Environmental efficiency and opportunity cost of the Forest Code for the Amazon

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Abstract

The agricultural expansion in the Legal Amazon resulted in deforestation and environmental degradation. This expansion increased the discussion about the logic of occupation and exploitation of natural resources in traditional farming systems. There is an increasing search for agricultural activities of greater environmental efficiency that result in less pressure on ecosystems and forests. This study aims to examine the relationship between technical and environmental efficiency of agricultural production in the Legal Amazon, and estimate the opportunity cost of the current Forest Code. The results indicated negative association between technical and environmental performance. This negative association represents environmental constraints and opportunity cost, but only for those micro-regions of higher technical performance. The degradation of this biome with the removal of forest areas reduces the welfare world, given the importance of the Amazon forest for the global climate and biodiversity conservation, among other environmental benefits. For this reason, the existence of legislation and rigorous monitoring systems are not enough. Producers should be considered as providers of environmental services to society, and as such, they should be paid for it.

Keywords: Forest Code; Legal Amazon; Opportunity Cost.

1. Introduction

Historically, the Amazon region, in terms of agricultural and agro-industrial production presented a pattern linked to subsistence and local provision of primary products. However, this scenario has changed in face of international pressure for environmental enhancement and shift of production to the productive north and Cerrado[1]. Such a change in circumstances highlighted it as a strategic region, both in terms of potential supply - domestic and international - and in relation to possible routes of product flow.

Parallel to these expectations of production expansion in the Legal Amazon[2], deforestation and environmental degradation resulting from agricultural expansion increased the discussion about the logic of occupation and exploitation of natural resources in traditional farming systems. These systems rely on massive use of new areas, pesticides, fertilizers and fossil fuels. Moreover, there is the prospect of homogenization of rural landscapes and societies and reduction of biological, cultural and agricultural diversity in these regions. This production system results in large

[1] The accelerated expansion of the border to the Amazon and Cerrado biome, which occurred in the 1970s, fostered the growth of productive activities in these regions, affecting the relationship between large-scale production - to meet growing demand - and the available natural resources. This process, according Christoffoli (2007), resulted in an expansion pattern that became known as the arc of deforestation (or arc of fire), a vast region that begins in eastern state of Acre and runs to the northeast state of Pará, with about 3,000 km long.

[2] In 1953, the territories of the State of Maranhão (west of 44 ° meridian), State of Goiás (north of 13° parallel, which is currently the state of Tocantins) and Mato Grosso (north of parallel 16 ° south latitude) was joined to the Brazilian Amazon, by Law 1806 of 01.06.1953, for the purpose of economic planning. This territory became known as the Legal Amazon. This Law, suffered alterations and additions in the year 1966 with the creation of SUDAM by Law 5173 and in 1977 with the implementation of the Complementary Law No. 31 of 10.11.1977, through wich the states of Acre, Pará, Amazonas , Amapá, Roraima, Rondonia, Tocantins (created as a state in 1989), Mato Grosso and part of the state of Maranhão in the west of 44 ° meridian were incorporated to the territory known as Legal Amazon. These states belong to the Amazon Basin and have part of the Amazon forest in its territory, presenting, therefore, similar characteristics of social and economic aspects.

ecological and social costs which are not accounted for by enterprises (NEPSTAD; ALMEIDA, 2004, p.4 cited CHRISTOFFOLI, 2007).

Recognizing the potential degradation of the Amazon region arising from the inadequate exploitation of its resources and the importance of ecosystem services provided by forests, national actions to control deforestation and haphazard land use were taken (FASIABEN, 2010; PALMER, MAIA, 2010). The creation of the Brazilian Forest Code by Law No. 4771, on September 15th, 1965, the establishment of Law No. 7754, on April 14th, 1989, for the protection of existing forests in the headwaters of rivers and the edition of Provisional Measure 1,511 in 1996 , which increased the percentage of legal reserve requirements for properties in the Legal Amazon were the government response to the pressure to conserve ecosystems. These laws imposed on producers the reduction of their property rights, in that occupation and land use were limited (FASIABEN, 2010; PALMER, MAIA, 2010). These documents had the main objective of limit the advance of deforestation on forest areas in the Amazon region, by increasing the percentage of legal reserve and increasing the opportunity cost of exploitation of forest soils.

