUM APPLIED TO LUC AND GHG EMISSIONS FROM SUGARCANE ETHANOL

In order to analyze and discuss the results for ethanol carbon emissions associated to LUC due to the increase in sugarcane production, we replicated two RFS-2 DRIA scenarios: "Imports Only" (Baseline) and "Control Case" (Shock).[17] These scenarios permitted us to isolate the effect of the Brazilian increase in sugarcane production and the emissions related to the land use change due to a shock on ethanol demand.

In the "Baseline" scenario, the demand for ethanol is 0.6 billion gallons, while in the "Shock" scenario it has been increased by 2.5 billion reaching 3.1 billion gallons. We considered that all additional demand would be produced and supplied by Brazil, as done by CARD/FAPRI in the results published in the RFS-2 DRIA. Since we are doing the analysis only for Brazil, we used the Brazilian net exports published in the "Imports Only" scenario for both scenarios for all products, except for ethanol. This procedure is important to guarantee that all LUC effects would take place within Brazil, not internationally, because the exports of all other activities were maintained fixed in the "Shock" scenario and equal to the "Imports Only". Fixing net trade for all activities and having all other demand and supply components variable and depending on prices and profitabilities, the model will find a vector of prices that solves all markets simultaneously, as explained before.

According to RFS-2 DRIA, only Brazil has ethanol excess of supply to support an additional demand of 2.5 billion gallons in the United States, as considered in the Shock scenario. However, the results found that only 56% of total ILUC associated to this increase is within Brazil, assuming that Brazil does not have enough land to accommodate all the increase in sugarcane production.

In contrast to RFS-2 DRIA results, Nassar et al. (2008) is one of the studies showing that, during the last six years, there was no need to convert land in other countries due to the increase in the Brazilian ethanol production given that livestock and all grains production have also been raising significantly and at the same time as the increase in sugarcane production. Furthermore, the study pointed out that part of the total area converted to sugarcane came from crops and pasture yield improvements (it can also be observed in

[17] See the following documents and spreadsheets: **Control case:** EPA-HQ-OAR-2005-0161-0860. Available at http://www.regulations.gov/search/Regs/home.html#documentDetail?R=090000648099548c. **Imports Only:** EPA-HQ-OAR-2005-0161-0862. Available at http://www.regulations.gov/search/Regs/home.html#documentDetail?R=090000648099548e.

Annex 1). These arguments support the hypothesis that all LUC associated with the increase in sugarcane production would take place within the Brazilian frontier, as considered in this document.

As mentioned in section 2, the own and cross elasticities activities of the BLUM structure allow us to calculate the land use change caused by relative variations on the own activity profitability and the other competing activities profitabilities, respectively.

In the Shock scenario, for example, when the Brazilian ethanol exports is increased by 2.5 billion gallons, the amount of land that sugarcane will expand due to the increase on its own profitability after the shock and the amount of land that it will exchange with other activities, in a relative terms, was calculated based on the own and cross sugarcane elasticities, respectively.

More specifically, the cross elasticities in sugarcane share of area equation ($\varepsilon_{sugarcane,j}$ where *j* = other crops) are the variation of sugarcane share caused by a change in the other activities returns. The cross elasticities determine the part of sugarcane share that is lost to other activities. In the same way, the cross elasticities in the other activities share equations, considering a sugarcane return variation ($\varepsilon_{i,sugarcane}$ where *i* = other activities) is the part of the other activities share that was displaced by sugarcane. The net sum of these effects, that is, the share that sugarcane loses and gains from other activities, is the final variation of sugarcane share. The area allocated for each activity in each region is obtained by multiplying the total agricultural land in each region by each crop and pasture final shares. The effect of the increase in sugarcane production over other activities after the shock in each region can be measured comparing the area allocated for each crop in both scenarios in 2022.

Considering the regularity conditions of homogeneity, symmetry and adding up, as explained in section 2, pasture area share is determined by the residual of all other crops share expansion, while the sum of all crops and pasture shares of total land allocated to agriculture must be equal to 100 percent.

According to BNDES & CGEE (2008) and Assad & Pinton (2008), the largest part of the potential land for sugarcane expansion is located in the Center–South of Brazil, where the climate and soil are favorable for sugarcane production. Considering that, in the BLUM, pasture area represents 78 percent of the total agricultural area in the regions South, Southeast and Center-West Cerrado in 2008, most of the area suitable for sugarcane is currently used as pasture. In addition, remote sense images show that most of the increase in sugarcane production took place over pasture and other agricultural uses.[18] For the Center-South region, in 2007 and 2008, 98 percent of the increase in sugarcane area was over pasture and other agricultural uses. These evidences support the fact that sugarcane doesn't expand over natural vegetation. So, for the purpose of this analysis, the amount of sugarcane expansion over pasture area can be calculated as the result of total sugarcane expansion minus sugarcane expansion over crops, which are both outputs of the BLUM as explained earlier.

