The Brazilian Land Use Model – BLUM

BLUM is a one-country, multi-regional, multi-market, dynamic, partial equilibrium economic model for the Brazilian agricultural sector which comprises two sections: *supply and demand* and *land use*. The model includes the following products: soybeans, corn (first and second crop), cotton, rice, dry beans (first and second crop), sugarcane, wheat, barley, dairy, and livestock (beef, broiler, eggs and pork). Commercial forests are considered as exogenous projections. Combined, these activities were responsible for 95% of total area used for agricultural production in 2008. Although second and winter crops, such as corn, dry beans, barley and wheat do not generate additional need for land (they are smaller and planted in the same place as first season crops, in double cropping areas), their production is accounted in the national supply.

The supply and demand section

In the supply and demand section, the demand is projected at the national level and formed by domestic demand, net trade (exports minus imports) and final stocks (which are not considered for dairy and livestock sectors and sugarcane), 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 beginning stocks (again considered only for grains and final sugarcane-based products) and responds to expected profitability of each commodity, which depends on costs, prices and yields.

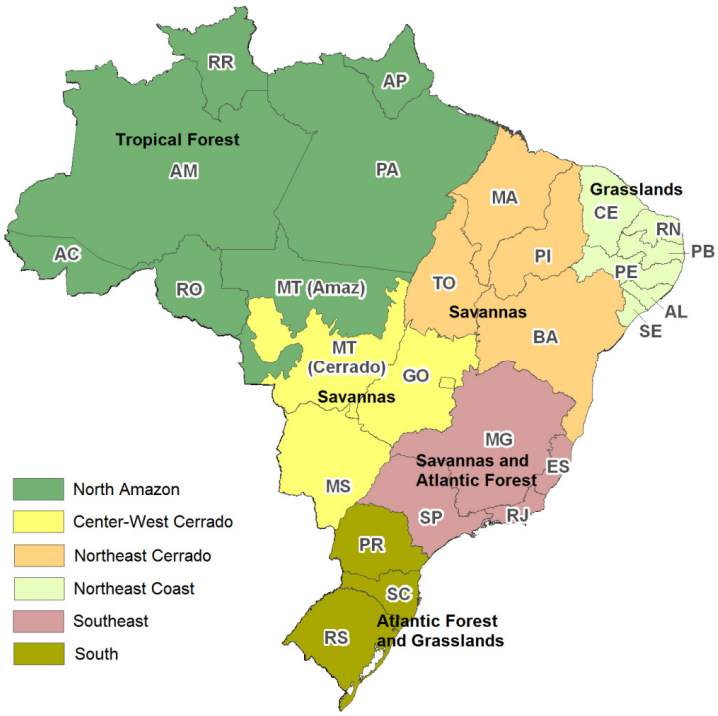
Land allocation for agriculture and livestock is calculated for six regions[1], as showed in Figure 1:

- South (states of Paraná, Santa Catarina, and Rio Grande do Sul);
- Southeast (states of São Paulo, Rio de Janeiro, Espírito Santo, and Minas Gerais);
- Center-West Cerrado (states of Mato Grosso do Sul, Goiás and part of the state of Mato Grosso inside the biomes Cerrado and Pantanal);

[1] The main criteria to divide the regions were agricultural production homogeneity and individualization of biomes with especial relevance for conservation.

- Northern Amazon (part of the state of Mato Grosso inside the Amazon biome, Amazonas, Pará, Acre, Amapá, Rondônia, and Roraima);
- Northeast Coast (Alagoas, Ceará, Paraíba, Pernambuco, Rio Grande do Norte, and Sergipe);
- Northeast Cerrado (Maranhão, Piauí, Tocantins, and Bahia).

Figure 1 – Regions considered in the Brazilian Land Use Model - BLUM



Source: ICONE, IBGE and UFMG.

National supply and demand and regional land use of each product respond to prices. Consequently, for a given year, equilibrium is obtained by finding a vector of prices that clears all markets simultaneously. Year by year, a sequence of price vectors are found, which allows the market trajectory to be followed through time. The outputs of the model are: regional land use and change, national production, prices, consumption and net trade.

