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Opportunity cost of environmental preservation: the case of the Brazilian Legal Amazon

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Abstract: Currently, the region named Brazilian Legal Amazon (BLA) represents the agricultural frontier of Brazil, and it concentrates the deforestation processes, so-called arc of deforestation. This region covers the total area of Acre, Amapá, Amazonas, Pará, Rondônia, Roraima, and Tocantins, and part of Mato Grosso and Maranhão states. A recurrent discussion involves what to do to reducing deforestation process. A compensation to no-deforestation is a way to this. This work estimated the opportunity cost involved in preserving the local forest by private agents in the Brazilian Legal Amazon (BLA), an important consideration for planned compensation program. In general, the traditional approach considers only the current local earnings to estimate this compensation. But, the no-deforestation option implies to the agent an opportunity cost, represented by expected cash flow that these agents lose by not using the land for agricultural production in the future. In this case, a compensation program should consider the lost future income. The formation expectation process is uncertain, but the occupation in Brazil's Midwest, a region near to BLA, in the seventies and eighties, can provide a proxy. The Midwest was region of more intensive agricultural growth in last forty years in Brazil. So, the agents in BLA can compare the actual development stage, in their region, with to the Midwest, forty years ago. In other words, BLA production would be at a similar stage to Midwest in early seventies, and the BLA's producers would expect to similar performance to the Midwest in the next years. We use the stochastic frontiers method, with land, labor, and capital as inputs, and real agricultural production as output, to compare both regions and conclude that the actual production mode in BLA is really very similar to the Midwest, in the past. So, we take the production function estimate to the Midwest, for the 1970 to 2006 periods as a proxy to the production in BLA, conditioned to BLA's characteristics, and we estimated the future income flow for this region. This is the same that assume a maximum expected profitability for BLA production. The results show that the producers in the BLA region would expect a 9% to 13% increase in average annual income for the next forty years, depending on the discount rate of the cash flow.

Keywords: Environmental preservation; climate change; land use.

JEL Code: D60, Q51, Q58.

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1. Introduction

Since the seventies, the Brazilian agricultural frontier has expanded to the North and Midwest regions of the country. In the eighties and nineties, this movement was marked by the occupation of the states of Mato Grosso and Mato Grosso do Sul (two states in the Brazil Midwest region) by cultures like corn, rice, soybeans and livestock. Currently, the Brazilian agricultural frontier area is the Amazon region, especially the so-called arc of deforestation, which covers the states of Mato Grosso, Pará, Rondônia and Acre.

This paper presents an estimation of the opportunity cost that would incur private economic agents located in agricultural frontier areas to stop down new forest areas for the purpose of economic exploitation, ie, the cost that the preservation of forest means to them. This cost can be indicative of the maximum amount required to encourage such officers to stop deforestation.

The main hypothesis is that Amazon region is currently in a production stage similar to the Midwest in seventies, a period that began intensifying productive occupation of the states of the Midwest. Based on this assumption, it is assumed that the producers of the Amazon may form their expectations about the future profitability of the production in the similar way as recorded in the Midwest in the last forty years.

The present value of the expected income with the productive use of the land is assessed through the construction of a stochastic production frontier, assuming that the land has maximum profitability, given its efficient use. Therefore, we estimated a land rent function to the control region (Midwest), from data of agricultural censuses of 1970, 1975, 1980, 1985 and 2006. Comparing with actual data to Amazon region, we identified this region in the estimated curve. The opportunity cost of non-expansion of the converted area was calculated as the difference between current income and the present value of expected income, according to the estimated function.

The empirical work is divided into four methodological steps. The first consists in determining the production frontier to Midwest municipalities, using data from the Agricultural Censuses. In the second one, we estimated the income producer based on the results of the stochastic frontier. It is assumed, therefore, that the producer is a typical capitalist owner, or belong to him land and capital used in production. In the third one, there is a projection of expected income by the producer of the Amazon, from the identification of the period of the development of agricultural production corresponding to the current state of the Amazon. The present value is obtained from the application of the most appropriate discount rate to the expected income for municipalities as determined by the stochastic frontier estimated.

The results show that the producers of the Amazon region expect significant increase income. Some institutional factors, however, can affect the rate at which the decision makers discount the time. The literature suggests that the presence of uncertainty of land tenure in the region can cause such rate is higher than expected. Moreover, empirical studies point to the fact that producers are risk averse by stating that they would be willing to accept compensation below the expected value of future production. Anyway, the results obtained in this study can be considered a proxy for the maximum value to be transferred to the owners of land in order to discourage the expansion of agricultural activities on forest areas, assuming the efficient use of resources, maximum profitability production and the existence of official support, as occurred in the Midwest.

The paper is organized as follows. In the next section we make a review of the literature on environmental services and economic returns of deforestation. Next are described the methods used. The fourth section describes the data used. The fifth section presents the results obtained. The last section develops some final considerations and possible prospects for future work.

2. Literature review

This work fits in the discussion of the environmental services that nature provides to individuals. The Amazon region, specifically, is important in regulating the rainfall of the South

American subcontinent, besides the fact that it is home to ecosystems that are among the richest in the world and has a high potential to conserve and sequester carbon in the soil (IPCC, 1996).

Igliori (2006) opposed these services to the value represented by goods and services that are no longer produced under alternative land uses, determining the existence of a trade-off between development and environmental conservation. This trade-off becomes particularly critical due to the poverty of the Amazon region. The author adds that there is conflict between horizons, and between private and global vision for the costs of activities that degrade the environment in decision-making regarding land use.

Young (1996) addresses the issue of land conversion, through the composition of a portfolio of assets, in order to generate income flow. Like other portfolio problems, two parameters are fundamental: the discounted future flow of revenue associated with each option of land use, and the degree of risk or uncertainty involved in each option. The uncertainty about future prices and fine definition of property rights are phenomena that differentially affect the process of decision making regarding land use. Basically, the possibility of replacement land at relatively low cost and uncertainty of tenure induce a reduction of the time relevant to decision making.

At profitability achieved by the conversion of forests should be contrasted environmental benefits offered by its preservation. Young and Faust (1997) emphasize the importance of economic valuation of natural resources by assigning economic values to the benefits derived from goods and services that are not captured by the market. The estimation of such values has serious difficulties, due mainly to the absence of markets for most of the natural resources and the presence of market failures. Additional difficulties may still arise from the fact that property rights on environmental assets are often not well defined and that the preferences of future generations are not taken into account when prices are assessed.