Once sugarcane expands over grains and pasture areas, and historical data shows that pasture yields improve (see Annex 1) at the same time that both sugarcane and grains areas are increasing overtime; we can conclude that grains also directly displace pasture area. BLUM results reflect exactly that dynamic: *sugarcane increases over other crops and pasture; crops displace pasture, and pasture displaces natural vegetation.*

In terms of carbon emissions associated to LUC, which are *ex post* calculated based on BLUM results for LUC, the total displacement caused by the increase in sugarcane production is the total amount of pasture converted to crops (sugarcane plus grains), summed to natural vegetation converted to pastures. For each region, these types of land conversion, the pasture converted into crops and the pasture over natural vegetation, were transformed in coefficients. These coefficients represent the percentage of each type of conversion in the region, considering the weight of each region in the total land displaced in Brazil. These factors are used directly to calculate the average emission associated to each category in each region.

The land allocated to sugarcane calculated in the model is different from total land displaced by sugarcane due to the decrease on grains areas in some regions. The reason is that an increase in ethanol demand generates an increase on its price in order to get a higher production, and reduce the excess of demand until the market equilibrium is reached. In order to expand, sugarcane takes place over other crops and pasture, decreasing their share on total land allocated to agriculture. However, part of the grains demand is fixed (net trade is fixed and equal to the results obtained in the "Imports Only" scenario) and, in order to get the supply and demand equilibrium in the grains markets, two simultaneous effects were

[18] See Nassar et al. (2008).

observed. Firstly, the grains prices increased in order to recover the production levels as before the ethanol shock. As a result, the higher prices caused a small decrease in domestic demand. Since the aim of this analysis is to assess carbon intensity and, also, keep constant the domestic consumer welfare, the area that grains lost due to ethanol shock was incorporated (*ex-post*) to the total area, proportionally to LUC coefficients.

Using the results from BLUM, the methodology used to transform LUC into CO_2-e emissions is very similar to the one used in the RFS-2 DRIA. As in the original analysis, CO_2-e emission per hectare of sugarcane expansion is the emissions factors weighted by LUC coefficients. The LUC coefficients are a major change in our analysis, however. In the original analysis, they were estimated for the past, using geospatial analysis, and it was assumed that the same pattern would occur in the future, so they do not change over time or according to different possible shocks. In other words, the original LUC coefficients were not connected to the economic model.[19] One of the major improvements proposed in our work is that by using BLUM the LUC coefficients can be calculated based on the results of the model and, consequently, they are dependent on the scenario construction as well as on the economic assumptions as macroeconomic variables.

The values for carbon stocks and emissions for all different conversions, as well as the way to calculate emissions factors, were exactly the same as proposed by Winrock International for EPA in the spreadsheet for Brazil.[20] As the LUC results from BLUM are presented for the six Brazilian regions, in an *ex post* analysis, we weighted the emissions factors per state presented by Winrock, resulting in an average emission factor for each BLUM region.

The only difference adopted concerns the carbon uptake by sugarcane. Winrock considered an uptake of 5 MT CO_2-e per ha for crops, as suggested by the Intergovernmental Panel on Climate Change (IPCC). However, since sugarcane is a semi-perennial crop, which is very rich in biomass, the value of 5 MT CO_2-e per ha for crops does not accurately represent its carbon content. According to various specialists,[21] sugarcane biomass above ground is on average about 17 MT CO_2-e per ha. Given the availability of more reliable, accurate data on

[19] See document EPA-HQ-OAR-2005-0161-0891. Available at: http://www.regulations.gov/search/Regs/home.html#documentDetail?R=09000064809ad1c4.
[20] See document: EPA-HQ-OAR-2005-0161-0949.2 . Available at: http://www.regulations.gov/search/Regs/home.html#documentDetail?R=09000064809ad20e.
[21] See Amaral et al. (2008).

carbon stock for Brazil, we relied on this average value for all the increase in sugarcane, while holding 5 MT CO_2-e per ha for other crops expansion.

Applying the methodologies described in sections 2 and 3, the results are presented in the next section for land use change and carbon emissions considering the scenarios proposed by EPA.

