PAYMENT FOR ECOSYSTEM SERVICES: AN ALTERNATIVE FOR THE BRAZILIAN AMAZON

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ABSTRACT

The Brazilian Amazon has been facing intensive pressure by the expansion of cattle ranching and soybean toward forested areas. In the past 2 decades, the forest loss reached 33,6 million hectares, of which at least 5.7 million should be recovered to meet the minimum requirements of Legal Reserve and Permanent Preservation Area set on the Brazilian Forest Code. The urgency to enhance conservation and restoration policies is quite clear, and the 9.7 million hectares of expected deforestation until 2030 piles up new additional evidence that the government must take action to protect the Brazilian Amazon. Meanwhile, the ongoing fiscal crisis has been deepening the long-lasting tendency of public underspending on environmental management at the federal level and blocking the way to properly finance the environmental policy, especially concerning the conservation and restoration initiatives. Given this scenario, this article suggests the adoption of a Payment for Ecosystem Services program for conserving and restoring the Brazilian Amazon as a way to conciliate the lack of public resources with the necessity of improving the environmental outcomes in the region. The costs and environmental benefits in terms of carbon conserved and captured of the suggested PES program are estimated, and three alternative financial mechanisms are proposed as a means to fund its implementation, namely: (i) a tax on the forest deficit areas; (ii) a tax on the carbon emissions; (ii) a trade of REDD+ certificates. The results show that all three sources could consistently assist in reducing deforestation and foster forest restoration, except for the forest deficit taxation, which would not be very effective in the case of restoration.

KEY-WORDS: Payment for Ecosystem Services; Conservation, Environmental Restoration, Brazilian Amazon, Fiscal Crises, Financial Mechanism

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I. INTRODUCTION

The Amazon rainforest is a huge factory of ecosystem services, providing benefits to people and to the economic system in local, regional, national and global scale. The region hosts around 10% of the now known world`s biodiversity (SILVA *et al.*, 2005*Apud.* RAYLANDS, 2002) and 20% of all freshwater flowing into oceans (BRAGA *et al.*, 2017), and regulates the rain cycle in a large part of the South American continent (NOBRE, 2014). At the global scale, the Amazon is an important player for fighting climate change, given its great density of biomass per hectare and the low profitability of the alternative land uses that take place after the forest is cut-off (QUEIROZ 2008, YOUNG *et al.,* 2007; ALVARENGA JR. 2014, YOUNG *et al*., 2016). On average, one hectare of Amazon forest contains 505 tCO_2 (*SISGEMA*, n.d.), while the land opportunity cost is USD 55.22/hectare/year. Such conditions make Amazon a privileged area for conservation policies based on market mechanisms, especially those related to carbon pricing.

Still, large plots of Amazon rainforest and Cerrado have disappeared to give place to the sharp increase of cattle herds and soybean expansion in Brazil in the past few decades. From 1994 to 2017, the herds in Brazil grew by 56.7 million cattle heads, of which 90% took place in Amazon states, in addition to the 9.6 million hectares of soybean planted in the region. In total, 336,459 km^2 of Amazon rainforest were lost in this period.

Despite all efforts undertaken by the Brazilian Government to tackle deforestation from 2005 onward, most of them based on command and control policies, the forest loss in Amazon remains quite high. During this decade, Amazon has been losing an average of 6,354 km^2 of forest per year. In 2018, the deforestation rate reached 7,900 km^2 (the highest level since 2008), putting Brazil on the top of the list of countries with highest rates of rainforest loss in the world (McGRATH, 2019). Besides, all the main models for projecting deforestation point out to a large extent of forest lost in the coming years. The *SIGEMA* model expects 9.8 million hectares of extra forest loss until 2030, while the model DINAMICA EGO predicts 25.3 million hectares only in the Amazon rainforest.

In both cases, there is still a large room for improving and enhancing conservation policies. Furthermore, the importance of implementing restoration measures is recognized, since about 1/5 of Brazilian Amazon has already been deforested, and the risk of savannization is eminent. Anyway, additional financial resources are required for filling up these gaps. However, recently the federal budget for environmental management has shrunk at a high pace. From 2013 to 2017 federal resources for funding environmental policy were cut by 35.2% (the inflation already discounted), partially due to the ongoing fiscal crisis in Brazil. The substantial budget cuts have led to the discontinuation or the reduction of the scope of many environmental policies in the Federal Level, such as the Bolsa Verde[5].

In this scenario, Payment for Ecosystem Services rises as a promising initiative for enhancing environmental outcomes. Firstly, the PES schemes represent an alternative to the current development pattern of *slash and burn* in Amazon, since it generates monetary values for the standing forest. Furthermore, PES is a very versatile economic instrument that can comprise a mosaic of funding sources that might help to circumvent the fiscal constraints faced by the federal government. A PES can be structured out of many funding arrangements, such as public spending (currently out of the table), donation, volunteer transactions between the beneficiaries and providers of the ecosystem services, Pigouvian taxation, and so on.

Recently, the Brazilian Ministry for the Environment (BME) carried out a study on the costs and benefits of implementing a PES program on the national level. The final report, authored by Young *et al.* (2016), estimated the land opportunity costs and some environmental benefits that would come out in case of the implementation of a national PES program. This paper departs from the methodology elaborated by Young *et al.* (2016) aiming to shed light specifically on the costs and benefits of the PES program for conservation and restoration for the Brazilian Amazon. Moreover, this paper aims to provide some alternative possibilities for financing this program, as it estimates the potential revenue from the three following financial mechanisms that do not rely on the current capacity of the federal government to spend: (i) a Pigouvian tax on Brazilian carbon emissions; (ii) a tax on the forest deficit area; (iii) a REDD+ scheme.

This paper is divided into four sections, aside from the introduction and the conclusion remarks. Section II offers a theoretical discussion on PES, trying to define and delimitate the concept and to clarify how such instrument works. The third section situates the challenges for enhancing environmental outcomes through public policies, especially due to the long-lasting trajectory of insufficient spending on environmental policies at the federal level. Section IV presents the methods, data, and parameters used in this paper, and finally, section V presents the results.

[5] Bolsa Verde was a monetary transference made by the federal government to small farmers and traditional communities to assist in the rural poverty alleviation and conditioned to the conservation of the forest remnants inside their properties. In a broader definition, Bolsa Verde can be categorized as a PES program.

II. PAYMENT FOR ECOSYSTEM SERVICES: AN THEORETICAL OVERVIEW

Healthy ecosystems provide goods and services that are essential to humans. The provision of water, timber, and non-timber forest goods, fishery, genetic resources are examples of ecosystem goods and services that are directly consumed by the economic agents as final goods or inputs in the production process. Many others such as climate regulation, soil formation, and protection, water quality and pollination are not directly consumed but support the production and productivity of many economic activities. Water quality affects fishery, climate affects agriculture, soil erosion and siltation affect hydropower production, and thus all variation on the influx of these services affect the revenue of firms and the well-being of economic agents, even when it is difficult to perceive the consumption of these services in daily life.

In order to keep the inflow of ecosystem goods and services (ES) at a proper level, it is necessary to find ways to use the natural resources parsimoniously, respecting the carrying capacity of ecosystems. This is the main objective of environmental policies and of sustainable management.

Currently, these policies are divided into two main groups: (i) command-and-control; (ii) market-based mechanisms. The former seeks specific environmental outcomes by setting up rules, standards, and parameters with regard to the use of natural resources that should be followed by all the economic agents, as well as sanctions and penalties for those who deviate from the desirable behavior. The later uses a range of economic instruments that aim to alter the relative prices as a way to guide economic agents to adopt production technics and consumption standards compatible with the sustainable use of natural resources. The idea is that behind the decisions regarding the use of natural resources there is a misleading calculation that does not consider the social costs of depleting ecosystems (PERMAN *et al.*, 2003). The distorted calculation derives from the fact that many of the benefits provided by ecosystems can be framed as:

(i) **Public goods:** are non-excludable and non-rival goods, meaning that no economic agent can keep others from consuming that good, and the consumption choice of an agent regarding that good has no impact on its availability for the others.

(ii) **Common goods:** are non-excludable and rival goods, meaning that no agent can exclude others from consuming the good, but now one`s consumption constraints the consumption possibilities of the others.

In both cases, it is hard to define properly who has property rights of the good. Since both public and common goods are non-excludable, everybody has access to them, and thus the challenge becomes to define who plays the seller and who plays the buyer in a potential market transaction. In other words, it is quite unlikely that agents would be willing to pay for something that they can get for free. The absence of market leads to a situation where the economic value of these services cannot be expressed into prices. Therefore, many ecosystem services are perceived as "cost-free" to the profit and utility functions of economic agents, which tends to lead to an over-use of those (SEROA DA MOTTA, 1997).