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

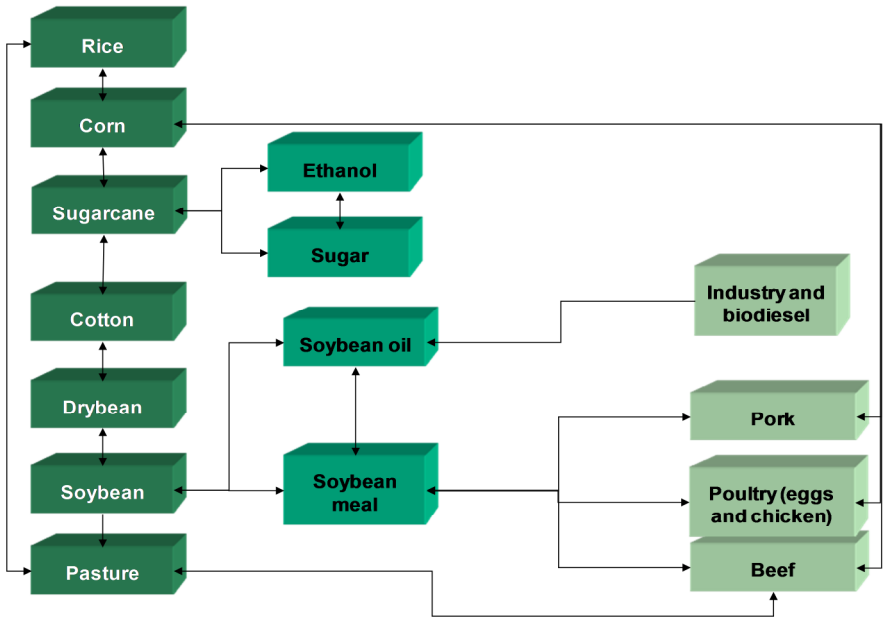
$$\textit{Beginning stock} + \textit{Production} + \textit{Imports} = \textit{Ending Stock} + \textit{Consumption} + \textit{Exports}$$

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 the grain 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 for corn and soybeans. In the case of the soybean complex, the components soybean meal and soybean oil are parts of the domestic demand for soybeans and are determined by the crush demand. Similarly, ethanol and sugar are the components of sugarcane demand (Figure 2).

Figure 2. Interactions between BLUM sectors



Source: ICONE

The land use section

The land use dynamics is divided in two effects: *competition* and *scale*. Intuitively, competition effect represents how the different activities compete 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. This need is accommodated by the expansion of total agricultural area over natural vegetation.

The competition effect consists in 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, the increase in the profitability of one activity will result in an increase in the share of

area dedicated to this activity and reduce in the share of area of your competing activities.

The regularity conditions (homogeneity, symmetry and adding up) are imposed so that the elasticity matrices (and associated coefficients) are theoretically consistent. For any set of these coefficients we calculate own and cross impacts and competition among activities. Then, using this structure, simulations in BLUM allow us to calculate not only land allocation, but also land use changes. In other words, the conditions allow the identification of the exchanged area for each activity, considering the amount of total allocated agricultural area.

In order to guarantee coherence of the above mentioned conditions, pasture area is regionally and endogenously determined, but modeled as the residual of total agricultural area minus crop area. In the context of the Brazilian agriculture, it is particularly relevant to project pasture both endogenously and regionally, since it represents around 77% of total land used for agricultural production.

Although the competition among activities may represent regions where the agricultural area is stable and near its available potential, this is an insufficient analysis for Brazil. Recent Brazilian agricultural history shows that crops, commercial forests and pastures combined respond to market incentives by contributing to an expansion of the total area allocated to agriculture (as can be seen in Nassar et al., 2010a)[2]. This effect is captured in the scale section of the BLUM. This methodological improvement is essential to adjust the model skills to the specific reality of the Brazilian agricultural land use dynamics.

The scale effect refers to the 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 for agriculture, and this share responds to changes in the average return of agriculture regionally.