4. LAND USE AND GHG EMISSIONS RESULTS

The results for land use and GHG emissions calculations are summarized in the file "ICONE_BLUM_EPA.xls" for both Baseline ("Imports Only") and Shock ("Control Case") scenarios. The file comprises thirteen spreadsheets with all formulas, calculations and results for land use change and GHG emissions. More importantly, the "Land Use Change" spreadsheet presents the results on land use change that are used as the base for the final coefficients for the calculation of per hectare factor emission. The results on life cycle and GHG emissions are presented in the "Results_2022" spreadsheet.

Since net exports for grains and beef are hold fixed for both scenarios, using CARD/FAPRI results for Brazilian net exports, the results for total supply and demand are very similar for all products, except for ethanol. In this case, the additional Brazilian net exports for the Shock scenario were 2.5 billion gallons, comparing to the Baseline scenario. In order to avoid the displacement of Brazilian ethanol consumption by U.S. imports, Brazilian ethanol domestic demand was also kept fixed according to the results obtained in the Baseline scenario.

The intention for using the net trade of the Baseline scenario for grains and beef was to guarantee that the increase in sugarcane production in Brazil in the Shock scenario would not cause any international LUC, because Brazil would be providing all the quantities internationally in the same amount as before the shock, which is perfectly acceptable as explained in the previous sections. Thus, there is no need for other countries to expand production to maintain the same supply in the international market.

Once production is very similar in both scenarios, the most relevant results are in the land use section. More detailed results are available in "Area Allocation Imports Only" and in "Area Allocation Control Case" spreadsheets in the attached file. For the purpose of this document, since all the calculations for land use change are based on the comparison of both scenarios, Table 4 summarizes the additional land used for grains, sugarcane and pasture for the Shock scenario in 2022, comparing to the Baseline scenario.

Since the Southeast region is the current largest producer of sugarcane, sugar and ethanol in Brazil, a shock in ethanol exports can be expected to have more effect on LUC in this region, mainly in Cerrado biome.[22] The 1,032 thousand hectares of sugarcane expansion in Brazil resulted in a 405 and 422 thousand hectares decrease in pasture and grains areas decrease in, respectively, and an additional total agricultural area of 206 thousand hectares.

Table 4 – Additional Area for Agriculture, Grains, Sugarcane and Pasture comparing Shock and Baseline scenarios in 2022 (in 1,000 hectares)

Region	Agriculture Area	Grains*	Sugarcane	Pasture
South	21.17	-38.96	79.08	-18.96
Southeast	99.63	-342.36	708.51	-266.52
Center West Cerrado	48.42	-66.27	101.50	13.18
North Amazon	23.22	8.29	8.80	6.13
Northeast Coast	3.96	12.10	118.87	-127.00
MAPITO and Bahia	9.41	5.53	15.72	-11.83
Brazil	205.81	-421.67	1,032.47	-404.99

** Grains are the sum of corn (first crop), cotton, soybeans, dry beans (first crop) and rice.*
Source: ICONE

From BLUM model, it is possible to estimate the direct and indirect land use changes after some calculations, as explained in section 3. The intermediary steps to calculate the impacts are summarized in Table 5.

Table 5 – Sugarcane displacement for the shock scenario comparing to baseline scenario

	South	Southeast	Center West	North Amazon	Northeast Coast	MAPITO & Bahia	Brazil
a) Sugarcane Expansion	79.1	708.5	101.5	8.8	118.9	15.7	1,032.5
b) Grains to Sugarcane	72.9	470.4	98.7	5.5	0.2	13.6	661.3
c) Pasture to Sugarcane	6.2	238.1	2.8	3.3	118.7	2.1	371.2
d) Total Ag Land Expansion	21.2	99.6	48.4	23.2	4.0	9.4	205.8
e) Grains Expansion	-39.0	-342.4	-66.3	8.3	12.1	5.5	-421.7
f) Pasture to Grains	34.0	128.0	32.5	13.8	12.3	19.1	239.6
g) Pasture Total Loss	40.1	366.2	35.2	17.1	131.0	21.2	610.8
h) Pasture Net Loss	19.0	266.5	-13.2	-6.1	127.0	11.8	405.0

Source: ICONE

[22] Two ecosystems prevail in this region: Atlantic Forest and Cerrado. The expansion of the total agricultural land is expected to take place in the southeast Cerrado because the majority of land available in this region is located in the Cerrado.