The methods used for the valuation of environmental resources try to calculate the total economic value of these resources through the willingness to pay of the officers, assigning monetary value to the desire to preserve the environment (Faust and Young, 1997; Tietenberg and Lewis, 2009; Field, 2001). The total economic value of an environmental good is given by the sum of direct use (consumption, non-consumption and production) or indirectly (derived from ecosystem functions), the option value, that is, the possibility of future use, and the value of existence or non-use, regardless of current or future use³. As explained by Andersen (1997), in the case of tropical forests, the direct use value relates to cutting wood, non-timber extraction activities, tourism and genetic material available for them, as they are examples of value indirect use to protect soil and water systems.

Since environmental goods can be priced in accordance with the flow of income or benefits they may generate in the future, the discount rate used to estimate the present value of this flow is also a crucial factor in the valuation of such assets (Field, 2001; Andersen, 1997). Two factors stand out in the discussion of the discount rate. The first is the definition of property rights, since uncertainty about the possibility of holding assets in the future increases the discount rate, which can lead to overexploitation of resources. The second concerns the preferences of future generations. Given that the discount reflects the perspective of the current generation, he tends to value less future benefits relative to current.

The price of environmental resources, obtained from valuation, is compared to the costs involved in its preservation. Field (2001) indicates four main costs that must be considered: the opportunity costs (social and private), notably the production sacrificed, the costs linked to changes in prices, since internalization of externalities should generate an adaptation to the new situation of the markets, the cost of the physical facilities necessary to protect the resources in question, and the cost of public regulation, which involves knowledge of cost structures of firms, information on the conditions of market demands, etc.

³ Pearce (1993) points out that the existence value reflects moral, cultural, ethical or altruistic values. He calls "environmental charity" the fact that some people are willing to pay for the simple existence of environmental resources.

This work focuses on the first of these costs, dealing specifically with opportunity costs of agents located in the Amazon region. Some studies have sought to further this work, and will be briefly reviewed below.

Andersen (1997) compares the costs and benefits of environmental conservation in the Amazon region from the point of view of private agents, the federal government and a global social planner. Costs are measured by net present value of agricultural land uses, and benefits, the total economic value of the standing forest. The values used for calculating the net present value were obtained in studies of IMAZON (Instituto do Homem e Meio Ambiente da Amazônia), conducted in the first half of the nineties, who analyze the farming methods used in state of Pará, reporting initial costs and annual profits for different land uses. Andersen takes Paragominas municipality as a reference due to its early occupation.

Andersen calls attention to the importance of the indirect positive effects of deforestation on the urban economy of the region, that enhance the overall benefits generated by deforestation, and the fact that the price of land is the main factor determining the intensity of land use. The author considers an land use sequence begins with logging, followed by extensive cattle and finally, the crop, whose intensity increases over time, and concludes that in the actual stage of deforestation, the expansion of deforested area was more advantageous than the preservation of forest under any of the optical analyzed. In the case of the first occupants of the land, the establishment of an agriculture based in the burn of the forest, despite the decrease in profits, in proportion to the the nutrients reduction, it would be economically advantageous, due to the perspective of land sale to occupants of the second generation, with greater access to capital. From the social planner point of view, however, it would only be justified if the land was used more efficiently. As emphasized in the work itself, however, these estimates of costs and benefits presented relate to a specific point of each curve, associated with a level of deforestation of 10%. As deforestation increases, growing costs, this will exceed the value of agricultural land in some point.

Dias and Schwartzman (2005) examine the possible effects of a policy of compensated reduction in Amazon region deforestation through carbon credits. The authors point out that monitoring by the government will not be enough to stop the expansion of deforested area, unless environmental conservation can generate a stream of income from long-term It is necessary search the break-even point, that is, the carbon price that would make the preservation as profitable as the main alternative land uses (livestock, soybean cultivation and forest management). The paper points out that soy, although with higher returns, have chances of limited growing due to geographical factors. Livestock, on the other hand, is seen as a guarantee of tenure, making it the primary use of land converted, although not present such high returns.

The work based on the hypothesis that the change in land use follows the following cycle: forestry, livestock farming for about five years and finally soy cultivation. The authors use as reference the NPV (Net Present Values) rates of return calculated by Seroa da Motta (2002) and Margulis (2003) for forestry and livestock, respectively, and the economic return of soy in state of Mato Grosso as a reference for this activity. The total horizon considered is 30 years. The results show that carbon credits priced between \$14/tC and \$ 22/tC would be enough to make conservation attractive in the eyes of private producers. The current prices of carbon credit, however, although they could compete with forestry and livestock, would not be enough to make soybean cultivation less attractive. The authors note, however, that the implementation of a policy of compensated reduction would be extremely difficult, as would also be extended to other agents in addition to private producers and governance tools require more advanced than those currently existing.

Pinedo-Vasquez et al. (1992) also come very close to what it intends to do in this project: they are interested in estimating the economic returns obtained from the conversion of forest areas in the Peruvian Amazon. For this, they use an inventory of plant species present in the area in 1985-86 and data on production costs and prices of

timber resources and agricultural crops raised by farmers' union in the region⁴. According to the authors, the regional agents adopt a horizon of decision in the very short term due to uncertainty as to the ownership of land. Their results indicate that in the present context the local population should continue converting forest area to agriculture through burning unless alternative land uses become more attractive economically.

According to Margulis (2001), deforestation provide clear economic gains in private point of view, and these gains stem primarily from productive activities, and not speculative. The agents who appropriate these gains are loggers and intermediaries that transform the native forest to pasture (small agents with the lowest opportunity costs), and especially ranchers and farmers. On the other hand, the author points to the approach of the agricultural frontier of the densest area of the forest, where heavy rainfall prevents the realization of any economic activity.

Margulis (2003) estimated the income potential of private ranching in the Eastern Amazon region. Thus, we conducted surveys and panels with 43 producers in 4 municipalities. From the results of this survey, it was estimated Internal Rate of Return (IRR) of private activity and income potential. Research has shown that livestock in the region has high productivity, responsible for an IRR above 10%, with a private income potential R\$75/ha/year (more or less US\$ 35/ha/year). The results also indicated that producers have high risk aversion, accepting a compensation of R\$ 45/ha/ year (US\$ 20/ha/year) not to expand the area under cultivation in forest areas (these values may rise to R\$ 200/ha/year no - less than US\$ 100/ha/year - when it is supposed lower risk aversion). When simulated the effects of a tax on deforestation, the results showed only a change in the mix of cultures, not a decrease in the deforested area.