Payment for Ecosystem Services (PES) can be assembled in the second group of environmental policies since it tries to create a voluntary change in the private choice concerning natural resources through a set of monetary incentives. There is no consensual definition of PES. Some of the definitions are quite vague in terms of objectives, functionalities, and some are quite too narrow. This seems to be the case of the definition offered by WUNDER (2005). According to the author, PES is a voluntary transaction of a well-defined ecosystem service (or the required land-use to assure its provision) that brings together at least one buyer and one seller, where the former pays the later if and only if the later pledges to secures the provision of the ecosystem service. "*In essence, PES is thus defined as an integration of a user fee with a targeted, conditional subsidy*" (WUNDER, 2015: p.236).

Many criticisms have aroused toward this definition, especially concerning the two following points: (i) terminology; (ii) narrowness. Firstly, the use of terms sellers and buyers presupposes market relations and previous appropriation of the ecosystem services. *"However, environmental services are qualities associated with elements (for example the quality of water flowing through a drainage basin, or the carbon storage capacity of a forest) that cannot be appropriated".* (KARSENTY, 2011: p.1). Moreover, the definition given by Wunder (2005) clearly describes a Coesean (voluntary) PES scheme, and cannot deal with the whole range of possibilities concerning the real world cases of PES. Many of the PES projects have been financed by government or donations of companies, NGOs, multilateral institutions or even other countries' government. In those cases, there is an intermediary agent between those who provide the ES and those who benefit from it. Such a situation is quite common when dealing with public and common goods. As mentioned before, it is fairly unlikely to find someone willing to pay for a good or service, when it is not possible to exclude other agents from consuming it, especially because those who oppose paying still can have access to it. Besides, the idea that all PES schemes involved voluntariness among its participants is also very restrictive, since in many situations such programs are made financially possible by resources coming from taxes on externalities and environmental fines, for which the payment is not an option (BAKKER, 2014). Finally, the idea that the PSA is built from well-defined ecosystem services is also quite narrow, either in the comprehensiveness of benefits and, consequently, in the number of beneficiaries involved. The main PES experiences reveal that a substantial part of positive externalities is spatially diffuse, and thus PES has to account also for offsite externalities (WUNDER, 2015).

Given the limits of the definition offered by WUNDER (2005), MURADIAN *et al*. (2010: p.1205) tried to stretch the concept of PES defining it as "*A transfer of resources between social actors, which aims to create incentives to align individual and/or collective land use decisions with the social interest in the management of natural resources*". The main problems in this case are that the authors, by trying to solve the narrowness of the Wunder`s definition, went too far gone in opening the PSE concept. Basically, the definition describes most economic instruments for conservation.

Later on, TACCONI (2012: p.35) defined PES as "*a transparent system for the additional provision of environmental services through conditional payments to voluntary providers*." In this sense, the author focusses on two points that were absent on Wunder`s definition: the additionality and the voluntary engagement only in the ES supply side. The first point is quite troubling because it makes the lines that delimitate the PES borders to change very dynamically. In fact, the inclusion of additionality as a defining criterion:

> […] *could be problematic, since it depends on an ex-post evaluation of PES impacts. […]. If we included this outcome criterion in their respective definitions, could an ineffective forest law not be labeled "a law", or a paper park not be labeled a protected area? In conclusion, we better not mix impact assessments into concepts and definitions.* (WUNDER, 2015: p.236)

In 2015, Wunder reviewed his definition of PES, trying to incorporate some of the criticism he got it in his 2005 paper. The new definition stands that a PES can be described as a "*voluntary transaction between services users and services providers that are conditional on agreed rules of natural resource management for generating offsite services*" (WUNDER, 2015). The author kept the voluntariness in both supply and demand side of ecosystem service, alleging that this is not a binary concept, so that different PES schemes may present different degrees of voluntariness among the agents involved. Distinctively from Wunder`s first attempt, this definition is not too narrow to lock some PES schemes outside the room, and not too vague to encompass a considerable number of economic instruments that do not lie under the PES umbrella.

Despite the different definitions, the cornerstone of any PES schemes relies on the Protector-Receives Principle (PRP) that establishes agents should be rewarded by undertaking conservation actions. This is a *sine qua non* condition for any PES schemes. Still, some PES schemes can also assemble punitive mechanisms[6], like those combining PRP and the Pollutant-Pays Principle (PPP). This is the case of PES initiatives funded by taxes on environmental externalities.

The voluntariness of PES and the PRP are tight connected to each other. PES can only raise voluntary commitment among ecosystems providers if and only if the amount they receive for conserving the ecosystems within their properties is at least equal to their land opportunity costs, i.e. the profits they could be earning by using their land to other purposes. For any smaller value, landowners would be better off by dedicating their lands to any other alternative uses than conservation.

In this regard, PES should not be taken for granted as a policy that can deliver positive environmental outcomes in any contexts or as WUNDER (2015) pointed out: *"... perceiving PES as a silver bullet could easily misguide conservation investments. Decision-makers should always evaluate the pertinence of PES vis-à-vis other available policy instruments."* From the environmental economics standpoint, PES only pays off when the value of the positive externalities (environmental additionalities) that society can get out of it exceeds the costs of implementing such a policy. In many situations that may not be the case, and so other policies may be required for targeting conservation, such as command-and-control initiatives. Thus, PES should not be seen in opposition to other environmental policies, but as a complementary effort to enhance environmental governance and sustainability.

One of the greatest advantages of PES over other environmental policies consists of the range of financial mechanism that can be used to fund such programs. Recently, YOUNG *et al.* (2016) conducted a survey on sub-national PES initiatives, which identify at least 12 different funding mechanisms. The survey not only reveals that the funding sources are quite diverse, but also that a single project can count on several sources of funding.

Finally, it is important to consider that the opportunities for implementing PES schemes may vary very dynamically, especially in response to fluctuations on the fund-raising[7]. Even after the growing engagement of the private sector in environmental conservation and restoration practices in recent

[6] In this cases, the punitive mechanisms operates through the price system, not through the legal-administrative system, like command-and-control policies.

[7] The commodity prices are also a very important source of instability because they can vary abruptly in the short run, creating several disturbances in the land opportunity costs.

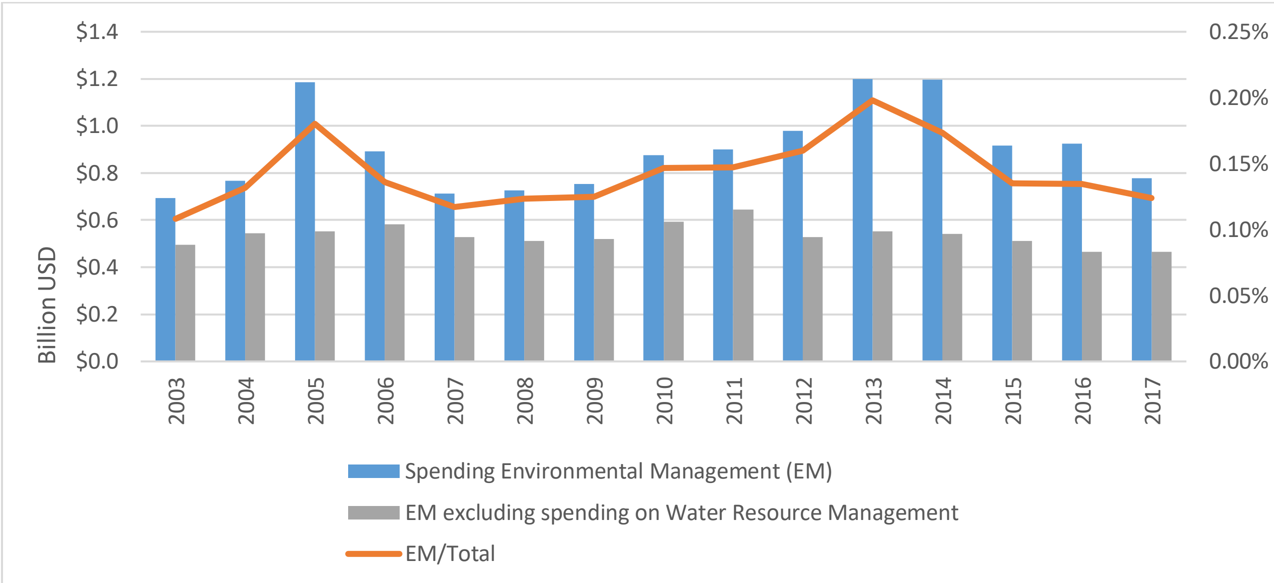
decades, the public budget remains the main source of funding resources for environmental policy in Brazil, what makes environmental spending very susceptible to the fiscal situation. On the other hand, resources from international donations and fines are quite unstable and poorly predictable (YOUNG *et al.* 2018). Therefore, it is advisable to base PSA programs on diverse sources of resources, this tends to make them more financially resilient.