Briefly, Table 5 data can be read as follows. From 1,032.5 thousand hectares of sugarcane expansion:

- Direct displacement of 661.3 thousand hectares of grains (coming from the competition equations for each region) and 371.2 thousand hectares of pasture areas;
- Total agricultural expansion of 205.8 thousand hectares;
- Decrease of 421.7 thousand hectares in grains area;
- Direct displacement of 239.6 thousand hectares of grains over pastures, (e) + (b);
- Total pasture displacement of 610.8 thousand hectares, (c) + (f);
- Since there were 205.8 thousand hectares expansion of total agricultural area (d), which can be considered as pasture expansion over natural vegetation, the net pasture area expansion is -405 thousand hectares (h).

As shown in Table 5, it is possible to calculate the indirect land use over natural vegetation in Brazil, which was 206 thousand hectares (d). These LUC can also be identified by BLUM regions and, therefore, estimated by type of vegetation. The direct impact is the displacement of grains and sugarcane over pasture or pasture total loss (g). Using these calculations, Table 6 summarizes the results used for the LUC and ILUC calculation and the share of each in total Brazil impacts.

Table 6 – Summary of land use change from an ethanol shock (in thousand hectares) and share of each effect for GHG emissions calculation (in %)

	South	Southeast	Center West	North Amazon	Northeast Coast	MAPITO & Bahia	Brazil
Sugarcane Expansion	79.1	708.5	101.5	8.8	118.9	15.7	1,032.5
Grains Expansion	-39.0	-342.4	-66.3	8.3	12.1	5.5	-421.7
Pasture to Crops	40.1	366.2	35.2	17.1	131.0	21.2	610.8
ILUC Forest	21.2			23.2			44.4
ILUC Savanna & Shrubland		99.6	48.4		4.0	9.4	161.4
Total Displacement	61.3	465.8	83.7	40.3	134.9	30.7	816.6
Total Displacement + Grains Expansion	100.2	808.1	149.9	32.0	122.8	25.1	1,238.3
Land Use Change Coefficient for Calculation of Per Hectare Factor Emission							
Pasture to Crops	5%	45%	4%	2%	16%	3%	75%
ILUC Forest	3%	0%	0%	3%	0%	0%	5%
ILUC Savanna & Shrubland	0%	12%	6%	0%	0%	1%	20%

Source: ICONE

From Table 6 results, total crops displacement over pasture was 611 thousand hectares and the LUC over natural vegetation was 206 thousand hectares. BLUM regions were used to separate the biomes on which total agricultural expansion is taking place. For that, we used data collected from satellite images and used the most significant type of vegetation with the largest land available and suitable for agriculture in each region, as described in section 2. The analysis indicated that almost all the available and suitable area for agriculture in the South and North Amazon are in tropical forests and, for all other regions, are in savanna and shrubland. Considering each region calculations for direct and indirect land use change in Brazil, the displacement results are: 75% over pasture, 5% over tropical forest and 20% over savanna and shrubland. According to this and the results of Table 6, total ILUC over natural vegetation is divided in 165 thousand hectares over savanna and shrubland, and the remainder 44 thousand hectares was over tropical forest.

Taking into account that grains area were reduced due to domestic demand adjustments after ethanol shock, all this loss (-422 thousand hectares) was incorporated as a direct impact of land use change for CO_2-e emissions calculations (1,238 thousand hectares) using the same per hectare coefficients.

The new LUC factors (Table 4) were used to weight the emission factor, resulting in 16.6 MT CO2-e per ha of crop expansion in Brazil in year 0, and 4.54 and 0.28 in years 1-19 and 21-79, respectively.

Total emission for LUC reached 616,680 g CO_2-e/mmBtu when it is considered 100 years and 2% discount rate, which represents around 47% of all net emissions associated to sugarcane ethanol. For an analysis of 30 years and no discount rate, total emission for LUC reaches 703,378 g CO_2-e/mmBtu and thus represents 59% of all emissions.

In comparison with EPA results for the reduction on ethanol emissions related to gasoline, ICONE’s results shows a decrease on the emissions levels by 25-34 percentage points, respectively for 100 years with a discount rate of 2% per year and 30 years and no discount rate, which are quite significant. Considering methodological advantages in using the BLUM for the analysis proposed, as described in the previous sections, we strongly urge that EPA uses these results for land use change and GHG emissions in the final rule.

5. FINAL CONSIDERATIONS

This document detailed the reasons why the BLUM can be considered a powerful tool to asses LUC in Brazil and, in coordination with international economic models and data for carbon emission factors, can be a useful tool to estimate more accurately GHG emissions associated with biofuels production than prior models.