Scale and competition effects are not independent. In conjunction, they are the two components of the own return elasticities of each activity. Considering a *ceteris paribus* condition, the increase in profitability of one activity has three effects: increase in total agricultural area (through average return), increase in its own share of agricultural area

[2] Nassar, A. M.; Antoniazzi, L. B.; Moreira, M. R.; Chiodi, L.; Harfuch, L. 2010a. An Allocation Methodology to Assess GHG Emissions Associated with Land Use Change: Final Report. ICONE, September 2010. Available at <http://www.iconebrasil.org.br/arquivos/noticia/2107.pdf>.

and, therefore, reduction in the share of agricultural area of other activities. For competing activities, cross effects of profitability on area are negative.

As mentioned previously, 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 the scale elasticities of each activity. Therefore, competition elasticities can be calculated directly after total Agland elasticity while total own elasticities were obtained through econometric analysis and literature review.

Land use equations

In the BLUM land use section, the area *a* of crop *i* of each region *l (l=1,…,6)* in year *t* is defined by the following equation:

$$a_{ilt} = A_l^T * m_{lt} * s_{ilt} \tag{1}$$

A_l^T is the total area available for agricultural production in the region *l*; m_{lt} is the share of A_l^T that is currently used for agricultural production (all crops and pasture), and s_{ilt} is the share of the area used by agriculture that is dedicated to crop *i*. A_l^T is an exogenous variable defined by GIS modeling.

The variable m_{lt} is endogenous to the model and responds to the average agricultural market return (profitability) index of region *l* (r_{lt}), so the share of area allocated to agriculture can be defined as:

$$m_{lt} = \frac{A_{lt}}{A_l^T} = k r_{lt}^{\alpha_{lt} \varepsilon_{r_l}^{Al}} \tag{2}$$

where *k* is a constant parameter; $\varepsilon_{r_l}^{Al}$ is the land supply elasticity (with respect to the average return) for region *l* (results for the Brazilian average is presented in Barr et al. 2010). The parameter α_{lt} is positive, higher or lower than one and can be defined as:

$$\alpha_{lt} = 1 - \frac{A_{lt} - A_{l0}}{A_l^T} \tag{3}$$

where A_{l0} is the land used for agriculture in a defined base period. When agricultural land in period *t* is close to the base period, α_{lt} is close to 1 and it does not affect $\varepsilon_{r_l}^{Al}$. However if agricultural land in *t* is larger than in the base period, the parameter α_{lt} is

smaller than one and reduces the effect of $\varepsilon_{r_l}^{Al}$. The opposite occurs when current agricultural land is smaller than (A_{lo}), increasing the land supply elasticity.

The r_{lt} is calculated through evidences that indicate which activities most expand in the agricultural frontier defined as:

$$r_{lt} = \sum_{i=1}^{n} r_{it} * d_{li} \tag{4}$$

Where d_{li} is a weighting vector of deforestation rate caused by each agricultural activity obtained by satellite imagery and GIS modeling. We can then calculate the weighting vector d_{li} as follows:

$$d_{\mathrm{l}i} = \frac{\mathrm{D}_{\mathrm{l}i}}{\mathrm{D}_{\mathrm{l}}^{\mathrm{T}}}; \text{where } \mathrm{D}_{\mathrm{l}}^{\mathrm{T}} = \sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{D}_{li} \tag{5}$$

According to Holt (1999) the cross area elasticity of crop *i* with respect to the return of other crops *j* can be defined as:

$$\varepsilon_{r_{lj}}^{l,i} = \frac{\partial a_{ilt}}{\partial r_{jlt}} \frac{r_{jlt}}{a_{ilt}} = A_l^T \left(\frac{\partial m_l(r_{lt})}{\partial r_{lt}} \frac{\partial r_{lt}}{\partial r_{jlt}} s_{ilt}(r_{ilt}, r_{jlt}) + m_l(r_{lt}) \frac{\partial s_{ilt}(r_{ilt}, r_{jlt})}{\partial r_{jlt}} \right) \frac{r_{jlt}}{A_l^T m_l(r_{lt}) s_{ilt}(r_{ilt}, r_{jlt})} \tag{6}$$