III. UNDERSPENDING ON ENVIRONMENTAL MANAGEMENT: THE CRISIS BEFORE THE CRISIS

Even though the burst of the economic crises in Brazil posed new fiscal challenges to the continuity of many public-funded environmental policies, the underspending on environmental management is rooted much further back in time. The lack of budgetary resources has been reported in many studies since the late 1990s (YOUNG & RONCISVALLE, *et al*., 2002, ROCHA, 2011; YOUNG *et al.*, 2015; MEDEIROS *et al*., 2018). The persistence of the underspending in so many different economic contexts piles up evidence to support that the lack of resources for funding environmental policies reflects at some extent an allocational issue, i.e. this is also a matter of low political prioritization. Even though the political will is somehow difficult to quantify, Graph 1 drops some hints in this regard, by showing the share of the federal budget destined to environmental management. As one can notice, since 2003 the federal government has been dedicating averagely 0.15% of its budget for funding environmental policies, with the values ranging from 0.13% to almost 0.20% (Chart 1)

Aside from the level of federal spending on environmental management is important to account for the economic context during the analyzed period. The period 2005-2010 was marked by the intense economic growth which also led to an increase in tax revenues and a comfortable fiscal situation at the federal level. Since there was no decoupling in the Brazilian economy at the time, GDP growth can be understood as a proxy for increasing pressure on the environment (higher production requires a greater amount of natural resources). While the GDP grew by 24.5% in the period, spending on environmental management dropped 26.1%, both in real terms. In the whole period (2003-2017), GDP grew 39.6%, while environmental spending grew 12.1%. As a result, environmental spending per thousand dollars of GDP dropped by 19.7%, from USD 0.61 to USD 0.49.

Graph 1.Spending on Environmental Management total Federal Spending (at 2016 prices)

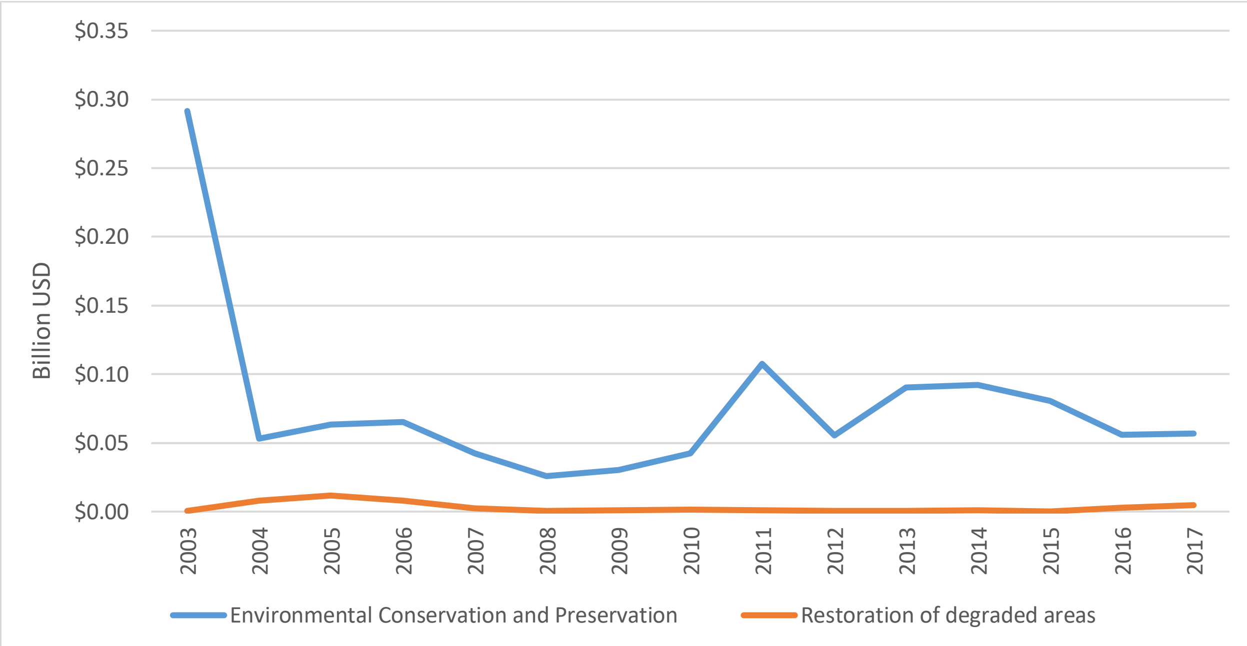


Source: own elaboration based on SIOP data.

Graph 1 also shows that the public budget for the environmental policies in Brazil is largely concentrated on one of its budgetary subfunctions[8]: the management of water resources. Excluding the spending on water management from the environmental management budget, it is possible to notice that remaining resources (grey bars) are virtually stagnant. In the absence of a consistent increase on these remaining resources, the budgetary endowment of a certain environmental subfunction can only increase by cutting resources from the other subfunctions. This increasing competition within the environmental management budget was particularly perverse to two subfunctions of great importance for the purpose of this paper: (i) the environmental conservation and preservation; (ii) the restoration of degraded areas. From 2003 to 2017, the environmental conservation and preservation subfunction had lost about 80.6% its resource. The restoration of degraded areas had lost 58.2% from 2005 on. (Graph 2)

[8] Within the fiscal planning in Brazil, the public spending are classified by function. In this sense, the budgetary resources are grouped according to the general purposes of programs and actions that they aim to finance. If the projects, programs and actions target the improvement of environmental conditions, (ideally) these resources are grouped in the budget for environmental management. The environmental management itself can be splitted in many other budgetary subfunctions, according to the specific objectives of the policy to be implemented, such as: environmental preservation and conservation, environmental control, water management, restoration of degraded areas, and so on.

Graph 2. Federal spending on the environmental conservation and preservation and on the restoration of degraded areas (at 2016 prices).



Source: own elaboration based on SIOP data.

Underspending on the environment management should not be evaluated only on the supply side, i.e. the amount of resources available to fund environmental policies. In fact, an appropriate approach should also consider how the economic context impacts the social demand for new environmental policies. This demand can only turn into public policies if there is a certain amount of resources to finance its implementation.

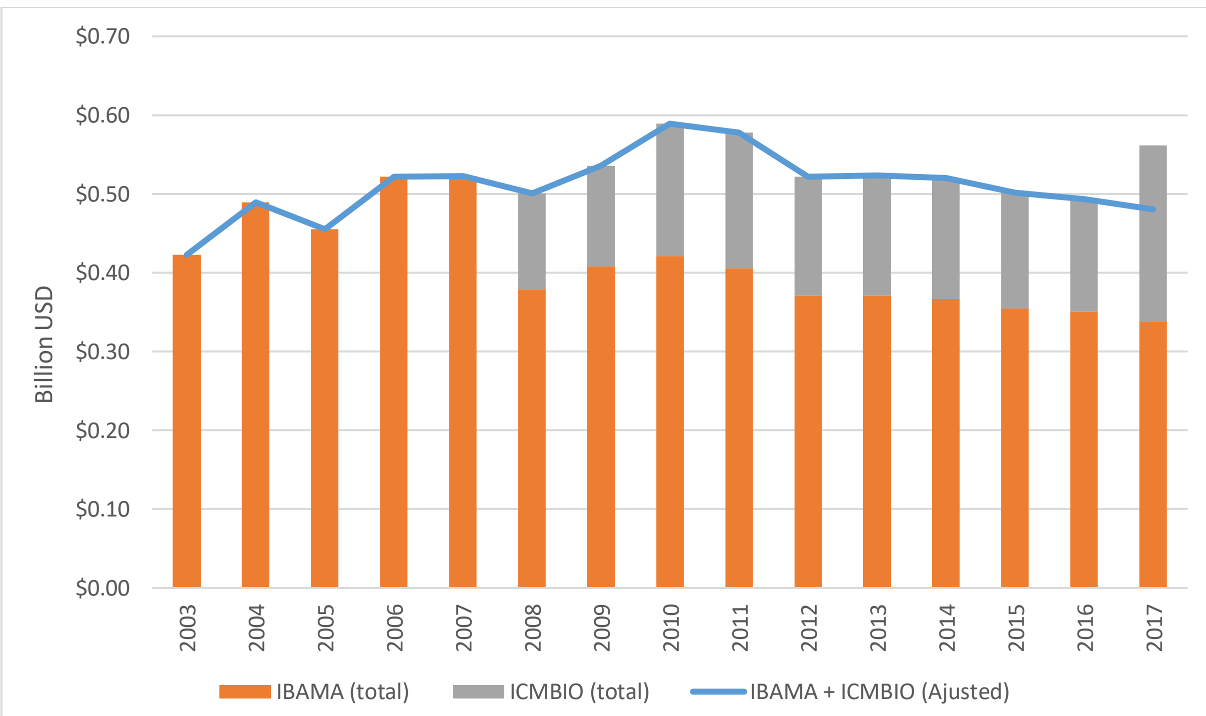
In this sense, the 2000s brought new elements to the table. From 2007 onward, the Federal Government launched the Growth Acceleration Program (PAC), a program that aimed to boost economic growth through the amelioration of the Brazilian energetic, logistic and social urban infrastructure (SEPAC, 2016). More than USD 475 billion were spent in nine years (2007-2016). This led to a sharp increase in environmental licensing applications, that jumped from 965 to 1675 applications between 2006 and 2010 (FORATTINI, 2011). Adding to that, the complexity and high potential for generating consistent environmental impacts of infrastructure projects tend to increase the average time required to analyze the environmental licensing processes diligently. Both elements clearly pressure the budget endowment of the licensing authority[9], creating a demand for additional financial resources.