Using BLUM results, together with Winrock database for EPA, we estimated reductions of 69% and 60% of GHG emissions for ethanol comparing to gasoline, for 100 year with a 2% discount rate and 30 years with no discount rate, respectively. As explained above, the LUC coefficients are the core difference of the analysis undertook. Considering all the advantages explored in this document to support these results, we urge that EPA revise its results and use the ones proposed by ICONE.

Our results are likely far more conservative for two reasons. First, we have used an overestimated total area available for agriculture though it is quite reasonable to expect that competition effect would have been stronger than scale effect, thus diminishing expansion over natural vegetation. Second, we are incorporating significant amounts of “International farm inputs and Fert N_2O” (as estimated by the original RFS-2 DRIA), which is also associated with international LUC. This, in turn, is, by hypothesis, not considered here, since we hold the Brazilian net exports to avoid international leakage. Third, we have not addressed necessary changes to the EPA’s calculations of the emissions of sugarcane ethanol that, based on a cursory review, appear not to include some of the significant efficiency improvements evidence in Brazilian agriculture.[23] Given our cautious approach, we would expect that further research and analysis may well show the reduction of GHG emissions for sugarcane ethanol higher than projected in this document.

[23] See Velasco, J. "Comment submitted by Brazilian Sugarcane Industry Association (UNICA), Document ID EPA-HQ-OAR-2005-0161-1761.1." Letter to Environmental Protection Agency, Docket EPA-HQ-OAR-2005-0161. 2 Sept. 2009. MS. EPA/OTAQ, Washington, DC.

BIBLIOGRAPHY

AMARAL, W.A.N. do; MARINHO, J.P.; TARASANTCHI, R.; BEBER, A.; GIULIANI, E. (2008), Environmental sustainability of sugarcane ethanol in Brazil. In: Zuurbier and Vooren (eds), Sugarcane ethanol: contributions to climate change mitigation and the environment. Wageningen: Wageningen Academic Publishers, 2008.

ASSAD, E.D.; PINTO, H.S. Aquecimento Global e a Nova Geografia da Produção Agrícola no Brasil. São Paulo: Posigraf, 2008.

BANCO NACIONAL DE DESENVOLVIMENTO ECONOMICO E SOCIAL – BNDES; CENTRO DE GESTÃO E ESTUDOS ESTRATÉGICOS – CGEE (Coord). Sugarcane-based Ethanol: Energy of Sustanable Development. Rio de Janeiro: BNDES, 2008. Available at: http://www.bioetanoldecana.org/en/download/bioetanol.pdf.

BRIDGES, D.; TENKORANG, F. Agricultural Commodities Acreage Value Elasticity Over Time – Implications for the 2008 Farm Bill San Diego: American Society of Business and Behavioral Sciences. v.6, n.1, February 2009.

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY, AIR RESOURCES BOARD. Proposed Regulation to Implement the Low Carbon Fuel Standard. Staff Report: Initial Statement of Reasons. Volume I. Sacramento, March 5, 2009.

CONAB – Companhia Brasileira de Abastecimento. Available at: http://www.conab.gov.br/conabweb/index.php?PAG=101

FAPRI – FOOD AND AGRICULTURAL POLICY RESEARCH INSTITUTE. Models. Ames: FAPRI-CARD, 2008. Available at: http://www.fapri.iastate.edu/models/

HOLT, M. T. A linear approximate acreage allocation model. Fargo: Journal of Agricultural and Resource Economics. v. 24, n. 2, p. 383-397, 1999.

INPE – NATIONAL INSTITUTE FOR SPACE RESEARCH. Amazônia: Prodes. Sao José dos Campos: INPE, 2008. Available at: http://www.obt.inpe.br/prodes/index.html

IBGE - BRAZILIAN INSTITUTE FOR STATISTICS AND GEOGRAPHY. Agricultural Census 1995-1996: Pasture database. Brasília: IBGE, 1996. Available at: http://www.ibge.gov.br/home/estatistica/economia/agropecuaria/censoagro/1995_1996/default.shtm

IBGE - BRAZILIAN INSTITUTE FOR STATISTICS AND GEOGRAPHY. Agricultural Census 2006: Pasture database. Brasília: IBGE, 2006. Available at: ftp://ftp.ibge.gov.br/Censos/Censo_Agropecuario_2006/

IEA – INSTITUTE FOR AGRICULTURAL ECONOMICS. Pasture Data. Sao Paulo: IEA, 2008. Available at: http://www.iea.sp.gov.br/out/banco/menu.php

IEA – INSTITUTE FOR AGRICULTURAL ECONOMICS. Pasture Data. Sao Paulo: IEA, 2008. Available at: http://www.iea.sp.gov.br/out/banco/menu.php

INPE – NATIONAL INSTITUTE FOR SPACE RESEARCH. Amazônia: Prodes. Sao José dos Campos: INPE, 2008. Available at: http://www.obt.inpe.br/prodes/index.html

NASSAR, A.M.; RUDORFF, B.F.T.; ANTONIAZZI, L.B.; AGUIAR, D.A. de; BACCHI, M.R.P.; ADAMI, M. Prospects of the sugarcane expansion in Brazil: impacts on direct and indirect land use changes. In: Zuurbier and Vooren (coord.), Sugarcane ethanol: contributions to climate change mitigation and the environment. Wageningen: Wageningen Academic Publishers, 2008.