Souza-Rodrigues (2011) seeks to determine the demand for deforestation in the Brazilian Amazon private property, defined as the area of forest felled due to differences in the amount of private agricultural land and forest. The authors estimate the effect of transport costs on deforestation and then resize these costs using the income in order to determine the difference in price per hectare of agricultural land and forest. The sample of farms is divided according to the size of the farms to take into account the existence of diminishing returns in agricultural land use. The estimated demand function is used to evaluate the costs and effectiveness of different policies to prevent deforestation. The results indicate that a pigouvian tax worth US\$ 100/ha/ano would have been able to retain 70% coverage in private areas (in contrast to the 40% observed), resulting in an annual revenue of US\$ 2.5 billion. A program of payment for environmental services, paying the same \$ 100/ha/ano, would have the same effect on the vegetation cover, costing between US\$ 2.1 billion and US\$ 5.33 billion per year, depending on the ability to identify farmers that in fact they intended to deforest. A REDD+ program with carbon price fixed at US\$ 1 per ton of carbon per year would increase the carbon stock in private forests from 4 to 7 billion tons, costing about US\$ 7 billion per year, or US\$ 2.33 /tC/year. Finally, the imposition of quantitative restrictions for land use setting 80% participation in the forest on private land, such as those that exist today, it would be so costly to farmers if there was an effective control that they

⁴ Take the more used techniques and the average production per hectare, the present value of agricultural activity based in continuous cultures of rotations is given by $R_{NPV} = \frac{R_1}{1-(e^{-ht_3})}$, where h is the continuous interest rate, t_3 , the rotation time, and R_1 , the liquid income adjusted to culture 1. R_1 is defined by $R_1 = (-C_1)(e^{-ht_1}) + (pV - C_2)(e^{-ht_2})$, where C_1 is the initial costs, t_1 , the plantation time, C_2 , the harvest transport cost, and t_2 , the harvest time. The liquid revenue adjusted to segundo culture is defined by $R_2 = R_1 (e^{-ht_3})$. This values are calculated with discount taxes of 5%, 10% e 15%. To this NPV it is possible to add the revenue due to timber extraction.

would be willing to pay up to US\$ 8.43 billion per year to prevent such a law were exercised. The author also points to the fact that medium and large farmers more responsive to these policies, due to diminishing returns submitted by the earth.

Regarding the studies, the main contribution of this paper is to seek to incorporate the expectations of economic agents about the future profitability of the land converted in the calculation of the net present value. Given that the Amazon region is a region of recent economic occupation, it is reasonable that producers located on it expect an increase in income generated by the land use, in that production methods are being adapted to the climate and local soil and the infrastructure region is developed. Given this, the levels currently observed returns cannot characterize the best reference values for estimating the economic value of land in the Amazon region, since it should reflect the present value of the expected income stream for the future. The comparison of the current stage of production in the Amazon region with that achieved by the Midwest is due precisely to the fact that the latter have already gone through the same process of economic occupation of farming and maturation.

3. Methods

The producer/owner who maximizes his expected income is given by

$$E(\pi_t) = E[f(x_t) - c(x_t)],$$

where $E(y)$ is the expected income, x is a vector of inputs and $f(\cdot)$ and $c(\cdot)$ are, respectively, the functions of revenues and costs expected for each time t .

Since the production function presents constant returns to scale, which is reasonable for an aggregate function for the entire industry, then it can be shown that the expected return is the producer

$$E(\pi_{it}) = E \left[f(x_{it}) - \sum_i \frac{df(x_{it})}{dx_{it}} x_{it} \right].$$

Defining $\sum_i \frac{df(x_{it})}{dx_{it}} \frac{x_{it}}{f(x_{it})} = \alpha$ as the share of production factors outside the farmer, it is concluded that the expected income producers, in each time t , equals the share of production factors owned by producers in total production, that is

$$E(\pi_{it}) = E[f(x_{it})(1 - \alpha)].$$

3.1. Stochastic frontier production

For each instant t , it is estimated the function $f(x_{it})$ through the production possibilities frontiers for the Midwest in the years 1970, 1975, 1980, 1985 and 2006 and for the Legal Amazon in 2006, used stochastic frontier method. This method, developed by Meeusen and Van Den Boeck (1977) and Aigner, Lovell and Schmidt (1977), is the estimation by maximum likelihood of a production function of the form

$$y_i = \epsilon_i f(x_i, \beta) e^{v_i},$$

where y_i is the production, $f(x_i, \beta)$ is the deterministic frontier common to all producers, x_i are the inputs, β is the parameter vector, ϵ_i the term is indicative of inefficiency and v_i is the random component. Linearizing equation and setting $u_i = -\ln \epsilon_i$, it follows that

$$\ln y_i = \ln f(x_i, \beta) + v_i - u_i$$

Thus, the deviation from the deterministic part of the production frontier is given by u_i and v_i , determining the characteristic of the composite error model. The term u_i capturing the inefficiency, if $u_i > 0$, there is inefficiency, the producer operates under the production line if $u_i = 0$, the producer is efficient, operating on the border. The term v_i follows a normal distribution and captures random shocks beyond the control of the firm and specifically affecting the i th producer, as well as observation and measurement errors in y . Thus, v_i expresses the fact that the boundary may vary randomly from a

company to the other or over time for the same firm (Aignel, Lovell and Schmidt, 1977).

As

$$\varepsilon_i = v_i - u_i,$$

and since $u_i \geq 0$, we have that the composite error is asymmetric, and adds to the hypothesis that it is nonzero.

3.2. Factor analysis

How many variables had high multicollinearity, we adopted the method of factor analysis, which is to reduce the number of these variables through factor analysis, using regression techniques to estimate, from the variations observed between correlated variables, a number lower latent variables or factors capable of explaining the observed variables⁵. The observed variables would be a linear combination of latent variables plus an error term, so that we seek to produce factors that explain as much as possible the variance of the observed variables.

Given a set of variables $X = x_1, x_2, \dots, x_n$ with averages $\mu_1, \mu_2, \dots, \mu_n$, suppose

$$x_i - \mu_i = a_{i1}F_1 + a_{i2}F_2 + \dots + a_{ik}F_k + \varepsilon_i,$$

where a_{ij} are constant, F_j are unobserved variables, with zero mean and mutually independent and independent of the error, and ε_i is an error term with zero mean and finite variance ψ . In matrix terms,

$$x - \mu = AF + \varepsilon,$$

where A is a matrix of constants, or loading matrix, and F , the vector of unobserved variables or factors. Thus, since $cov(x - \mu) = \Sigma$, it has been

$$\Sigma = AA' + \psi,$$

which allows us to estimate A and F for a given sample.

The main advantage of this method is to reduce the number of variables, is commonly used when you want to reduce a large number of observed variables to a smaller number of factors. However, the factor analysis is also used when the observed variables have measurement errors.

3.3. Estimating the net present value of expected future income

From the results obtained, it is possible to estimate the participation of producers in the product generated and subsequently the estimated present value of future income from the present value formula,

$$\Pi = \int_{\tau}^{\tau+n} \pi(t)e^{-rt} dt,$$

where $\pi(t)$ is the production function estimated by the borders was stochastic discount rate. The adjustment of this function over time, is made from a polynomial model, type,

$$\ln \pi(t) = \ln y = at^2 + bt + c,$$

where y is the actual income 2000, and t , time in years. The net present value of the expected income can then be calculated by

$$\Pi = \int_{\tau}^{\tau+n} e^{at^2+bt+c-rt} dt,$$

corresponding to the projected income discounted by the interest rate.