[9] On the federal level, the environmental licensing is an institutional competence of the Brazilian Institute for the Environment and Renewable Resources (IBAMA)

In the 2000s, the Brazilian government intensified the siege against deforestation in the Amazon. As part of the strategy, a mosaic of conservation units was created in the area of intensive agriculture expansion. Between 2003 and 2016, the government created more than 30.4 million hectares of conservation units (not including indigenous lands), most of them in the Amazonian biome. (BRAGANÇA 2014, 2016).

The increasing demand for environmental licensing and in the creation of federal protected areas should have been followed by an increase in budgetary resources, given the necessity to hire new employees, as well as the acquisition of capital goods (vehicles, buildings and equipment) required for the expansion of the management capacity of the competent authorities. However, that was not the case. While the number of licensing requests grew by 73.6%, and the area of Conservation Units grew 17.5 million hectares from 2006 to 2010 (BRAGANÇA, 2014), the budget of IBAMA and ICMBIO grew 12.8% in the same period (Graph 3).[10]

Graph 3. IBAMA and ICMBIO budgets (at 2016 prices).



Source: own elaboration based on SIOP data.

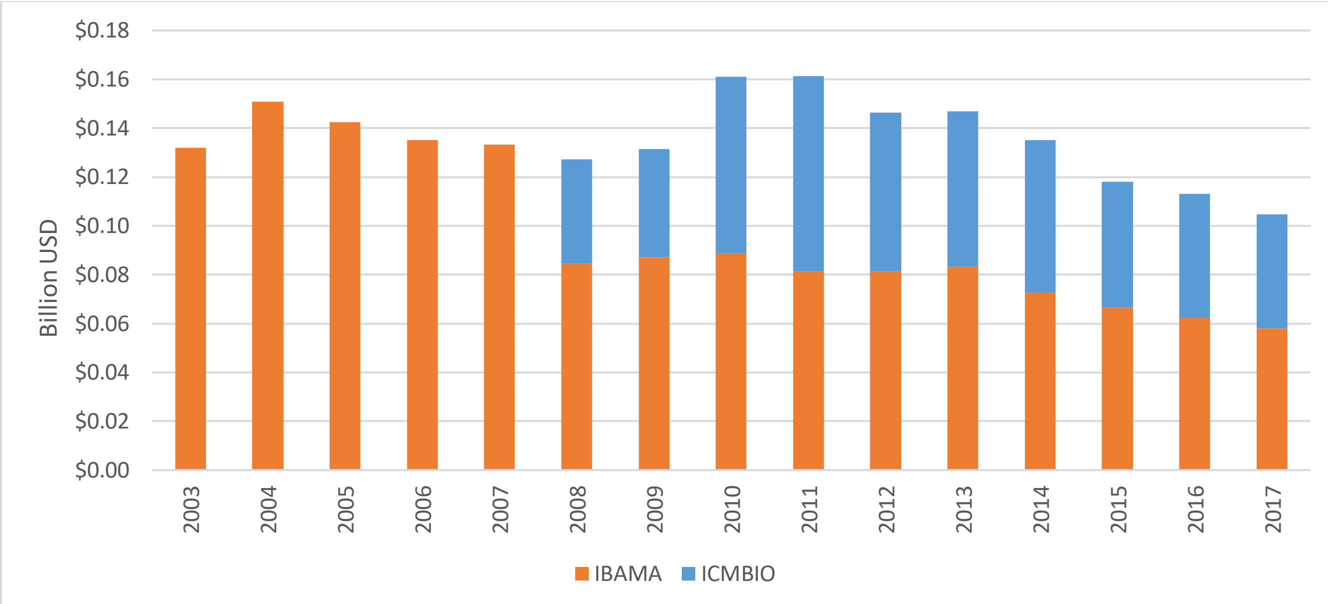
[10] ICMBIO was created in 2007 to execute the actions within the scope of the National System of Conservation Units, that embrace the implementation, management, protection, supervision and monitoring of the Conservation Units established at the Federal level, which were responsibilities of IBAMA before the institutional reform. After that, IBAMA concentrated its powers on deforestation control actions and on Environmental Licensing.

The trajectory of ICMBIO and IBAMA budgets can be divided into two periods. One ascendant, that goes from 2003 to 2010, and the other descendant, that goes from 2011 on. Note that the decreasing of the budget endowment of these institutions started four years before the begin of the Brazilian economic and fiscal crisis. In 2017, after 6 years of budget cuts, there was a consistent growth in the ICMBIO fiscal resources. This deceptively suggests an increase in prioritization of environmental policy. However, the leap on the values is due to an unprecedented payment of precatory (a payment order issued against the government by a court decision). In 2016, ICMBIO spent USD 146 thousand in precatories, while in 2017 the amount reached USD 81.4 million (SIOP, n.d). The blue line in Graph 3 gives a hint of what would be the budget of ICMBIO without the payment of precatories in 2017. So, the adjusted time series reveals that from 2010 to 2017, the ICMBIO lost 18.5% of all its budgetary resources.

A more appropriate way of addressing this topic is to analyze the trajectory of the discretionary spending of both institutions. The discretionary spending is the share of the budgetary resources that can be freely allocated by the policymakers, i.e., the remaining resources the payment of the obligatory expenses, such as wages, pensions benefits of retired employees and interest over debts. From the acquisition of a vehicle, a building or a software, up to the payment of consultants or the simple purchase of a pen, all the required inputs (except for internal human resources[11]) for accomplishing the target of a policy are categorized as discretionary spending. In summary, these are the resources that can be destined for new programs and plans, according to the opportunities and society`s demands. Now, it becomes clear how the capacity of IBAMA and ICMBIO to undertake new policies to counteract the aforementioned increasing pressure has been eroded. After an increase of 22% between 2003 and 2010, the discretionary spending of IBAMA and ICMBIO dropped by 35% from 2011 to 2017.

[11] As mentioned, the payment of employees` wages is classified as an obligatory expense, meaning that it cannot be cancel or postpone by the policy maker.

Graph 4. Discretionary Spending of IBAMA and ICMBIO (at 2016 prices).



Source: own elaboration based on SIOP data.

These susceptive budget cuts are jeopardizing the continuity of many government programs at the federal level and compromising their expected results. In 2016, the Brazilian Institute of Natural Resources (IBAMA) had to resort to a loan from the Amazon Fund[12] to pay for the rent of vehicles to monitor and control deforestation in the Brazilian Amazon. Indeed, in the past five years, IBAMA has increasingly relied on the resources of Amazon Fund to pay for the monitoring of the deforestation.

> "By 2014, most of the resources from the Amazon Fund were distributed to the states. Secondly, to the NGOs. Only in third place came the federal agencies. This scenario has changed. Last year, the largest share of Norway's money went to federal agencies: 46%. The states came second, and NGOs third" (CALIXTO, 2017).