Which by rearranging terms leads to:

$$\varepsilon_{r_{lj}}^{l,i} = \frac{\partial m_l(r_{lt})}{\partial r_{lt}} \frac{\partial r_{lt}}{\partial r_{jlt}} \frac{r_{jlt}}{m_l(r_{lt})} + \frac{\partial s_{ilt}(r_{ilt}, r_{jlt})}{\partial r_{jlt}} \frac{r_{jlt}}{s_{ilt}(r_{ilt}, r_{jlt})} \tag{7}$$

The first term on the right hand side of equation (6) can be defined as the scale effect of the cross area elasticity $\varepsilon_{r_{lj}}^{s_{l,i}}$:

$$\varepsilon_{r_{lj}}^{s_{l,i}} = \frac{\partial m_l(r_{lt})}{\partial r_{lt}} \frac{\partial r_{lt}}{\partial r_{jlt}} \frac{r_{jlt}}{m_l(r_{lt})} \tag{8}$$

The competition effect of the cross area elasticity $\varepsilon_{r_{lj}}^{c_{l,i}}$ is the last part in the right hand side of equation (6):

$$\varepsilon_{r_{lj}}^{c_{l,i}} = \frac{\partial s_{ilt}(r_{ilt}, r_{jlt})}{\partial r_{jlt}} \frac{r_{jlt}}{s_{ilt}(r_{ilt}, r_{jlt})} \tag{9}$$

By analogy, the area elasticity of crop *i* related to its own return is also formed by the scale and competition effects and can be written as:

$$\varepsilon_{r_{li}}^{l,i} = \frac{\partial m_l\left(r_{lt}\right)}{\partial r_{lt}} \frac{\partial r_{lt}}{\partial r_{ilt}} \frac{r_{ilt}}{m_l\left(r_{lt}\right)} + \frac{\partial s_{ilt}\left(r_{ilt}, r_{jlt}\right)}{\partial r_{ilt}} \frac{r_{ilt}}{s_{ilt}\left(r_{ilt}, r_{jlt}\right)} = \varepsilon_{r_{li}}^{s_{l,i}} + \varepsilon_{r_{li}}^{c_{l,i}} \tag{10}$$

Where $\varepsilon_{r_{li}}^{s_{l,i}}$ is the scale effect and $\varepsilon_{r_{li}}^{c_{l,i}}$ is the land competition component of the area elasticity of crop *i* with respect to its own return[3].

The land competition component can then be calculated as:

$$\varepsilon_{r_{li}}^{c_{l,i}} = \varepsilon_{r_{lt}}^{l,i} - \varepsilon_{r_{li}}^{s_{l,i}} \tag{11}$$

The link between the regional land supply elasticity ($\varepsilon_{r_l}^{Al}$) and the scale effect of each activity ($\varepsilon_{r_{li}}^{s_{l,i}}$) can be observed. The land supply elasticity can be defined as:

$$\varepsilon_{r_l}^{A_l} = \frac{\partial m_l}{\partial r_l} \frac{r_l}{m_l} \tag{12}$$

And, rearranging:

$$\frac{\partial m_l}{\partial r_l} = \frac{\varepsilon_{r_l}^{A_l} m_l}{r_l} \tag{13}$$

The elasticity with respect to the variation in return of a given crop *i* in region *l* is:

$$\varepsilon_{r_{li}}^{s_{l,i}} = \frac{\partial m_l}{\partial r_l} \frac{\partial r_l}{\partial r_{li}} \frac{r_{li}}{m_l} \tag{14}$$

Which, from equation (14) and with some calculation, can be rewritten as:

$$\varepsilon_{r_{li}}^{s_{l,i}} = \varepsilon_{r_l}^{A_l} \frac{\partial r_l}{\partial r_{li}} \frac{r_l}{r_{li}} \tag{15}$$

From equation (4), equation (15) can be rewritten as:

$$\varepsilon_{r_{li}}^{s_{l,i}} = \varepsilon_{r_l}^{A_l} d_{li} \frac{r_l}{r_{li}} \tag{16}$$

Using equation (15), if the land supply elasticity is known, the scale effect of activity *i* can be easily calculated. As a result, the vector containing all land competition component elasticities $\varepsilon_{r_{li}}^{c_{l,i}}$ represents the diagonal of the competition matrix (one for each region *l*). Along with other restrictions (such as the regularity conditions and negative cross elasticities) the diagonal terms are then used to obtain the cross elasticities in the competition matrix, as represented in equation (9).