4. Data

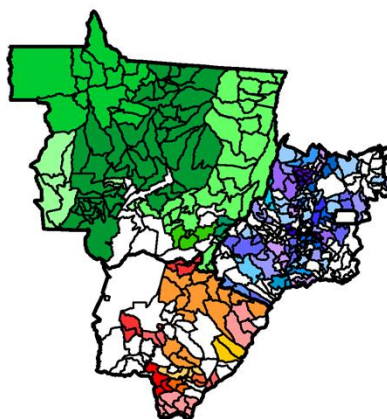
The data used are from the Agricultural Census, conducted by IBGE in each of the years cited. Sought to identify information related to production factors present in all years. The Census data from 1995/1996 were not used due to methodological

⁵ See Lawley e Maxwell (1973), Bartholomew et al. (2008), Hair et al. (2006).

differences between this and the other censuses considered, and the lack of observations in this year of some variables used.

Since the observations of Census concerned the counties in each year, built up from the Minimum Comparable Areas (MCA) provided by IPEA for the period 1970 to 1997, minimum comparable areas for the Midwest region for the period 1970-2006. Thus, the observations of 252 municipalities in 1970, 253 in 1975, 280 in 1980, 363 in 1985 and 466 in 2006, were condensed, every year, in 222 AMCs. In the case of Amazon region, were disregarding the municipal regions of state Mato Grosso, as recorded in the Midwest region, since this state was occupied with agricultural purposes before the rest of the region. The rest of the municipalities belonging to the Amazon region make a total of 630 observations for the year 2006.

Figure 1 – Minimum Comparable Areas



Source: Own elaboration from data from IPEA.

To labor factor, we considered the following Census data: number of employees, number of partners and responsible, and family members unpaid. The capital data used refer to the number of tractors, plows and harvesters used in the property. The earth is measured by the rural area⁶. The value of production in the year does not include the rural industry and that measured in real 2000⁷.

For analysis of the variables related to the factors labor and capital, there was high multicollinearity among the selected variables. It was necessary, therefore, to perform a factor analysis. The data available in each year with respect to capital (number of tractors, plows and harvesters used in the year) represent only part of the total capital involved in agricultural production, but the capitalization of the firm positively affects all observed variables. Furthermore, the possibility of measurement errors in the data relating to capital and labor is greater than those related to land, possibility aggravated due to changes in the methodology adopted by IBGE over the years.

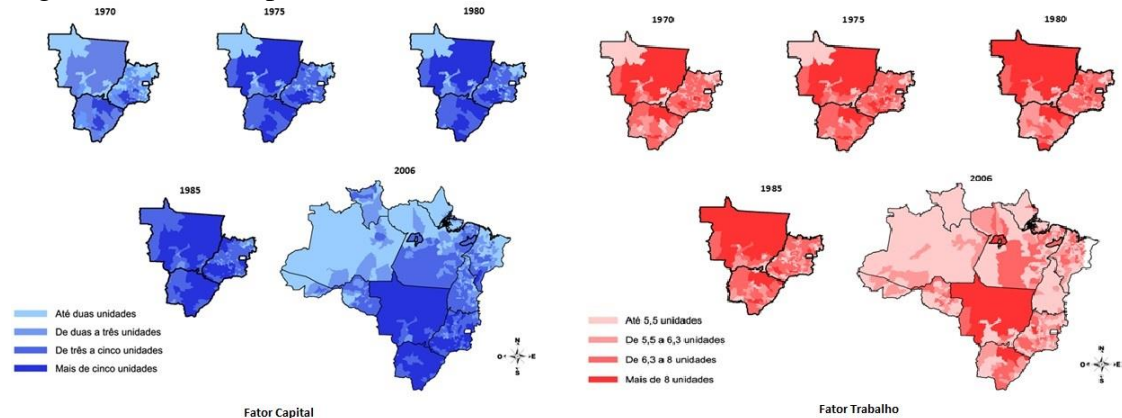
⁶ The methodology for calculating the total area of farms was changed in 2006 Agricultural Census, which began to take into account, in addition to the uses already computed in previous censuses, forest areas and / or natural forests for permanent preservation and legal reserve; of forest and / or natural forests (exclusive area of preservation and agroforestry systems); areas cultivated with forest species also used for crops and grazing animals; areas occupied by ponds, lakes, ponds and / or water area for public exploitation and aquaculture area buildings, improvements or paths. So as not to distort the estimates and allow comparisons between different years, it was considered, for the year 2006, the total area minus the area devoted to the uses mentioned above.

⁷ The value of production, presented in local currency for each of the years, was brought to real 2000 to allow comparisons between years. For this, we used the implicit GDP deflator agricultural calculated by IPEA.

The number of observations (in the Midwest, 222, and in the Amazon region, 630 for variables related to labor and 500 for those relating to capital) and the number of observable variables (three for each latent variable) are consistent with those raised by literature for generating robust results⁸. The estimation method used was the main factor that makes the factor analysis from the correlation matrix (without rotation) between the observed variables to maximize the explanatory power of the first factor. The factors were standardized so as to make the sum of the coefficients of each variable were first observed, making it possible comparisons between the years and regions.

The spatial distribution of each of the variables as well as their evolution over time is illustrated in Figures 2, 3, 4 and 5 below. Descriptive statistics can be found in Annex II.

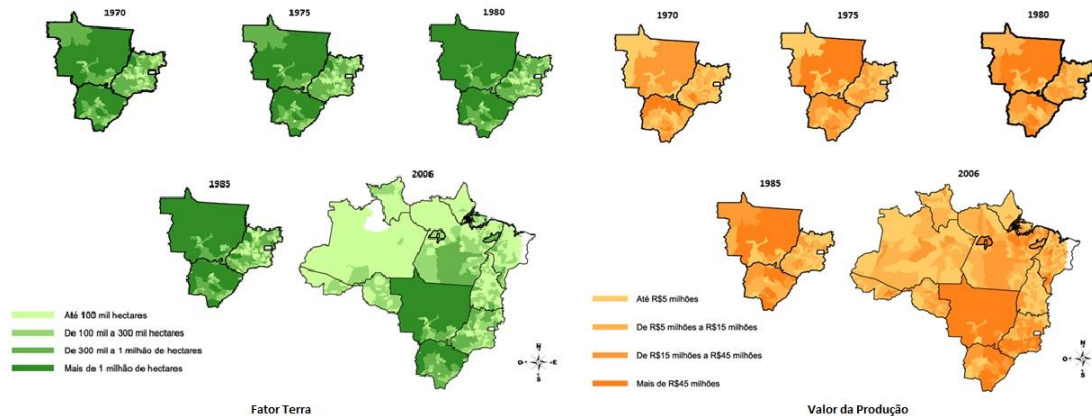
Figure 2 - Use of capital and land factors



Source: Own elaboration from IBGE Agricultural Census.