Moreover, since the beginning of 2000, the states bound by the Legal Amazon have built protection tools at various levels. Most notable are the environmental license for production, stricter monitoring of protected areas, increasing investment in research to develop more resistant seeds to pests and diseases, allowing less use of pesticides or the use of less pollutant products and, or biodegradable.

However, these protection tools are mainly initiatives of the type "command and control", which can result in the reduction of the potential economic returns of land use and, consequently, reduce its value. Moreover, these mechanisms require from the State the ability to monitor compliance with the law, since the producers do not receive economic incentives for compliance. Among these tools, one of the most important is the Brazilian Forest Code, which have been ineffective in its goal, given the low capacity of state supervision (NOGUEIRA; SIQUEIRA, 2004).

Having as justification the income reduction of small farmers and the complexity of the Forest Code resulting from the large number of regulations and decrees, it was proposed Bill 1.876/99, which repeals Law No. 4.771/65. This Bill amends the area for preservation in the river beds; allows consolidated areas on the top of hills, areas with slope above 45 ° and riverbanks have their occupation maintained; relieve the recovery of deforested areas of legal reserve, and permit the occupation of the legal reserve in properties with less than 4 modules.

These changes may result in increased occupation of risk areas, removal of vegetation from the riverbanks, reduction of legal reserve areas and contribution to climate change through increased emissions of greenhouse gases (ELLOVITCH, 2010).

In this context, there is an increasing search for agricultural activities of greater environmental efficiency that result in less pressure on ecosystems and forests. In this study, the environmental efficiency is understood as the largest agricultural production possible, given the deforested area required. Thus, this study aims to examine the relationship between technical and environmental efficiency of agricultural production in the Legal Amazon, and estimate the opportunity cost of the current Forest Code.

2- Production theory under the environmental perspective

The prominence given to environmental aspects and its effects on economic and social dynamic is not new. The first thoughts on environmental issues date back to Malthus, in the XIX century, when he developed a theory based on the Principle of

Scarcity. This indicated that the capitalist system driven by effective demand led to a squandering of scarce productive resources for a growing population (HENRIQUES, 2007). One criticism of this approach is to disregard, for example, technological change, which could mitigate these effects. However, it is known that this thought is very important to raise the discourse about the scarcity of natural resources which form the basis of the productive system.

In a more recent analysis, much has been discussed about the sustainability of current production system. Sustainable development is understood as the one that balances three aspects: the environment, economic growth and social welfare. According to these principles, economic growth and environmental conservation should not walk in opposite directions. Sustainable economic growth attributes the increased demand for environmentally efficient goods and services to income additions. This increased demand influences the formulation of public policies that force companies to adopt a standard of environmental conservation, or its products will not meet consumer market.

In this context, one of the first attempts to incorporate the relationship between natural resources and production system resulted from the restructuring of the neoclassical theory of production, performed by Georgescu-Roegen (1971). The objective of this restructuring was to strengthen the link between environmental assets and economic activity. According Calvalcanti (2004) the neoclassical theory of production has its foundations focused on the idea that the free market is able to promote the efficient allocation of resources, equity of income distribution, accelerated technological progress, the elimination of poverty and environmental preservation. However, the main critics of this theory, including Georgescu-Roegen (1971), argue that the functioning of the market without regulation inevitably would lead to the depletion of natural resources and unsustainable economic system functioning. In general, the forest and the environment present characteristics of pure public goods (not rival and not excluding) and, therefore, the market would not be efficient to offer the environmental services, being necessary the government intervention. Thus, the purpose of this author is based on the idea that economic growth measured only by the increase in Gross Domestic Product (GDP) is not sustainable and needs to be changed, and became known as the Theory of Economic Decrease.

From that thought there is a demystification of the extremist view of maintaining untouched natural resources, leading to a critical view in relation to unrestricted economic growth and to environmentalists ideas to keep untouched natural resources (Cechin, 2008). The focus of the theory of Georgescu-Roegen (1971) is then the relationship between the economic system and the environment.

Principles of the Theory of Economic Decrease highlight the need to amend the current economic system because this is essentially dependent on non-renewable resources, to incorporate other types of wealth produced by the economic system, such as ecosystem health, so that the measurement of wealth only by monetary indicators is unsatisfactory because it minimizes the importance of other types of wealth other than the material one (LATOUCHE, 2009).

In fact, many criticism are listed to the dominant capitalist model, so that the theoretical reformulation proposed by Georgescu-Roegen (1971), aims to restructure the economic system incorporating the principles of sustainable growth, considering that it is not possible to separate economic growth of its impact on the environment. Moreover if economic growth continues uncontrollably, this will cause irreversible damage to the ecosystem.