[3] Also explained in Nassar *et al.* (2009) available at http://www.iconebrasil.com.br/arquivos/noticia/1872.pdf

For winter or second crops, such as wheat, barley, corn second crop and dry bean second (and third) crop, the allocated area and production have different dynamics than the first crops presented above. Since corn second crop does not compete for land as it is planted after a principal crop, the area projections were based on the following equation:

$$a_{it}^{l} = \alpha_{i}^{l} + \beta_{i}^{l} a_{jt}^{l} + \delta_{i}^{l} r_{jt}^{l} + \varphi_{i}^{l} r_{it}^{l} + \phi_{i}^{l} a_{it-1}^{l} \qquad \text{i=corn, j=soybean} \qquad (17)$$

Where r_{it}^{l} is the profitability of corn second crop, r_{jt}^{l} is soybeans return, a_{jt}^{l} is the soybean area and a_{it-1}^{l} is the previous observed corn second crop area. For the parameters: $\beta>0$, $\delta>0$, $\phi>0$ and $\varphi>0$.

For dry beans second crop we have a simpler dynamics, which projected area depends only on its own returns. Wheat projections depend on its own expected return (positively) and negatively to the barley expected return. In the case of barley, area projections depend on its own return, wheat returns, and its own lagged area.

Allocating BLUM results in the Brazilian micro-regions

The micro-region allocation model follows the structure of BLUM in the supply side and it allocates the impacts of a specific scenario in the micro-regional level.

The BLUM results for area and production in each of 6 regions for soybean, corn (first crop and total), rice, cotton, dry beans (first crop and total), sugarcane, cattle herd and pasture are allocated into 558 Brazilian micro-regions.

The micro-region allocation model dynamics is based on two steps: first allocating BLUM results in each state and then distributing the state results for its respective micro-region.

Allocating BLUM results in each state

BLUM total area used by agriculture (first crop and pasture), A_l, is allocated in a state level in a way that:

$$A_{l,t} = \sum A_{s,t} * e_{l,t} \qquad l=(1,..,6);\ t = (2011,...,2030)$$

Where $e_{l,t}$ is the correction factor for each BLUM region l in each year t for the difference between the area estimated by micro-region model and BLUM model. In general this factor is less than 10%, since both models follow similar economic structure and assumptions. The variable $A_{s,t}$ is the total area allocated to agriculture (first crop and pasture) in each state s in the year t. It is defined by the equation:

$$A_{s,t} = A_s^T * m_{s,t}$$

A_s^T is the total area available for agricultural expansion in the state s. It is an exogenous variable determined by GIS modeling. The variable $m_{s,t}$ represent the share of area used for agriculture production (first crops and pasture). It is endogenous to the model and responds to the average agricultural market revenue (determined by price and yield) of state s, so the variation of share of area allocated to agriculture in each state can be defined as:

$$\Delta m_{s,t} = \frac{A_{s,t}}{A_s^T} = \Delta r_s^{\alpha_{s,t}\varepsilon_{\eta}^{A_l}}$$

where $A_{s,t}$ is the area used to agriculture (first crops and pasture) in the state s and year t; A_s^T is the total area available for agriculture expansion in the state s. In the second part of equation, $\varepsilon_{r_l}^{A_l}$ is the land supply elasticity for each region l of BLUM model and $\alpha_{s,t}$ is a positive parameter defined as:

$$\alpha_{s,t} = 1 - \frac{A_{s,t} - A_{s,0}}{A_s^T}$$

where $A_{s,0}$ is the land used for agriculture in a base period. When agricultural land in the year t is close to the base period, $\alpha_{s,t}$ is close to 1 and it has small effect over $\varepsilon_{r_l}^{A_l}$. However if agricultural land in t is larger than in the base period, the parameter $\alpha_{s,t}$ is smaller than one and reduces the effect of $\varepsilon_{r_l}^{A_l}$. The opposite also can occur.