It can be noticed a clear trend towards increased use of capital intensity over time, probably as land is occupied and it becomes difficult to increase production by expanding the cultivated area. This growth, however, occurs at decreasing rates, becoming the capital value of more stable between 1985 and 2006. The number of observations with zero capital falls 3 to 12 in 1970 to 1 in 1975 in 1980. From 1985, all counties use some form of capital.

Figure 3 - Use of land cost and value of production



Source: Own elaboration from IBGE Agricultural Census.

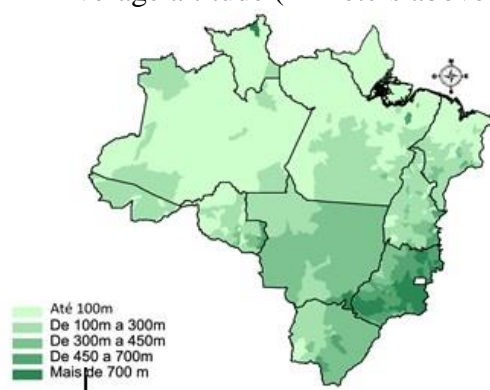
⁸ HAIR et al. (2006).

With regard to work, there is a different trend from that presented by the capital: the use of factor initially grows (between 1970 and 1975) to then begin to fall at an increasing rate, characterizing the increase in agricultural labor productivity, as discussed in the literature that analyzes the results of Agricultural Census (Gasques and Conception, 2000; Gasques et al., 2010).

The land is the factor of production that has less variation over time in the Midwest, nevertheless, its use presents a clear movement, increasing land used until 1985 to fall between that year and 2006. This dynamic is consistent with the occupation of new frontier areas, decreasing the amount of land used as the region develops and urbanization.

The production value behaves as expected, showing a tendency to increase, in the Midwest region, over time, although the year 1985 represent a decrease in this trend.

Figure 4 - Average altitude (in meters above sea level)



Source: IPEA / University of East Anglia.

Given the evidence in the literature about the Amazon, the strong influence of climatic factors, especially rainfall on the higher suitability of certain areas for agricultural production (Margulis, 2003), determining their higher productivity, were still considered some controls related to climate and topology of the municipalities, saying about the estimates of rainfall and temperature averages quarterly and the altitude of the municipalities.

The control variables for the climate represent a historical average for each county, not varying, so from one year to another. To avoid multicollinearity problem in climate data, due to the low variations in temperature throughout the year, especially in the Amazon, but also in the Midwest, we tried to always use a single variable to control the temperature. But the rainfall was fairly significant, as was predicted by the literature.

5. Results

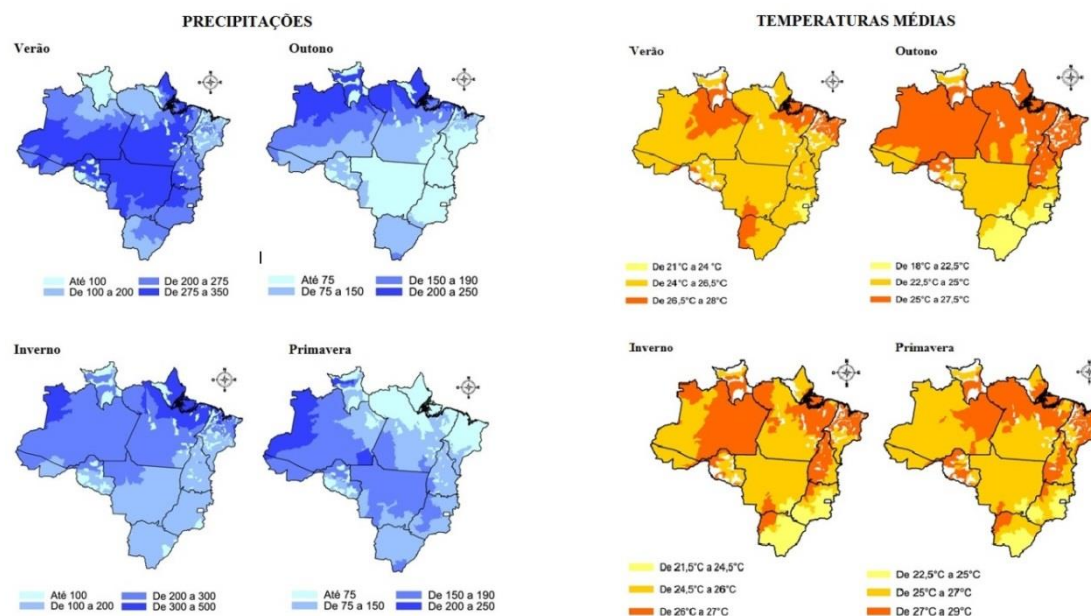
The production function estimated for each year was

$$\ln Y_i = \beta_0 + \beta_1 \ln T_i + \beta_2 \ln K_i + \beta_3 \ln L_i + v_i - u_i$$

For the v_i , we adopted the normal distribution, most commonly seen in such models. For inefficiency, we tested the half-Normal distributions, truncated normal and exponential. The estimations performed with exponential distribution showed convergence problems. The results of the half-normal distributions truncated normal, however, were very similar, so we present here only the results obtained with half-standard distribution.

We estimate two production functions: A Cobb-Douglas and translog. The results obtained with the translog function pointed to the non-significance of the interactions between the variables, which suggests that the Cobb-Douglas function best describes the production technology used.

Figure 5 - Estimates of the quarterly average rainfall (mm / month) and average temperature (oC)



Source: IPEA / University of East Anglia.

In the initial estimation, it was observed that the sum of weightings of different factors was always very close to 1, ranging between 0.95 and 1.05. Therefore, to allow better comparison between the years passed to impose the following estimates the condition that returns scale were constant, or

$$\beta_1 + \beta_2 + \beta_3 = 1$$

This restriction also facilitates the interpretation of the coefficients, which will represent the interest of each of the factors in agricultural income. The estimation results in the production line this restriction can be seen in Tables 1, 2 and 3 below.

Tabela 1 – Without controls Results

	1970	1975	1980	1985	2006	AL
β_0	8.7520*	9.2001*	9.6751*	9.6966*	13.3176*	10.1679*
β_1	0.1840*	0.1606*	0.1215*	0.0888*	-0.2556*	0.1241*
β_2	0.2430*	0.3586*	0.4846*	0.6955*	0.9986*	0.1687*
β_3	0.5731*	0.4808*	0.3938*	0.3330*	0.2570*	0.7071*

* Significativo a 1% ** Significativo a 5% *** Significativo a 10% ^{NS} Não significativo
 Source: Own elaboration.