The difference between this model and the conventional one is related to the attention given to the basic elements of the productive system. The factors of production are divided into two groups: the fundamental factors that make up the basis of the production process and the flow factors which are the ones transformed into a product by the process. Thus, the analysis of ecological economics is to verify the carrying capacity of the ecosystem and transfer the production process through the allocative efficiency of productive resources (SEKIGUCHI; PIRES, 1995).

This analysis is the inverse of the traditional production function that does not distinguish between production agents and flow elements that are the essence of the agents activity, specifically, the transformation of some flows in other ones. Because of this, the neoclassical theory, through the Cobb-Douglas production function proved that physical capital can replace, without limitation, natural resources, by not considering that the increase in capital implies increased use of resources to produce it and keep it (GEORGESCU-ROEGEN,2005).

Many initiatives have been undertaken to quantify the environmental dimension of sustainable growth, but there is still no theoretical clarity in the measurement of sustainability, the main problem being the lack of monetary values to environmental goods and services.

Another theory of great importance for explaining the relationship between environment and economic growth is the one that deals with externalities. According to Varian (2002), externalities are understood as the result of action of certain agent on the environment of another one. Thus, this can affect both the utility of a consumer and the production of a firm.

Externalities arise from market failures that allow differences between private and social costs, so that the social costs (social, environmental and health impacts) of economic activity are not incorporated into prices, and these costs are absorbed by society. Practical problems with externalities arise from poorly defined property rights; consider the Amazon biome owned by society as a whole and, therefore, difficult to protect because it involves costs of protection to be distributed among all (VARIAN, 1992; FRIEDMAN, 2002; SOARES; PORTO, 2007; LEACH; MUMFORD, 2008).

Externalities can also be negative or positive. A negative externality entails costs to other economic agents, reducing the utility or production possibilities when considering consumers or firms, respectively. The positive externality is the one that produces benefits to other economic agents, who, however, does not pay the costs of production. Externalities can also be classified as indirect (when they impact productivity, global warming, desertification, deforestation, etc.) or direct (when they cause damage / benefits to human health) (FRIEDMAN, 2002).

In this study, the conservation of forests in agricultural properties is seen as a positive externality, since the preservation of the environment generates benefits to society as a whole. The opportunity cost to keep the area with forests instead of using it for agricultural production is a cost paid only by the producer, but that should be passed on to society, through government incentives, in order to facilitate law enforcement and agricultural production.

Considering the importance of the issues presented in this section, this study uses the methodology data envelopment analysis (DEA) to analyze the environmental and economic efficiency of agricultural production in the regions of the Legal Amazon.

3- Empirical framework

Consider the existence of n DMUs (decision maker units) that uses three factors: inputs, desirable and undesirable products. Assume the vector of inputs $x \in R_{+}^{m}$

comprising production area, labor and dairy herd; the vector $y^g \in R_+^{s_1}$ comprising the desirable product agricultural revenue; and the vector $y^b \in R_+^{s_2}$, composed of deforestation, the undesirable product. This production technology is represented in (1):

$$T = \{(x, y^g, y^b): x \; pode \; produzir \; (y^g, y^b)\} \quad (1)$$

Assume that on this technology of production, reduction of undesirable products is not free. A proportional reduction in undesirable product implies a proportional reduction in the desirable product (weak disposability). Furthermore, assume that y^g and y^b are jointly zero, so the undesirable product is necessarily produced with the desirable one.

Thus, measuring the performance of the n-th DMU must recognize as efficient the one with the greatest production of desirable products and the minor production of undesirable products proportional to the use of inputs. This measurement is modeled by Zhou, Ang and Poh (2006), using the efficiency model based on slack (slack-based efficiency measure - SBM) initially proposed by Tone (2001). The efficiency index proposed by Zhou, Ang and Poh (2006) also allows the estimation of the impacts of environmental regulations.