The situation of ICMBIO is also quite critical. In 2012 the TCU audited the Protected Areas in the Brazilian Amazon and concluded that only 4% of them presented a high degree of implementation (TCU, 2012). In the document, the insufficient budget has been pointed out as one of the main causes of the unsatisfactory results (TCU, 2012). Even though the lack of resources for conservation policies negatively impacts all the Federal Conservation Units (UCs), the situation in Amazon is by far the most dramatic. According to table 1, the Amazon presents the larges UCs in the country and the smallest

[12] Most of the financial resources of the Amazon Fund come from international donations, especially from Norway and Germany.

availability of discretionary resources. On average, the Federal discretionary spending in Amazon Conservation Units totals USD 0.10 per hectare (Table 1).

Table 1. Federal spending on conservation units (at 2016 prices).

Biome	Average Area	Average Discretionary Spending	Discretionary Spending/Ha
Cerrado	195,568	$104,449.70	$0.53
Amazônia	574,386	$58,247.37	$0.10
Caatinga	122,874	$127,937.81	$1.04
Pantanal	73,739	$82,485.47	$1.12
Atlantic Forest	42,405	$129,364.11	$3.05
Pampa	121,480	$114,828.90	$0.95
Marine P.A.	55,131	$54,947.64	$1.00

Source: Own elaboration based on ICMBIO data.

This critical situation tends to worsen in the coming years due to the approval of the Constitutional Amendment nº55/2016 (EC nº55). The EC nº55 established a new fiscal regime in Brazil that limits the expansion of the public spending to the inflation rate observed in the previous year – i.e., no expansion in real terms is allowed until 2036. In the best-case scenario, the environmental public budget will be frozen while the demand for budgetary resources to finance environmental policies will increase (at least in response to the economic growth). In such a context, it is important to identify potential new sources and mechanisms for funding environmental policies. A PES program might help to alleviate the scarcity of public resources for environmental management since it can embrace new actors (private sector, NGO`s and multilateral institutions) and potential sources of funding.

IV. METHODS AND DATA

The next sections intend to present the costs and benefits of two PES programs for the Brazilian Amazon, one targeting the conservation of the forest remnants and the other aiming the restoration of the forest deficit in the region. In addition, some financial mechanisms will be suggested as a potential solution for funding both programs.

There is an ongoing debate about which areas should be eligible for a PES program. Some environmentalists and policymakers argue that only rural properties with additionalities to the Brazilian Forest Code should figure among potential target areas. The argument is that the minimum percentages of forest area determined by law should be at all costs respected and that deforestation above this limit should not be addressed by economic incentives but solved by legal sanctions. The contrary argument states that the persistence of deforestation claims for further action than command-and-control policies. Since there is still no law in Brazil constraining the participation of properties in debt with the Forest Code, the estimation here will consider that all properties are eligible.

IV.1 Costs and benefits of a PES for conserving Brazilian Amazon

Even though all the areas are considered as potential receiver of PES projects, it is assumed that PES will only target the areas under pressure of agriculture expansion. This paper is based on the *Sisgema* Model of land use change, developed by YOUNG *et al.* (2016).This model projects the deforestation by extrapolating the trend line of forest remnants for each of the 5570 Brazilian municipalities, including the 775 Amazon municipalities, given the most recent five-year period for which information on the stock of forest remnants is available[13]. By hypothesis, the format of the projected trend line is described by an inverse of an exponential function, parametrized for each municipality.

This paper proposes a 15-year PES program as a potential solution to curb the projected deforestation. The following steps deal with the methodological procedures for estimating the costs and benefits in terms of conserved carbon by such a policy.

The annual cost of implementing a PES program for conservation in the Brazilian Amazon can be estimated as follows in equation one:

$$TC = \sum_{i=1}^{775} C_i * A_{i,t} \quad \textbf{(1)}$$

TC = total annual cost of the PES per year;

C_i = average land opportunity cost in the municipality i (USD/hectare);

A_i = avoided deforestation in the municipality i in the year t.

The land opportunity costs (Ci) refers to the Environmental Statistic Database of the Environment Economic and Sustainable Development Research Group (SISGEMA), elaborated by Young (2016) to assist the Brazilian Ministry of the Environment in the decision-making on the implementation of a National PES Program. In that occasion, three different methodologies were carried out to estimate the land opportunity cost (Table 2), and Ci value reflects the average of these three methods.

[13] The information availability can vary from one biome to another.

Table 2. Summary of methodologies for estimating Land Opportunity Costs.

Model	Proxy Variable	Explanation
Profit-Model	Agricultural Profits (US$/Ha/Year)	C_i results from the estimation of the average profit per hectare/year of all land uses established in the municipality i.
Property-Price Model	Exogenous Rental Costs (USD/ha/Year)	Departing from the database of prices of properties sold in 2013 (ANUALPEC, 2014), the authors estimate the rental cost of one hectare of land in the municipality i. The rental cost was obtained by applying a discount rate of 6% per year over the rural property prices. This value for the discount rate reflects the average long –term interest rate in Brazil between 2006 and 2015
Econometric Model	Endogenous Rental Costs (USD/Ha/Year)	The authors estimated the property prices through an econometric model with the following dependent variables: agricultural potential; average slope and altitude; mean and standard deviation of rainfall of the period 2000-2013; mean and standard deviation of the temperature of the period 2000-2013; number of tractors in 2013; rural credit in 2013; road density (km / km2); cost of transportation to the nearest capital and cost of transportation to São Paulo. After that, the rental cost was obtained by applying a discount rate of 6% per year over the rural property prices.

Source: own elaboration

Originally, the values of C_i are expressed at 2013 prices. This paper updated the land opportunity costs values to 2016 prices using a deflator built up from the accumulated variation of agricultural GDP of each of the nine Amazon states from 2013 to 2016. In this sense, the updated value for the land opportunity costs in the municipality i equals C_i times the deflator referred to the GDP agricultural growth in the state it belongs (Equation 2). The hypotheses here is that land opportunity costs vary accordingly to the aggregate agricultural income, given by the variation of agricultural GDP.

$$\boldsymbol{C_{i,2016} = C_{i,d} * \rho_d} \quad \textbf{(2)}$$

$\boldsymbol{C_{i,2016}}$ = Land Opportunity Costs at 2016 prices;

$\mathbf{C_{i,d}}$ = average land opportunity cost in the municipality i (USD/Hectare) at 2013 prices;

$\boldsymbol{\rho_d}$ = agricultural GDP growth accumulated from 2013-2016 in the state d.

Thus;

$$\boldsymbol{TC = \sum_{i=1}^{775} C_{i,2016} * A_{i,t}} \quad \textbf{(3)}$$

So, the total cost of the 15- year PES program for conserving the Brazilian Amazon equals the Net Present Value of the sum of the annual costs given by equation 3, at a discount rate of 6% per year.

Regarding the environmental benefits, a PES program for conserving the Amazon is expected to yield a reduction in carbon emissions by dropping the pace of land clearing. The total stock of forest carbon conserved per year can be estimated as follows in equation 4.

$$\boldsymbol{TCE = \sum_{i=1}^{775} E_i * A_{i,t}} \qquad \textbf{(4)}$$

TCE = Total of forest carbon conserved per year;

E_i = average forest carbon density in the municipality i;

$A_{i,t}$ = avoided deforestation in the municipality I in the year t.

Thus, the benefit results from the sum of the stock of conserved forest carbon for the 15 years of validity of the program.

IV.2. Costs and benefits of a PES program for restoration of the Brazilian Amazon

The New Brazilian Forest Code (Law n. 12,651/2012) determines the legal limits of deforestation within private properties, establishing the minimum percentage to be conserved in each biome (Legal Reserve), as well as the areas that should be permanently conserved (Permanent Preservation Areas)[14]. This paper addresses the forest deficit areas (PPA and LR deficits) declared by the landowners under the New Brazilian Forest Code as potential recipients of PES for forest restoration of the Amazon region.

The PES costs in this situation include, besides the land opportunity cost (C_i), all the costs (L_i) related to fencing the area to be recovered, the transportation cost of inputs, the administrative costs of the reforestation projects, as well as the costs of revegetation[15] (Equation 4). The PES cost per year can be estimated through equation 5:

$$\boldsymbol{TRC = \sum_{i=1}^{775} (C_{i,2016} + L_{i,2006}) * F_{i,t}} \qquad \textbf{(5)}$$

$L_{i,2016}$ = sum of input and services costs needed to reforest 1 hectare of forest in the municipality i;

$F_{i,t}$ = recovered area in the municipality i in the year t.

[14] According to the Brazilian Forest Code, Permanent Preservation Areas are "protected area, covered or not by native vegetation, with the environmental function of preserving water resources, landscape, geological stability and biodiversity, facilitating the gene flow of fauna and flora, protecting the soil and ensuring the well-being of the human populations" (Law n. 12,651/2012, art. 30)

[15] For further information, see YOUNG *et al*. (2016).