Tabela 2 – With controls Results (with altitude variable)

	1970	1975	1980	1985	2006	AL
β_0	8.2779*	0.8446 ^{NS}	4.5550*	5.8229**	5.9835***	0.5285**
β_1	0.1063*	0.2014*	0.1643*	0.0707*	-0.2472*	0.1239**
β_2	0.1647*	0.2829*	0.3656*	0.5212*	0.9878*	0.1993*
β_3	0.7290*	0.5157*	0.4701*	0.4082*	0.2594*	0.6769*
ChuvaV	-	-	-	-	1.2223**	0.4706**
ChuvaI	-1.2004*	-1.1435**	-2.5195*	-1.6807*	-	-1.0185**
ChuvaO	0.2585*	0.3500*	0.4687*	0.3582*	0.2078***	0.4282*
ChuvaP	0.8400**	0.8535**	1.5157*	1.0348*	-	-
TempO	-0.2446*	0.1266*	0.0340*	0.0245**	-	3.4284***
Altitude	0.9909 ^{NS}	2.4052 ^{NS}	2.4975 ^{NS}	1.8442 ^{NS}	-	0.0119 ^{NS}

* Significativo a 1% ** Significativo a 5% *** Significativo a 10% ^{NS} Não significativo
Source: Own elaboration.

Tabela 3 – With controls Results (without altitude variable)

	1970	1975	1980	1985	2006	AL
β_0	4.35901**	2.88887 ^{NS}	5.10863*	6.17469*	5.98346***	0.78024 ^{NS}
β_1	0.13770*	0.18547*	0.15927*	0.07015*	-0.24722*	0.15988*
β_2	0.15534*	0.29096*	0.36687*	0.52090*	0.98783*	0.21166*
β_3	0.70695*	0.52357*	0.47386*	0.40895*	0.25940*	0.62846*
ChuvaV	-	-	-	-	1.22232**	0.54293**
ChuvaI	-1.14173*	-1.18254*	-2.53855*	-1.70591*	-	-1.098*
ChuvaO	0.37077*	0.28734*	0.45407*	0.34723*	0.20779***	0.46063*
ChuvaP	0.51167**	1.02530*	1.56282*	1.08764*	-	-
TempO	2.03163*	1.87663*	2.36415*	1.74511*	-	3.28695***

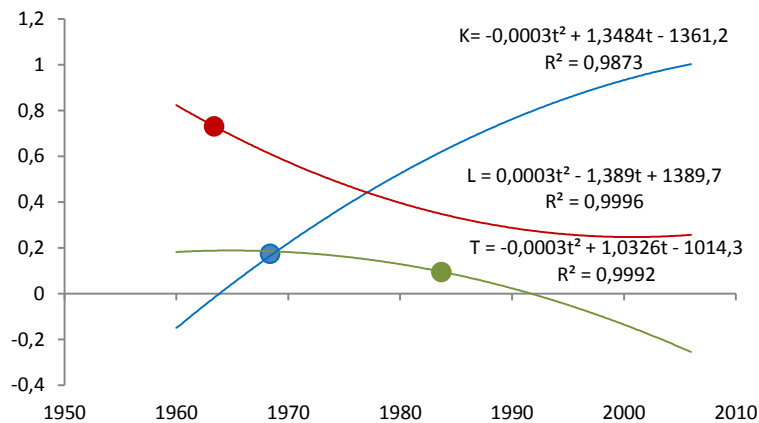
* Significativo a 1% ** Significativo a 5% *** Significativo a 10% ^{NS} Não significativo
Source: Own elaboration.

Despite minor variations in the coefficients of the different factors of production, when inserted different climate controls, in all estimations they have very similar movements: the coefficient of capital grows at a more or less constant, while the coefficients of labor and land decreases, the first to the second descent rates at increasing rates. In the case of labor, there is a stabilization of the coefficient from the mid-1990s.

As mentioned above, we tried to use only one temperature variable in the estimations due to the strong presence of multicollinearity between these variables. The temperature controls as well as rainfall, were significant, but the results indicate that the altitude does not interfere with agricultural production in these regions. This observation is quite reasonable when considering the cultures prevalent in the Amazon region and in the Midwest.

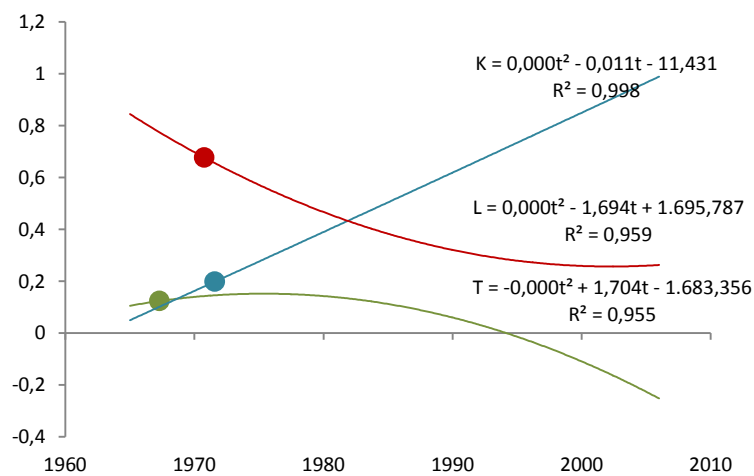
The climate controls in the Midwest region exhibit similar behavior between the years 1970 and 1985, but are altered significantly between the latter year and 2006. One possible explanation for this observation is that the new technologies available allow the producer to soften the effects of weather, especially temperature, on production.

Figure 6 - Controls without variation coefficient over time



Source: Own elaboration.

Figure 7 - Variation coefficient with controls over time



Source: Own elaboration.

As shown in Figure 6 and Figure 7 above, when there is no control for the climate of municipalities, it is not possible to find correspondence between the production frontiers in the Amazon region and in the Midwest. Once considered climatic variables, however, it may be noted that the current stage of agricultural production in the Amazon region is very close to that observed in the Midwest, between 1970 and 1975, which is in agreement with the assumption originally adopted, and reinforces the assumption that the producer of the Amazon region form their expectations based on the development of farming in the Midwest. With these results, it was possible to move to the next stage, which consisted of predictions of future production in the Amazon and in estimating their net present value.