The $r_{s,t}$ is the average revenue of each state and it is calculated through evidences that indicate which activities *i* most expand in the agricultural frontier and it as defined as:

$$r_{s,t} = \sum_{i=1}^{n} r_{i,t} * d_{l,i} \qquad s=(1,...,6)$$

where d_{il} is a weighting vector of deforestation rate caused by agricultural activity obtained by satellite imagery and GIS modeling for each BLUM region, that is, for each state and micro-region we use the weighting vector of their respective BLUM region, as described in the BLUM methodology.

The regional supply and national demand for each activity in Brazil is exogenous and determined by BLUM. The sum of state areas, $a_{i,s,t}$, for each crop *i* and year *t* is equal to the area of its respective region ($a_{i,l,t}$), this is

$$a_{i,l,t} = \sum_{s=1}^{n} a_{i,s,t} * e_{i,t}$$

Where $e_{i,t}$ is an adjustment factor.

Following the BLUM structure, the area *a* of crop *i* for state *s* in the year *t* is determined by the equation:

$$a_{i,s,t} = A_{s,t} * s_{i,s,t}$$

where $s_{i,s,t}$ is the share of area used by agriculture that is dedicated to crop *i* in the state *s* and it is determined by the following equation:

$$s_{i,s,t} = s_{i,s,t-1} * \sum_{j=1}^{n} \Delta r_{i,j,s} * \varepsilon_{r,i,j}^{s,i}$$

Similarly to the BLUM macro-region the cross area elasticity of crop *i* with respect to the revenue of other crop *j* is defined as:

$$\varepsilon_{r_{s,j}}^{s,i} = \frac{\partial m_s\left(r_{s,t}\right)}{\partial r_{s,t}} \frac{\partial r_{s,t}}{\partial r_{j,s,t}} \frac{r_{j,s,t}}{m_s\left(r_{s,t}\right)} + \frac{\partial s_{i,s,t}\left(r_{i,s,t}, r_{j,s,t}\right)}{\partial r_{j,s,t}} \frac{r_{j,s,t}}{s_{i,s,t}\left(r_{i,s,t}, r_{j,s,t}\right)}$$

The first term of equation is defined as scale effect of cross area elasticity $\varepsilon_{r_{s,j}}^{s_{s,i}}$ and the second one is the competition effect of the cross area elasticity $\varepsilon_{r_{s,j}}^{c_{s,i}}$.

The production for each state and crops is a result of area and yield, where the last is projected as:

$$y_{i,l,t} = \sum_{m=1}^{n} \frac{y_{i,s,t} * a_{i,s,t}}{A_{l,i,t}} * e_{l,i,t} \qquad s \in l \text{ and } l=(1,\ldots 6)$$

where $y_{i,l,t}$ is the yield of crop i in the state s and year t and $e_{l,i,t}$ is the correction factor for each macro-region l for the difference between the yield of each crop in each region and the weighted sum of yield in states.

Allocating the state results in each micro-region

In the second step of the allocation model, the micro-regions differentiate each other by prices and productivities. Basically, the direct relationship between the micro-region and its respective BLUM region is the vector of equilibrium prices of each activity considered at each year.

The prices projected for each micro-regional and each activity, following the variation of its respective BLUM region. The yield for each activity in each micro-region is a linear function of yield in its respective state and the production is the result of area multiplied by its respective yield.

The total agricultural area of each state is allocated in its respective micro-regions in a way that:

$$a_{s,i,t} = \sum_{m=1}^{n} a_{i,m} * e_{s,i,t} \qquad s = (1,\ldots,26) \text{ and } m \in s$$

where $a_{i,m}$ is the area allocated to activity i in the micro-region m and $e_{s,i,t}$ is the correction factor for each state for the difference between the state area and the sum of its micro-regions area.