Just like the land opportunity costs, L_i was originally estimated at 2013 prices. In order to bring the L_i to 2016 prices, its value was multiplied by the accumulated inflation index between 2013 and 2016.[16]

Once again, it will be considered a PES program lasting 15 years, therefore the costs of environmental restoration will be expressed in net present values at a discount rate of 6% per year.

The method for estimating the carbon captured will be very similar to those described in equation 4. However, the restored area ($\boldsymbol{F_{i,t}}$) in the municipality i in the year t will be multiplied by the factor of carbon capture of each municipality (equation 6).

$$\boldsymbol{K_t = \sum_{i=1}^{775} H_i * FD_{i,t}}$$

K_t = Captured carbon in the year t;

$H_{i,t}$ = captured carbon factor (tCO2/ha) in the municipality i ;

$FD_{i,t}$= Forest deficit recovered in the municipality “i” in the year “t

The total benefit of the PES results from the sum of the annual captured carbon over the 15 years of validity of the program.

IV.3. Funding capacity of the alternative financial mechanisms

As shown in section II, the environmental policy in Brazil has been facing a long-lasting insufficiency of public funding, especially devoted to the conservation and restoration of degraded areas. The ongoing fiscal crisis and the recent changes in the fiscal regime deepen even more the scarcity of financial resources, jeopardizing the continuity of crucial public policies for a satisfactory environmental performance in the country, such as the monitoring of deforestation and the management of conservation units by the competent administrative institutions.

Given this situation, this article proposes the three following sources of funding for the PSA projects aforementioned, all having in common their non-dependence on either the current public spending capacity or donations:

[16] In this case, there is no reason to believe that L_i would vary proportionally to the Agricultura GDP. L_i deals with input costs (fence, labor) and services costs (administration fees, transportation of inputs), which are at some degree indexed to past inflation.

i. **Taxation on carbon emissions**[17]: it is suggested a tax rate of USD 0.25 per tCO_2e, where the average emission of Greenhouse Gases (GhG) in the last decade in Brazil will be taken as a basis for estimating the fund-raising potential of this mechanism.

ii. **Taxation on forest deficit areas**: it is suggested an annual aliquot of USD 25.00 per hectare of deficit of Legal Reserve and Permanent Preservation Areas.

iii. **REDD+:** the potential of this mechanism results from the total stock of carbon conserved/captured times the price paid for the forest carbon in the market, which is around USD 5.1/tCO2, according to the last report on the state of the voluntary carbon markets, authored by HAMRIK & GALLANT (2018)**.** Furthermore, this paper will also present an estimative for the implicit price of carbon – i.e the price per ton of carbon that would be sufficient to make up to the conservation costs derived from the implementation of the PSA program in each of the Amazon municipalities.

The tax rates for the carbon and the forest deficit taxation were arbitrarily chosen at a relatively low level to show that, in some cases, even a very small aliquot can produce a consistent outcome in terms of conserved and restored area in the Brazilian Amazon. Still, the next section will also provide the conservation and restoration capacity of these mechanisms for a range of tax rate values. This exercise might help to guide the competent authorities to set the value for these rates given some conservation and restoration goals that they might want to target.

IV.4. Source of data and parameters

Table 3 summarizes the information on the required data of this paper, while Table 4 summarizes all the parameter used in this paper.

[17] This mechanism finds support in successful international experiences, such as the case of the PES program in Costa Rica, which the main source of funds comes from the taxation of 3.5% of fossil fuel sales (PAGIOLA, 2007).

Table 3. Required data and respective sources

Related topic	Required Data	Unit of measurement	Administrative Level	Source
Financial Costs	Land Opportunity Cost	R$/ha/year	Municipal Level	SISGEMA (n.d) /YOUNG (2016)
	Cost of forest recovering	R$/ha/year	Municipal Level	
Environmental Benefits	Forest Carbon Density	tCO2/ha	Municipal Level	
	Carbon Capture	tCO2/ha/year	Municipal Level	
Financial Sources' Potentiality	Carbon Emission	tCO2/ha	National Level	OBSERVATORIO DO CLIMA (n.d)
	Deficit of Legal Reserve	Hectare (ha)	Municipal Level	IMAFLORA (2017)
	Public Spending on Environmental Management	R$	Federal Level	SIOP (n.d)
Multiple Purpose	Deforestation rates	Hectare (ha)	Regional Level	INPE (n.d)

Source: own elaboration

Table 4. Parameters

Parameters	Value
Exchange Rate	R$ 4.00/USD
Discount Rate	6% per year
Tax on Carbon Emission	USD 0.25/tCO2e
Tax on Forest Deficit	USD 25.00/Ha
Forest Carbon Price	USD 5.10/tCO2e

Source: own elaboration

V. RESULTS

According to data from the Rural Environmental Inventory, the Brazilian Amazon states hold a forest deficit of approximately 5.7 million hectares, divided into 1.3 million hectares of APP deficit and 4.4 million hectares of RL deficit. By applying an annual tax of USD 25.00 on the hectare of forest deficit area, it would be possible to raise USD 141.3 million per year, which totals USD 1.4 billion within a 15 years length, at net present values. Given the spatial concentration of the forest deficit, the states of Mato Grosso, Pará and Tocantins would account for approximately 84.6% of the total resources generated by this mechanism (Table 5).

Table 5. Forest Deficit area and potential revenue from forest deficit taxation

State	APP Deficit (Hectare)	RL Deficit (Hectare)	Total Forest (Hectare)	NPV Tax Revenue
Acre	27,668	40,814	68,482	$17,625,396
Amazônas	20,292	15,253	35,545	$9,148,332
Amapá	983	51	1,034	$266,183
Maranhão	50,189	279,550	329,739	$84,865,627
Mato Grosso	480,733	2,370,452	2,851,185	$733,816,728
Pará	426,207	898,852	1,325,059	$341,033,731
Rondônia	71,652	354,748	426,400	$109,743,718
Roraima	8,634	2,371	11,005	$2,832,289
Tocantins	183,302	418,514	601,816	$154,890,786
Total	**1,269,659.63**	**4,380,605.22**	**5,650,264.85**	**$1,454,222,790**

Source: own elaboration based on Imaflora (2017)

The funding raising capacity from carbon emission taxation is even higher. Considering the average emissions of greenhouse gases in Brazil during 2008-2017, and applying a tax rate of USD 0.25 / tCO2e, it would be possible to raise more than USD 397.3 million per year, which in fifteen years would result in USD 4.1 billion at net present values (Table 6). Just to put this into contexts, the potential revenue from carbon taxation in one single year represents approximately 51.1% of the total resources made available by the federal government for environmental management in 2017.

It is important to emphasize that the sectors that would most contribute to this tax collection are those associated directly and indirectly to the deforestation process. The land use change sector, where the emissions mainly come from the "slash-and-burn" strategy of converting forest into pastures or agricultural land, would account for 32.6% of the total tax collected, followed by the agricultural sector, which would account for other 30.3%. The agricultural sector is the main beneficiary of the deforestation process in the Brazilian Amazon and the second largest GHG emitter, given the large methane emission from enteric fermentation of cattle (OBSERVATÓRIO DO CLIMA, 2017).

Table 6. Average Emission by sector and potential revenue from carbon taxation

Sector	Average GhG Emission (2008-2017)	Tax Revenue/Year	NPV Tax Revenue (2016-2030)
Energy	412,563,112	$103,140,778	$1,061,823,994
Agriculture	481,203,665	$120,300,916	$1,238,485,902
Industry	95,594,652	$23,898,663	$246,034,345
Waste Management	81,233,507	$20,308,377	$209,072,707
Land Use Change	518,694,908	$129,673,727	$1,334,978,052
Total	**1,589,289,843**	**$397,322,461**	**$4,090,395,000**

Source: Own elaboration.

The Pigouvian tax not only can help to finance environmental policies to offset the negative externalities but can also encourage the adoption of practices that are less damaging to the environment. For instance, the agriculture sector, facing the obligatory payment for GHG emissions, might choose to adopt new technologies and practices to achieve higher production levels without promoting additional deforestation. By changing the amount of CO_2e emitted, an eventual improvement in the technology or an eventual reduction of deforestation due to – let's say - the adoption of a conservation PES program, would change the revenue from carbon taxation and therefore the capacity of this mechanism for financing environmental policies. Funding environmental policies through externality taxation bring to the table an apparent countercyclical behavior which determines that the worse one performs in environmental terms, the more money becomes available for compensatory policies, while the improvement of environmental conditions results in reducing upcoming financial resources. This does not imply that taxation is not desirable[18], but it stresses the importance of building up environmental policies from a range of financial mechanisms. In addition, it should be noted that the results presented in this section do not depart from projections for the Brazilian emissions or the Forest Deficit. This paper does not attempt to show how the trajectory of resources from tax on undesirable environmental outcomes would change over time. Instead, this paper aims to show what could be done given the current potential of the suggested financial mechanisms.