Initially the model of data envelopment analysis based on slacks (DEA - SBM) is calculated as proposed by Tone (2001). The linear form of the model can be represented by:

$$\min \tau_1 = t - \frac{1}{m}\sum_{i=1}^{m} S_i^- / x_{io}$$

s.t. (2)

$$1 = t + \frac{1}{s}\sum_{r=1}^{s} S_r^+ / y_{ro}$$

$$tx_o = X\Lambda + S^-$$

$$ty_o = X\Lambda - S^+$$

$$\Lambda \geq 0, \quad S^- \geq 0, \quad S^+ \geq 0 \;\; e \;\; t > 0$$

where $\Lambda = \mathrm{t}\lambda$, $S^- = \mathrm{t}s^-, S^+ = \mathrm{t}s^+$ and $\tau_1 = \rho_1$ of the primal problem. The term X denotes the vector of inputs, Y the vector of products, and s^- e s^+ are the existing slacks in the use of inputs and products, respectively, λ is the vector of intensity, t is a positive scalar and τ_1 is the vector of technique efficiency scores calculated for each DMU.

The model (2) can be modified to incorporate the undesirable products of agricultural activity in the calculation of technical efficiency, as proposed by Zhou, Ang and Poh (2006). The model (2) can be reformulated in (3):

$$\min \tau_2 = t - \frac{1}{m}\sum_{i=1}^{m} S_i^- / x_{io}$$

s.t. (3)

$$1 = t + \frac{1}{s}\sum_{r=1}^{s} S_r^+ / y_{ro}$$

$$tx_o = X\Lambda + S^-$$

$$ty_o = Y^g\Lambda - S^+$$

$$ty_o = Y^b\Lambda$$

$$\Lambda \geq 0, \quad S^- \geq 0, \quad S^+ \geq 0 \;\; e \;\; t > 0$$

where Λ, S^-, S^+ and X are as described above. The terms Y^g and Y^b are the vectors of desirable and undesirable products, respectively, and τ_2 is the vector of environmental technical efficiency calculated for each DMU.

Through τ_1 and τ_2, Zhou, Ang and Poh (2006) define an efficiency measure based on slacks to model environmental performance (SBEI) as:

$$\text{SBEI} = \tau_1/\tau_2 \quad (4)$$

This index can then be used to model the economic impact of environmental regulations. When SBEI = 1, there is no economic effect associated with the regulation. When SBEI <1, there is indication that environmental regulation results in inappropriate use of available resources and there is loss in the production of desirable outputs for the DMU under analysis. Quantitatively, the cost of environmental regulation can be calculated as:

(1-SBEI)*agricultural revenue (5)

4- Results

The model of environmental and technical efficiency was estimated as previously described using data from the Censo Agropecuário of 2006 (IBGE, 2011). The calculation of efficiency measures was performed using as inputs: area for agriculture, in hectares; effective cattle in agricultural establishments, in number of heads; and persons employed in agricultural establishments, over 14 years age, in number of people. The revenue from agricultural, in thousands of dollars, was considered as desirable product, and deforestation resulting from agricultural, as undesirable product. Deforestation has been calculated as the area used for farming above the percentage of 20% allowed by Brazilian legislation (BRASIL, 2011).

Table 1
Descriptive statistics of variables by state of Legal Amazon, 2006 (average by state)

State	Total area (ha)	Deforestation (ha)	Deforestation (%)	Revenue (R$1000)	Agricultural area (ha)	Herd (nº animals)	Labor (nº people)
Tocantins	27762091	6333757	22,81	560157	9058678	6076249	176831
Mato Grosso	90335791	19020775	21,06	8898509	28341212	19807559	358321
Maranhão	27906266	4947192	17,73	1439447	6778381	4722863	551557
Rondônia	23757617	3669030	15,44	821241	5285970	8490822	277756
Pará	124768952	8884190	7,12	2711446	13198247	13354858	792209
Acre	15258139	584960	3,83	205094	1262270	1721660	99578
Roraima	22429898	547561	2,44	79149	874330	480704	29509
Amapá	14281459	196882	1,38	92548	342324	57728	13095
Amazonas	157074568	1001570	0,64	495743	1692375	1154269	266667

Source: Research results.

Data analysis shows that the states that have the highest percentage area cleared for agricultural production are the ones in the agricultural frontier and that characterize the so-called arc of deforestation. It can also be observed that these states have the biggest areas designed to agriculture, which supports the hypothesis that the advance of deforestation is due to agricultural activities.

In this sense, the producer increases the area for agriculture as a strategy to increase production and hence farming revenue. The producer can expand the farming area above the legally permitted in order to increase revenue. Thus, the productive performance can conflict with the environmental one.

The average estimates for technical and environmental efficiency for the Legal Amazon are presented in Table 2 by state average. The states were organized in descending order considering environmental efficiency.