UFMG – University of Minas Gerais. Centro de Sensoriamento Remoto (database not published). Belo Horizonte: UFMG, 2008. Available at: http://www.csr.ufmg.br/

ANNEX 1: Technical Note: Explanation on the Construction of the Pasture Data and Second Season Crops included in the Brazilian Land Use Model (BLUM)

A. PASTURE DATA

Pasture data in Brazil is only officially available in the Agricultural Census, which is the most detailed database for land use in Brazil. Although the Agricultural Census is available for a several number of years (1970, 1975, 1980, 1985, 1996 and 2006), there is no up-to-date Agricultural Census given that the data from 2006 have been published only as preliminary. In addition, pasture data from 2006 Census have been highly criticized. Our opinion, which is shared with other experts in Brazil, is that the preliminary numbers underestimates pasture data and the final data will show more land allocated to pasture. 2006 Census brings 172 million hectares with pastures (planted and natural pastures) that probably will be correct to a magnitude between 195 to 205 million hectares, according to the discussions we have had with various experts. The reason for that are the difficulties in collecting the information in areas that are not easily accessible, especially in the Amazon states. Time series for pasture data is available only in São Paulo state from the Instituto de Economia Agrícola (IEA)[24] of the State Government. Therefore, specifically in the case of Sao Paulo, IEA data was used in the pasture dataset.

In order to have land allocation for pastures projected by BLUM, and considering the lack of up-to-date information on current use and time series for pastures, ICONE has used a two-step approach to construct a database for pastures. Firstly, pasture area was established for two points in time: 1996 and 2006. Secondly, a time series was constructed from 1997 to 2005, and extended to 2007 and 2008, in order to cover the whole period of data of the model. Although data in the model are presented in six regions, state level data were used for the definition of the 1996 and 2006 data.

Using the results generated by the University of Minas Gerais (UFMG) in a World Bank project that ICONE participated,[25] pasture area for 2006 was obtained using satellite images for almost all Brazilian municipalities (excluding the ones located on Pantanal, Caatinga and Pampa biomes). Considering satellite images and Agricultural Census for 2006, ICONE carefully analyzed both databases and considered some criteria to have final pasture area for

[24] See IEA (2008).
[25] Brazilian Low Carbon Study, not published.

the year 2006. Also, considering the limitations on Agricultural Census database, some corrections were made on 1996 data for some specific cases.

All the assumptions and criteria for pasture area in 1996 and 2006 were made considering each case, state by state. Basically, the most important assumption was that total land used for agriculture could not decrease considering the 10-year length, 1996 and 2006. In the case of the Amazon region, 1996 pasture data was recalculated based on 2006 satellite images discounting the deforestation rate from year by year for some states (like Acre, Amazonas, Para and Rondonia).[26] In the case of the state of Minas Gerais, we used satellite images for 2006 and 1996 data to correctly account for pasture areas located in high slopes areas were not captured by Agricultural Census area. In other words, we used Census database for 1996 plus this pasture area in higher slopes captured by satellite images in 2006. For the state of Sao Paulo, IEA pasture areas for 1996 and 2006 were used.

There are some points to be clear in the Center West region. For the Mato Grosso do Sul state, 2006 data was based on satellite images for the municipalities located on Atlantic Forest and Cerrado biomes and Census data for municipalities located in the Pantanal biome. For 1996, only Census data was used. In the case of Mato Grosso state, which is in both regions Center West and North Amazon, pasture areas from the Agricultural Census for 1996 and 2006 were used. To breakdown the state into the two regions, it was considered the municipalities in each biome, considering for the municipalities located on both biomes 50% of pasture areas in each region (3 and 4), methodology also used for all other crops areas. For the state of Goiás and Distrito Federal was used the same logic: satellite images for 2006 and Census for 1996.

For all other regions (South, Southeast except Sao Paulo and Minas Gerais states, MAPITO and Bahia) pasture areas were from Agricultural Census for both years 1996 and 2006.