V.1 Costs and benefits of a PES program for conserving Brazilian Amazon

The *Sisgema* model projects a deforestation of 9.8 million hectares in the Brazilian Amazon between 2016 and 2030 (Table 7). About 78.1% of the projected deforestation is concentrated in the states of Mato Grosso, Maranhão, Tocantins. Most of the land use change projected in these states will take place in the Brazilian Cerrado, a biome heavily under pressure by the rapid advance of intensive production of soybeans in recent decades, that has been taking over old and degraded pastures and moved the cattle herds toward the forested areas (ALVARENGA JR., 2014). The state of Pará responds for additional 14% of the projected deforestation, which means that 92.1% of the total deforestation in the period is expected to occur only in four of the nine states of the Brazilian Amazon.

[18] Indeed, the Pigouvian Tax is one of the available instruments for internalizing the social costs of projects, or in other words for internalizing the negative externalities.

Table 7. Projected Deforestation from 2016 to 2030 according to *Sisgema* Model.

State	Deforestation
Acre	106,457
Amazônas	210,833
Amapá	20,362
Maranhão	2,201,550
Mato Grosso	3,394,376
Pará	1,370,686
Rondônia	342,744
Roraima	88,724
Tocantins	2,051,333
Amazon	**9,787,065**

Source: own elaboration based on *SISGEMA (n.d) database*

Table 8 presents the descriptive statistics of the opportunity cost of land originally estimated by Young *et al*. (2016) and updated in this article. The Amazon municipalities have an average land opportunity cost of USD 55.22 per hectare/year. The median value reveals that a PES of USD 46.58 per hectare/year could compensate the agricultural monetary yields agricultural in half of the Amazon municipalities.

Table 8. Descriptive Statistics for the land opportunity costs in the Brazilian Amazon (at 2016 prices).

Variable	Mean	Median	Standard Deviation
Land Opportunity Cost	$ 55.22	$ 46.58	$ 35.09
Land Opportunity Cost (NPV)	$ 568.52	$ 479.58	$ 361.27

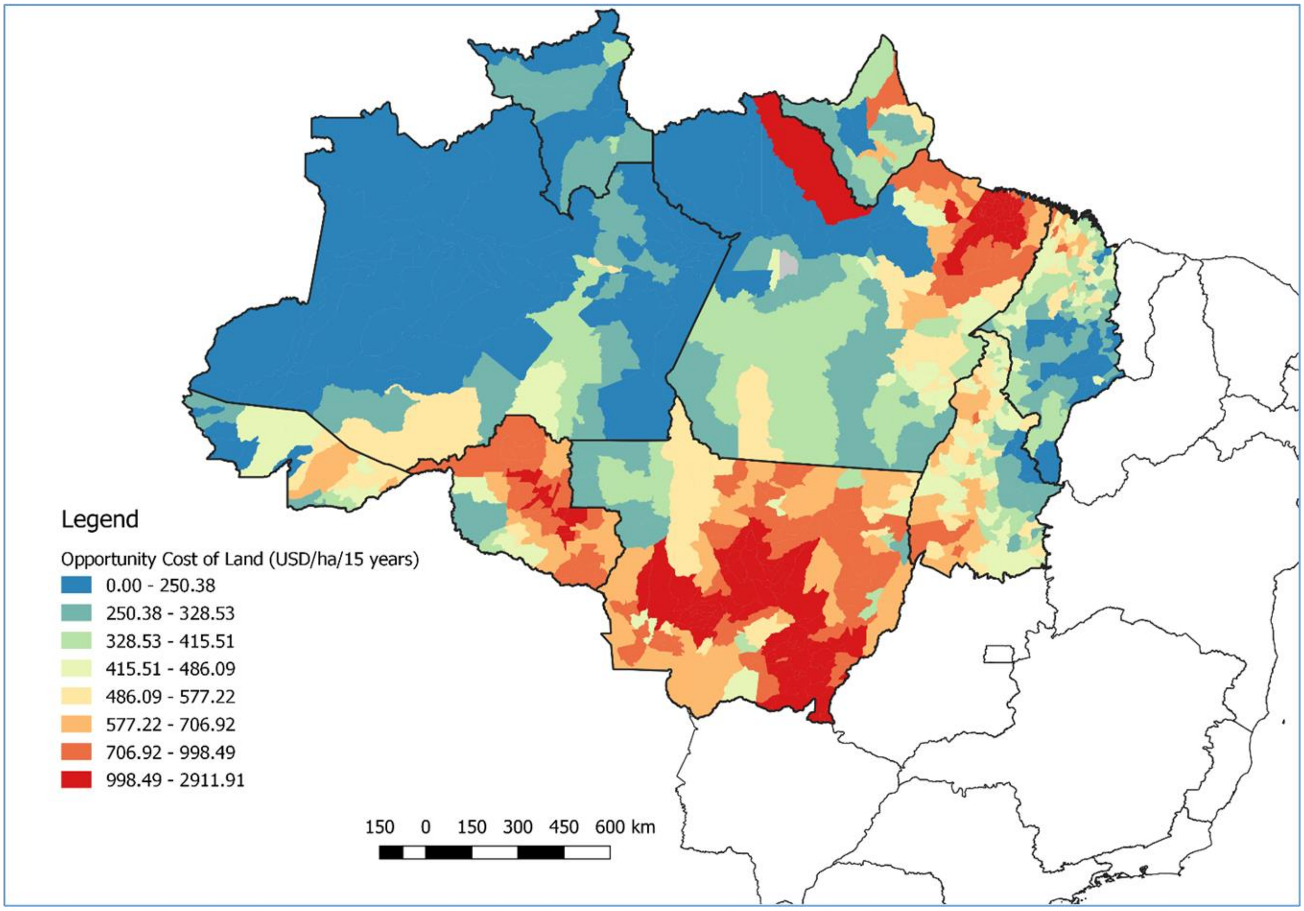
Source: Own elaboration based on SISGEMA (n.d) database

The low opportunity cost of land in the Amazon[19] reveals a window of opportunity for the implementation of conservation policies at a low cost. Map 1 shows the spatial distribution of the net present value of the costs of a 15-year PES program for conserving the Brazilian Amazon. The costsrange from USD 16.30/hectare in the extensive ranching areas in the interior of the Amazonas state,

[19] Despite the advance of mechanized soybeans over the Amazon region, the land use change in this region is manly motivated to accommodate the increasing cattle herd. According to INPE (2016), until 2014, only 5.9% of the deforested area in the Brazilian Amazon became cropland, while 63% gave place to pastures. Many studies draw the attention to the extensive pattern of ranching in the Amazon Region, such as QUEIROZ (2008), YOUNG et al (2007), ALVARENGA JR. (2014). More recently, SOARES-FILHO *et al.* (2015) pointed out that the productivity of pastures in the Amazon region is around 0.8 animal units per hectare. This low productivity leads to the low average profitability per hectare in the Amazon, and thus to the low opportunity cost of land in this region.

to USD 2,911.11/hectare in the areas of planted forest for pulp and paper production in the north of Pará state. On average, the highest costs of conservation occur in the state of Mato Grosso[20], in the intensive and mechanized areas of grain production (especially soybean) for exportation.