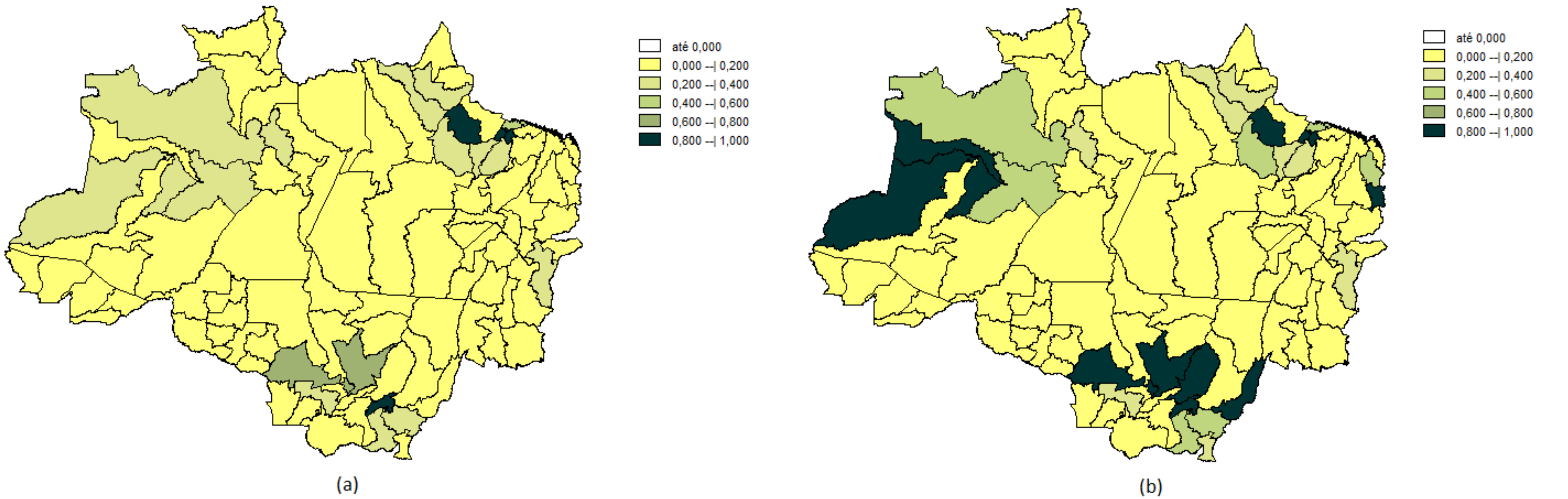
Table 2

Average estimates for technical and environmental efficiency for the Legal Amazon

State	Technical efficiency (average)	Environmental efficiency (average)
AM	16,88%	36,56%
MT	18,90%	32,31%
PA	22,42%	22,54%
MA	8,60%	22,44%
AP	14,98%	14,98%
RO	4,68%	4,68%
AC	4,62%	4,62%
RR	3,56%	3,56%
TO	3,06%	3,06%

Source: Research results.

The results indicate the low average technical performance of all of the Legal Amazon states analyzed, highlighting the states of Tocantins, Roraima, Acre and Rondonia. These states had efficiency scores less than 5%. The environmental efficiency presented higher average scores for states of higher technical performance, while for the states of lower technical performance the environmental efficiency presented mean results slightly different or equal. This behavior can be observed for the regions through the maps for technical and environmental efficiency (Figure 1).



Source: Research results.

Fig. 1 - Technical and Environmental Efficiency.

Superior environmental performance in comparison to technical performance is an indication that the law leads to inappropriate use of inputs and loss of desirable product. This loss of technical performance can be viewed for the states of greater efficiency, such as Amazonas, Mato Grosso and Pará (Table 2). For the ones of less technical performance, the constraint arising from the legislation indicated no loss of performance or production capacity. This may indicate that the states of reduced technical capacity could be subject to other factors restricting the productive efficiency more important than environmental constraints such as managerial ability.

The total cost of the legal restrictions imposed on the production systems arising from the restriction of the area by the forest code is shown in Table 3, in descending order by state. This cost was calculated as described in equation (5).