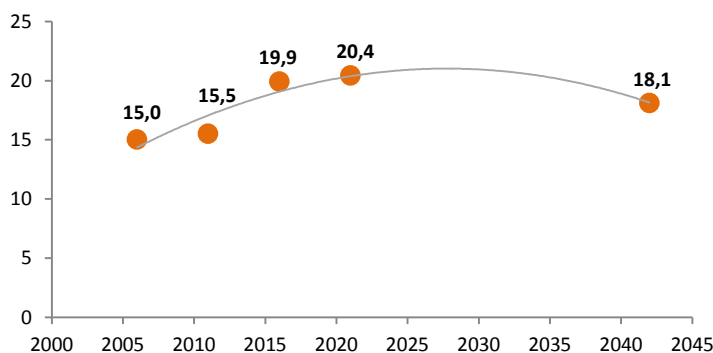
To estimate the future values of agricultural production in the Amazon, it was necessary to first design as alter the quantities of the factors of production used. For this, regressions were made to municipalities in the Midwest, the quantities of the factors observed every year from their initial values. The results of these regressions are found below.

$$\begin{aligned}
T_1 &= 1,01014 \quad T_0, \quad R^2_{ajustado} = 0,9996 \\
&\quad (0,0012787) \\
T_2 &= 1,005042 \quad T_0, \quad R^2_{ajustado} = 0,9865 \\
&\quad (0,0078773) \\
T_3 &= 0,9809367 \quad T_0, \quad R^2_{ajustado} = 0,9992 \\
&\quad (0,0018119) \\
K_1 &= 1,300719 \quad K_0, \quad R^2_{ajustado} = 0,9268 \\
&\quad (0,0244776) \\
K_2 &= 1,368725 \quad K_0, \quad R^2_{ajustado} = 0,9160 \\
&\quad (0,0277443) \\
K_3 &= 1,359387 \quad K_0, \quad R^2_{ajustado} = 0,8916 \\
&\quad (0,03173) \\
L_1 &= 0,9823098 \quad L_0, \quad R^2_{ajustado} = 0,9926 \\
&\quad (0,0056813) \\
L_2 &= 0,974838 \quad L_0, \quad R^2_{ajustado} = 0,9869 \\
&\quad (0,0075134) \\
L_3 &= 0,8473 \quad L_0, \quad R^2_{ajustado} = 0,9817 \\
&\quad (0,0077463)
\end{aligned}$$

In Midwest case, it was considered as the period zero to that corresponding to the current position of the Amazon region in the production frontier, that is, between 1970 and 1975. The first period corresponds to the observations of 1980, the period 2 to 1985, and 3 to 2006. Therefore, in the case of Amazon, the period zero corresponds to the observations of 2006; period 1, the projections for 2014, the second period, the projections for 2019, and the third, projected to 2040.

Considering the changes in the use of factors over time, it was possible to design the production figures for the Amazon region, which correspond to the 34 years following 2006. These values were calculated from the following equations in which the coefficients β_i are those shown in Table 3.

Figure 8 – Average value of production in the Amazon (in logarithmic scale)



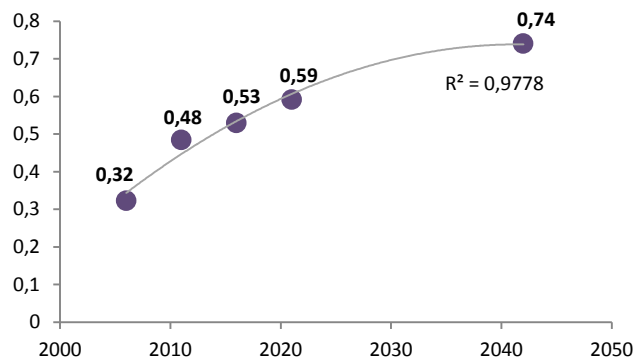
Source: Own elaboration.

An interesting fact is that, although the average utilization factors of initial capital and land in the Amazon region is similar to that of the corresponding period in the Midwest region, the amount of labor is much lower. When one takes into account that there is a drop in the use of labor over time, it is understandable why the value of production designed falls between periods 2 and 3.

The next step to estimate the net present value of the income of the land in the Amazon is estimating that portion of this amount the landowner appropriates.

Considering the hypothesis that these are capitalist owners, such portion is represented by the sum of the coefficients β_1 and β_2 . The evolution of this coefficient over time is illustrated in Figure 9 below.

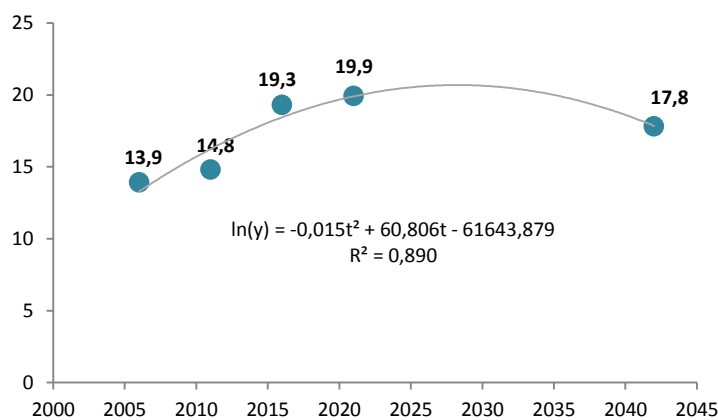
Figure 9 – Income producer as a share of total income of the agricultural sector



Source: Own elaboration.

The income of the owner of the land in the Amazon (in logarithmic scale) for each period is given by $\ln[(\beta_1 + \beta_2)e^Y]$. If there is no expansion of agriculture in the region, it is expected that production will stay at the current level, represented by the dotted line in Figure 10. If, on the other hand, there are agricultural expansion, through the expansion of deforestation, it is expected that income evolves according to the projections along the solid line in Figure 10.

Figure 10 – Producer income expected in the Amazon (in logarithmic scale)



Source: Own elaboration.

The present value of that income stream is calculated as described in section 3.3, representing the area under the trend line in Figure 10, even applying a discount rate r . As the agent to form expectations is a private, not expect it to cost, when evaluating future income, a discount rate that takes into account the social and environmental effects of the production, which is why we chose to discount the income stream by a real interest rate market, because that is the most relevant, the private point of view, the rate mentioned in the literature of environmental services. The table below shows the results obtained using real interest rates of 2%, 5% and 8%.

Table 4 - Present value of projected income stream (in logarithm)

	2%	5%	8%
Renda atual	13,9	13,9	13,9
VPL	22,86	22,24	21,64
Renda média esperada	19,28	18,65	18,05
Aumento relativo	12,9%	10,9%	9,1%

Source: Own elaboration.

The first line shows the logarithmic value of producers' current income, in values of 2000. The second line of the table presents the net present value of the projected income stream, also in logarithmic scale, for each real interest rate considered. The third line shows the average annual income that the land owner expects to get. Finally, the fourth line shows the average increase in annual revenue expected.