The land allocated for each crop in each micro-region, $a_{i,m,t}$, follows the structure of its respective state and it is defined by:

$$a_{i,m,t} = A_m^T * m_{m,t} * s_{i,m,t}$$

where A_m^T is the total area available for agricultural production in the micro-region *m*, exogenously determined. The variable $m_{m,t}$ represents the share of the area used for agriculture production (first crops and pasture) for each micro-region *m* and $s_{i,m,t}$ is the share of area used by agriculture that is dedicated to crop *i* in the micro-region *m* and it is defined by:

$$s_{i,m,t} = s_{i,m,t-1} * \sum_{j=1}^{n} \Delta r_{i,j,m} * \varepsilon_{r,i,j}^{s,i}$$

where $\varepsilon_{r,i,j}^{s,i}$ is the same cross area elasticity of crop *i* with respect to the revenue of other crop *j* calculated for the state *s*.

The production for each activity in each micro-region is the result of area multiplied by yield. The last one is a linear function of state yield in a way that:

$$y_{s,i,t} = \sum_{m=1}^{n} \frac{y_{i,m,t} * a_{i,m,t}}{A_{s,i,t}} * e_{s,i,t} \qquad m \in s \text{ and } s=(1,\ldots,27)$$

where $y_{i,m,t}$ is the yield of crop *i* in the micro-region *m* and year *t* and $e_{s,i,t}$ is the correction factor for each state for the difference between the yield of each crop in each state and the weighted sum of yield in the micro-regions.

In summary, the micro-region allocation model is an economic tool that distributes the supply and land use for the agricultural sector considering historical patterns and regional specifications.

Main Applications

The BLUM and allocation models can be used as important tools to assess the dynamics of different land occupation in different regions of Brazil. Thus, it can contribute to decision-making in the public and private sector, helping long-term planning for the country. The use of different exogenous variables, such as macroeconomic or technological ones, can generate different scenarios for land use and agricultural production.

Since the models calculate land use change in a ten or twenty years horizon, it can also be very useful to analyze land use change caused by an expansion of a certain

crop or product. We can simulate demand shocks for a product, such as sugarcane ethanol, and thus analyze how the other crops and pasture will react.

Considering land allocation models' results in the six different regions then in 558 micro-regions, and due to the fact that each region contains a predominant biome, the type of natural vegetation converted to agriculture can be determined. This means that, if the agricultural expansion results in conversion of natural vegetation, the model will be able to project which type of vegetation will be used. This general division is an important step forward comparing to global land use models. Further, the disaggregation of the regions on smaller scales can improve the accuracy of the GHG emissions calculations.

As BLUM, the micro-region allocation model can be used for different applications and objectives. First, it can be used to distribute area and production in small regional scale. Second, regional environmental and agricultural policies' impacts can also be measured. Third, land use restrictions, such as land availability and suitable for production, can be incorporated in the model in order to measure their impacts on land use dynamics. Fourth, logistics and infrastructure improvements can also be inputs in the model aiming to measure the agricultural dynamics and efficiency gains.

Main Publications using BLUM

NASSAR, A. M.; COSTA, A. C. P.; MACÊDO, F. S.; HARFUCH, L. (coord). **Outlook Brazil 2022: Agribusiness Projections**. São Paulo: FIESP/ICONE, 2012. Available at: http://www.fiesp.com.br/outlookbrasil/

De GOUVELLO; C. (lead author). **Brazil Low-carbon - Country Case Study**. Washington: The World Bank, 270 p. Available at:

http://siteresources.worldbank.org/BRAZILEXTN/Resources/3223401277832245764/LowCarbon_Fulldoc.pdf. 2010

Economic and Environmental Impacts of PPCerrado Policy using the Brazilian Land Use Model - BLUM. HARFUCH, L.; MOREIRA, M. M. R. Latin American and Caribbean Environmental Economics Program – LACEEP, Policy Brief n. 35, Feb. 2012. Available at: http://www.laceep.org/publications/policy-briefs/item/131-economic-and-environmental-impacts-of-ppcerrado-policy-using-the-brazilian-land-use-modelblum

Simulating Land Use and Agriculture Expansion in Brazil: Food, Energy, Agro-industrial and Environmental Impacts. NASSAR, A. M.; HARFUCH, L.; MOREIRA, M. M. R.; BACHION, L. C; ANTONIAZZI, L. B.; LIMA, R.C.A. Final Report, BIOEN-FAPESP Program, Feb. 2011. Available at: http://www.iconebrasil.org.br/arquivos/noticia/2256.pdf.