Table 3

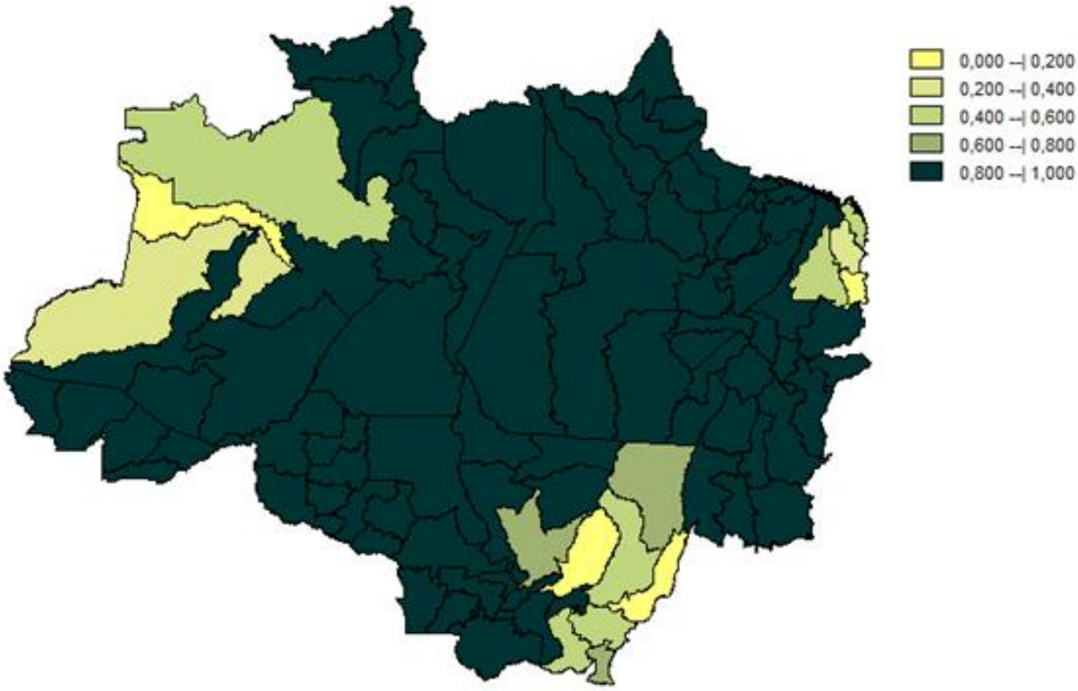
Opportunity cost of forest code, by state, 2006.

State	Opportunity cost (in thousands of Reais)
MT	954601
AM	580268
MA	531830
PA	18071
AP	0,00
RO	0,00
AC	0,00
RR	0,00
TO	0,00

Source: Research results.

In fact, the forest code reflects an opportunity cost only for those states with the largest technical performance, except the state of Amapá that has no opportunity cost. For these states, the Brazilian Forest Code (BFC) imposes the total cost of R$ 2,084,771 on agricultural production. This cost represents 15% of agricultural revenue in these states. This is represented by Figure 2.

The regions with important opportunity cost are western Amazon and eastern MatoGrosso and Maranhão. This result indicates that environmental regulation results in inappropriate use of available inputs, causing the loss of desirable inputs.



Source: Research results.

Fig. 2 - Slacks-Based Efficiency Measure (SBEI)

It must be highlighted that this opportunity cost reflects a positive externality for society, arising from environmental services provided by the conservation of forests. Therefore, policies should be directed to farmers in order to compensate them for the loss of their revenues caused by conservation and environmental services to society. Moreover, it is known about the low profitability of farming, especially in the Amazon region, which indicates the necessity of compensation actions from the state for these producers.

Clearly, low values for the opportunity cost does not reflect greater technical and environmental efficiency for micro-regions, but that comparatively the two efficiency levels are equal or approximate. This means that the states that had low opportunity cost have approximate values for the technical and environmental efficiency.

5- Conclusions

The positive association between technical and environmental performance has not been confirmed. The micro-regions of higher technical performance showed the highest environmental performance, but the greater opportunity cost. It is noteworthy that the environmental constraints represent opportunity cost only for those micro-regions of higher technical performance.

States belonging to the production frontier and that characterize the arc of deforestation, showed the greatest environmental cost of the framework legislation. The producers of highest technical performance are not encouraged to keep forests areas, because of the opportunity cost associated.

The degradation of this biome with the removal of forest areas reduces the welfare world, given the importance of the Amazon forest for the global climate and biodiversity conservation, among other environmental benefits. For this reason, the existence of legislation and rigorous monitoring systems are not enough. It is necessary a change in the way the producer is treated. Producers should be considered as providers of environmental services to society, and as such, they should be paid for it.

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