Box 1 below summarizes all the sources and criteria used for pasture area in each region.

[26] Amazon annual deforestation rate is calculated by INPE in the PRODES Project. Data are publicly available in the website http://www.obt.inpe.br/prodes/.

Box 1 – Sources used for pasture area by region

	Sources for 1996 and 2006		*Criteria for time series construction*
Region	**1996**	**2006**	**1997 to 2005, 2007 and 2008**
South	Ag Census 1996	Ag Census 2006	Regression lagged pasture and cattle herd
Southeast	Ag Census 1996 except Sao Paulo and Minas Gerais states	Ag Census 2006 except Sao Paulo and Minas Gerais states	Regression lagged pasture and cattle herd
São Paulo	IEA	IEA	
Minas Gerais	Ag Census 1996 corrected using high slopes pasture from GIS 2006	GIS 2006	
Center West	Ag Census 1996	GIS 2006 except Mato Grosso and Mato Grosso do Sul states	Regression lagged pasture and cattle herd
Mato Grosso	Ag Census 1996 using 50% of pasture area in municipalities which are both in the Amazon and Cerrado Biomes	Ag Census 2006 using 50% of pasture area in municipalities which are both in the Amazon and Cerrado Biomes	
Mato Grosso do Sul	Ag Census 1996	GIS 2006 using Census 2006 for Pantanal's municipalities	
Amazon	Deforestations correction from GIS 2006 to 1996	GIS 2006	Deforestation discounting crops expansion
Northeast	Ag Census 1996	Ag Census 2006	Regression lagged pasture and cattle herd
MAPITO and Bahia	Ag Census 1996	Ag Census 2006	Regression lagged pasture and cattle herd

Source: ICONE

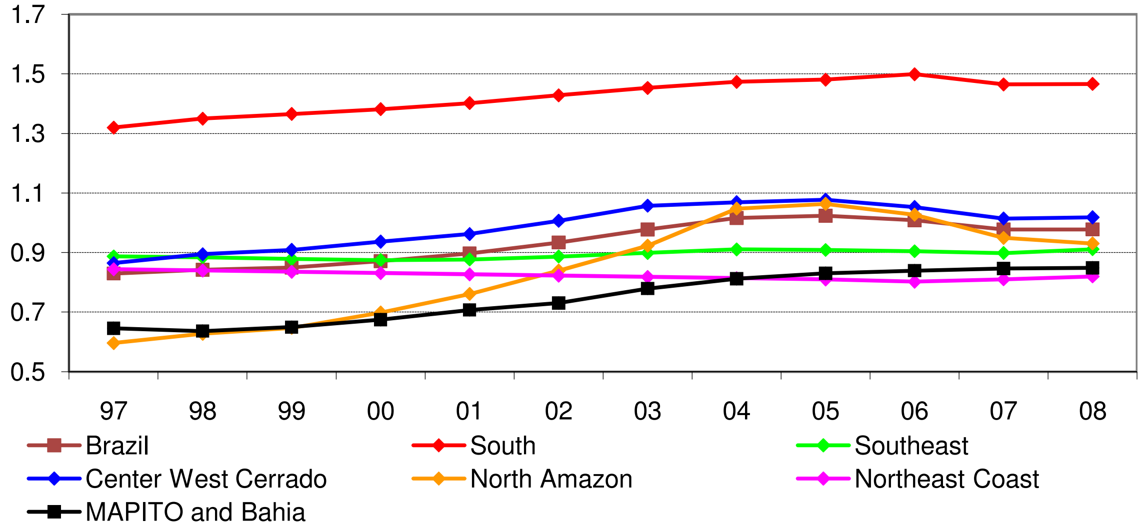
The second step is to construct a time series for the years that there were not available information for pasture areas. Two methodologies were used: (1) deforestation rate; (2) cattle herd and lagged pasture area.

For the Amazon region was used the deforestation rate discounting the expansion of crops areas year by year, from 1997 to 2005. For 2007 and 2008 the deforestation rate was added on 2006 pasture area.

For the other regions, since the state of São Paulo has a time series, it was estimated a regression on pasture area as a function of lagged pasture area and cattle herd. For all the regions were used estimated coefficients to construct the time series, considering some adjustments, except for the Amazon as explained above.

It is important to note that pasture area represents 82% of total area used in the BLUM (considering the crops modeled and pasture areas), leading grazing as the most important sector in terms of demand of total agricultural land. In addition, from pasture area and cattle herd time series, it is possible to have the stocking rate time series, as showed in Figure A1 below.