The presence of uncertainty of land tenure in the region can make agents deduct time at higher rates. Margulis (2003) points to the fact that producers are risk averse by stating that they would be willing to accept compensation below the expected value of future production.

6. Conclusion

The importance that has been given in recent decades to reduce carbon emissions in Brazil, resulting primarily from the advance of the agricultural frontier into the Amazon rainforest, brings out the dilemma between development and environmental preservation, since deforestation is associated with increases in income and well-being of local and regional development. In this context, it becomes urgent to discuss about the valuation of natural resources and the generation of alternative income for regions of agricultural frontier expansion of forested areas.

The valuation of natural resources, while public goods, cannot fail to take into account the opportunity cost that the preservation of natural resources and environmental services impose on the people of the agricultural frontier regions. The estimation of that cost should not only consider the current income generated by agricultural producers, but must take into account the expected future income of the producers, given the continuation, or even expansion of its activities and prospects.

Thus, this work sought to evaluate the specific case of the producers in the Brazilian Amazon region. The initial hypothesis that the current stage of development in this region is similar to that of the Midwest region during the seventies proved to be reasonable, given the results of the estimation of production frontiers for the two regions. On this basis, it is not incorrect to assume that the producers of the Amazon region form their expectations of future income relying on profitability presented by farming in the Midwest region from seventies to the present.

The projections based on the results of this work show that the producers of the Amazon may believe you, the next four decades, and an increase in average income, compared to the currently observed, about 9% to 13% per year. Any strategy to contain the spread of agriculture on the Amazon Rainforest in Brazil must take into account the expectation of gain for the environmental preservation it is not detrimental to local populations.

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8 – Anexes

AI - Results of analyzes of primary factor

Resultado da análise de fator principal para o trabalho				Resultado da análise de fator principal para o capital			
Ano	L1	L2	L3	Ano	K1	K2	K3
CO 1970	0,4050	0,4385	0,1564	CO 1970	0,3576	0,3596	0,2826
CO 1975	0,3957	0,4210	0,1831	CO 1975	0,3483	0,3469	0,3047
CO 1980	0,3927	0,3672	0,2309	CO 1980	0,3462	0,3433	0,3103
CO 1985	0,3928	0,3763	0,2308	CO 1985	0,3583	0,3601	0,2814
CO 2006	0,3573	0,3656	0,2769	CO 2006	0,3495	0,3418	0,3085
AL 2006	0,3486	0,3538	0,2975	AL 2006	0,3904	0,3825	0,2269

Fonte: Resultados próprios a partir do Censo Agropecuário do IBGE.

Fonte: Resultados próprios a partir do Censo Agropecuário do IBGE.

AII – Descriptive statistics

Estatísticas descritivas do fator capital

Ano	Observações	Média	Desvio-padrão	Mínimo	Máximo
1970	222	2,231	1,466	0,000	6,234
1975	222	3,101	1,524	0,000	7,008
1980	222	3,821	1,458	0,000	7,879
1985	221	4,070	1,512	0,611	8,351
2006	222	4,131	1,383	0,800	8,945
AL	500	2,431	1,145	0,000	5,582

Fonte: Resultados próprios a partir do Censo Agropecuário do IBGE.

Estatísticas descritivas do fator trabalho

Ano	Observações	Média	Desvio-padrão	Mínimo	Máximo
1970	222	6,042	1,051	1,897	8,817
1975	222	6,163	1,091	2,469	9,326
1980	222	6,002	1,112	3,117	9,687
1985	221	5,974	1,165	2,946	9,857
2006	222	5,174	1,118	1,835	10,788
AL	630	4,899	1,019	2,042	8,152

Fonte: Resultados próprios a partir do Censo Agropecuário do IBGE.

Estatísticas descritivas do fator terra

Ano	Observações	Média	Desvio-padrão	Mínimo	Máximo
1970	222	316.488	695.906	3.398	5.733.446
1975	222	353.149	815.861	3.941	6.867.526
1980	222	425.944	1.228.152	3.107	12.400.000
1985	222	447.692	1.327.724	3.725	13.400.000
2006	222	327.65	1.013.700	4.029	10.700.000
AL	627	64.161	79.412	96	944.25

Fonte: Censo Agropecuário (IBGE)

Estatísticas descritivas do valor da produção

Ano	Observações	Média	Desvio-padrão	Mínimo	Máximo
1970	222	5.823.336	9.587.428	85.282	78.100.000
1975	222	7.498.618	10.500.000	77.273	75.200.000
1980	222	9.474.108	16.000.000	203.641	121.000.000
1985	222	7.899.182	15.100.000	135.534	141.000.000
2006	222	57.700.000	259.000.000	251.827	3.410.000.000
AL	630	9.290.998	16.900.000	64.41	256.000.000

Fonte: Censo Agropecuário (IBGE)

Tabela 6 – Estatísticas descritivas das variáveis de clima na Amazônia Legal

	Obs	Média	Desvio-Padrão	Mínimo	Máximo
Precipitação pluviométrica média (mm/mês): verão	496	246.4	45.5	37.7	338.3
Precipitação pluviométrica média (mm/mês): inverno	496	245.6	89.1	103.4	496.1
Precipitação pluviométrica média (mm/mês): outono	496	68.2	68.3	2.1	393.6
Precipitação pluviométrica média (mm/mês): primavera	496	100.3	51	8.4	235
Temperatura média (°C): inverno	496	26.2	0.5	24.8	27.1
Temperatura média (°C): outono	496	26	0.8	23.2	27.4
Temperatura média (°C): primavera	496	27.1	0.6	25.4	28.7
Temperatura média (°C): verão	496	26.3	0.6	24.6	27.3
Altitude média	542	146	128.2	2	920

Fonte: IPEA/University of East Anglia.

Estatísticas descritivas das variáveis de clima no Centro-Oeste

	Obs	Média	Desvio-Padrão	Mínimo	Máximo
Precipitação pluviométrica média (mm/mês): verão	222	248.9	33.06	158.2	337.9
Precipitação pluviométrica média (mm/mês): inverno	222	118.2	12.63	90.8	227.2
Precipitação pluviométrica média (mm/mês): outono	222	17.1	15.15	3.2	76.2
Precipitação pluviométrica média (mm/mês): primavera	222	138.4	15.28	83.9	179.2
Temperatura média (°C): inverno	222	24.1	1.07	21.6	26.7
Temperatura média (°C): outono	222	22.1	1.5	18.5	25.1
Temperatura média (°C): primavera	222	25.1	1.06	22.6	27.3
Temperatura média (°C): verão	222	24.9	1.08	22.4	28.1
Altitude média	222	566.8	227.7	90	1189

Fonte: IPEA/University of East Anglia.