Figure A1 – Stocking rates for Brazil and BLUM regions (heads per hectare)



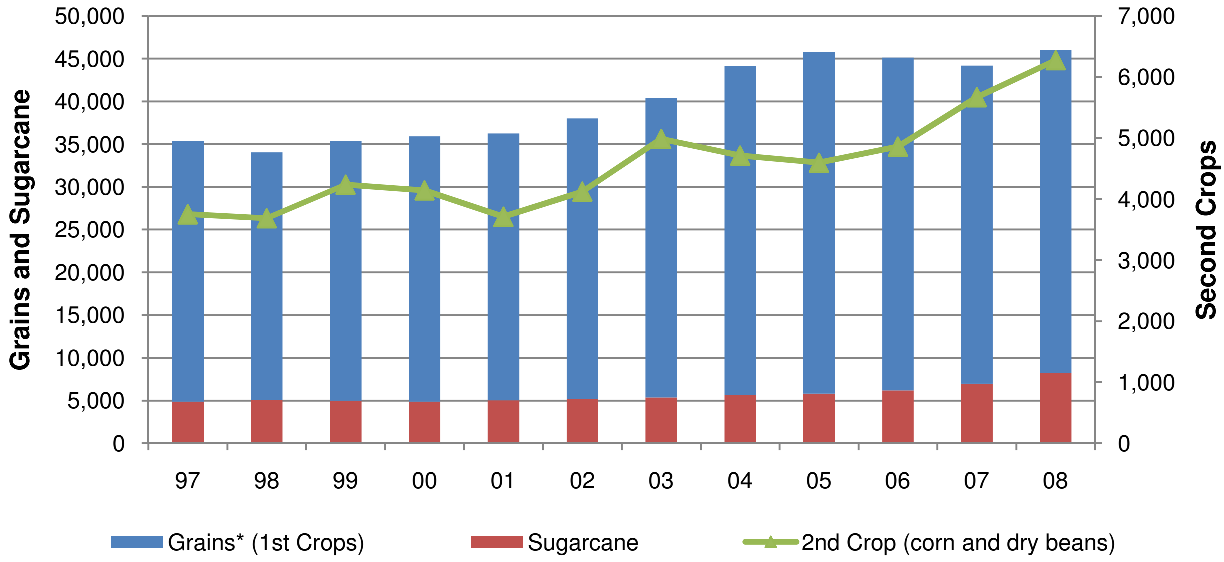
Source: IBGE, UFMG, ICONE

It can be observed from Figure A1 that stocking rates have an increasing trend in Brazil for all regions since the last eleven years, especially on those with more competition for land among crops and pasture. This trend does not occur only when cattle herd is decreasing more rapidly than pasture area decrease, due to its short period of internal cycle. Considering the intensification on grazing and the importance of pasture areas in Brazil, which are precisely considered in the BLUM, leaving pasture area and cattle herd out of the modeling, as the model used in RFS-2 DRIA, leads to significant errors on land use change dynamic analysis. For example, a 0.5% per year increase on stocking rate in Brazil, all other variables remaining constant, means a reduction on pasture area about 20 million hectares (from 2008 to 2022, with cattle herd fixed as 2008 levels), which are more than enough for crops expansion in this timeline.

B. SECOND CROPS OF CORN AND DRY BEANS

Another important point to consider is the increasing second crop season of corn production, which is mostly related to soybeans area of the same harvested season. This means that, even though corn area (first crop) is decreasing overtime due to the competition for land with soybeans, mainly, corn production is increasing as we have more second crop area and higher productivity levels. Figure B1 shows planted area for sugarcane, grains (first crops) and corn (second crop).

Figure B1 – Sugarcane, first crops grains and second crop of corn in Brazil (1,000 ha)



*Grains included (first season crops): corn, soybeans, dry beans, cotton, rice.

Source: IBGE

From Figure B1 it is also important to note that, historically, Brazil presented an upward trend in planted area for all crops, except for some specific years when had occurred crop season problems, which had impacts on the next harvesting years as happened in 2006 and 2007 for soybeans. Also, the increasing second crop of corn, mainly, has two important effects. First, the competition for land between the first season of corn and soybeans has been decreasing in the last years due to the increasing second crop of corn. Second, the decrease on the first crop of corn leads to higher production of soybeans and, more importantly, in terms of total production, it is offset by the second crop of corn. Again, second crops of corn and dry beans are projected in the BLUM in order to form the supply of these products, but they do not compete for land as do the first crops. As a result, ignoring the second crops can also lead to significant errors on land use change projections.