Map 1. Spatial Distribution of Land Opportunity Cost – Net Present Value



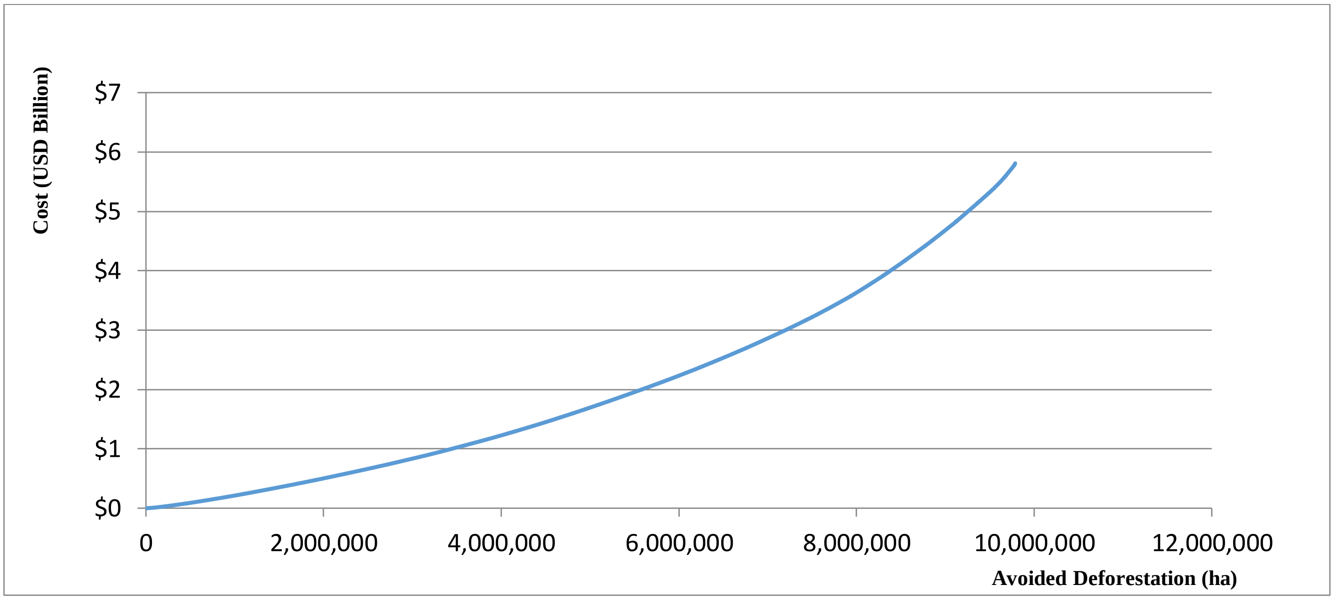
Source: own elaboration based on *Sisgema* (n.d) *database*.

The graph 5 presents the total cost of a 15-year PES program to tackle the expected deforestation in the period 2016-2030. The total costs vary accordingly to the area of avoided deforestation (i.e. the areas that would be receiving the PES program). With USD 5.8 billion it is theoretically possible to clear all the projected deforestation, leading to an avoided emission of 3.4 GtCO2e. Assuming that this stock of conserved carbon would be traded at USD 5.1/tCO2e (Table 4), it would be possible to generate around USD 17.4 billion through the REDD+ mechanism. Alternatively, assuming a PES program paying up to the median land opportunity cost (USD 46.58 per hectare/year), it would be possible to

[20] The state of Mato Grosso has a average land opportunity cost of USD 840.08 as net present values over 15 years. This is 47.9% higher than the average of the land opportunity costs of the Brazilian Amazon as a whole.

avoid deforestation in 4.6 million hectares at a total cost of USD 1.5 billion. In this case, approximately 1.9 GtCO2e would be conserved, and around USD 9.5 billion could be raised in REDD+ market. It is worth mentioning that in both cases the value of conserved carbon is much higher than the cost of implementing the PES itself. This fact reflects, on the one hand, the low profitability of the predominant land uses in the Amazon, and on the other, the high carbon density in this region locations, especially in the Amazon rainforest.

Graph 5. Costs of avoiding deforestation – in net present value



Source: own elaboration based on *Sisgema* (n.d) *database*.

The graph 5 also reveals how many hectares of deforestation could be avoided with the resources raised by forest deficit taxation and carbon taxation.

According to table 9, an aliquot of USD25.00/hectare of forest deficit would result in more than USD 1.4 billion within 15 years. This amount could pay for the conservation of 4.5 million hectares. In this case, the reduction of deforestation would prevent the release of approximately 1.9 GtCO2e in the atmosphere, capitalizing around USD 9.5 billion in the REDD+ market.

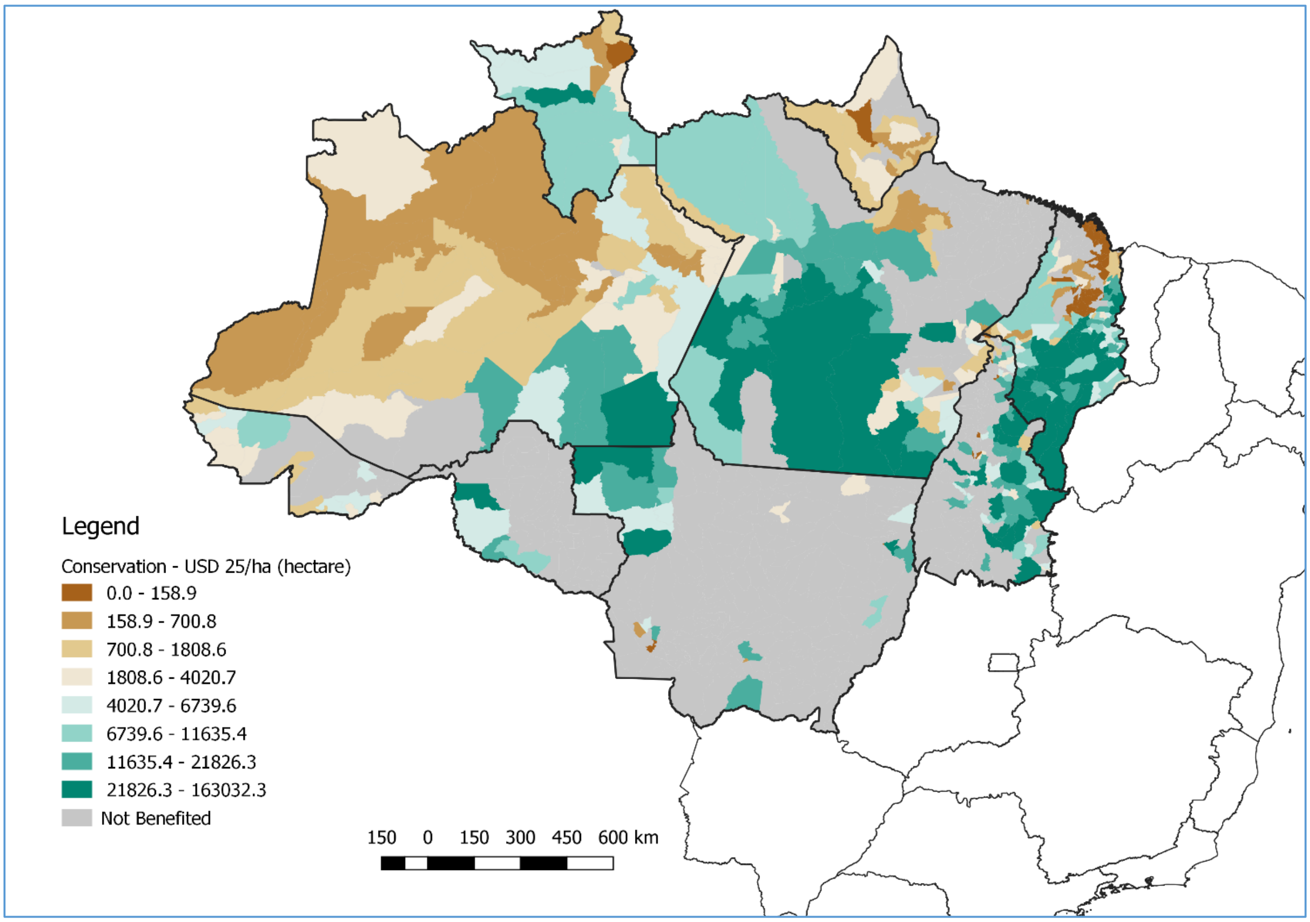
Table 9. Funding capacity of Forest Deficit taxation avoided deforestation and stock of conserved carbon

Tax on Forest Deficit	Total Revenue	Avoided Deforestation (Ha)	Carbon Conserved (tCO2e)	Value of the Carbon Conserved
	$1,454,222,790	4,508,865.68	1,854,959,648.68	$9,460,294,208

Source: own elaboration based on IMAFLORA (2017) and *SISGEMA* (n.d) *database*

Map 2 shows what areas would benefit from a PES program funded by a tax of USD 25.00/hectare of forest deficit. The Land opportunity costs were ordered from the lowest value to the highest, and the resources collected from the taxation of the forest deficit areas were allocated to the municipalities with the lowest PSA implementation cost (i.e., lowest opportunity cost of land). As expected, the benefited areas are precisely those where livestock still predominate, notably in its extensive form. For this reason, most of the avoided deforestation would take place in the states of Pará and Amazonas, besides the eastern part of Tocantins and southern part of Maranhão.

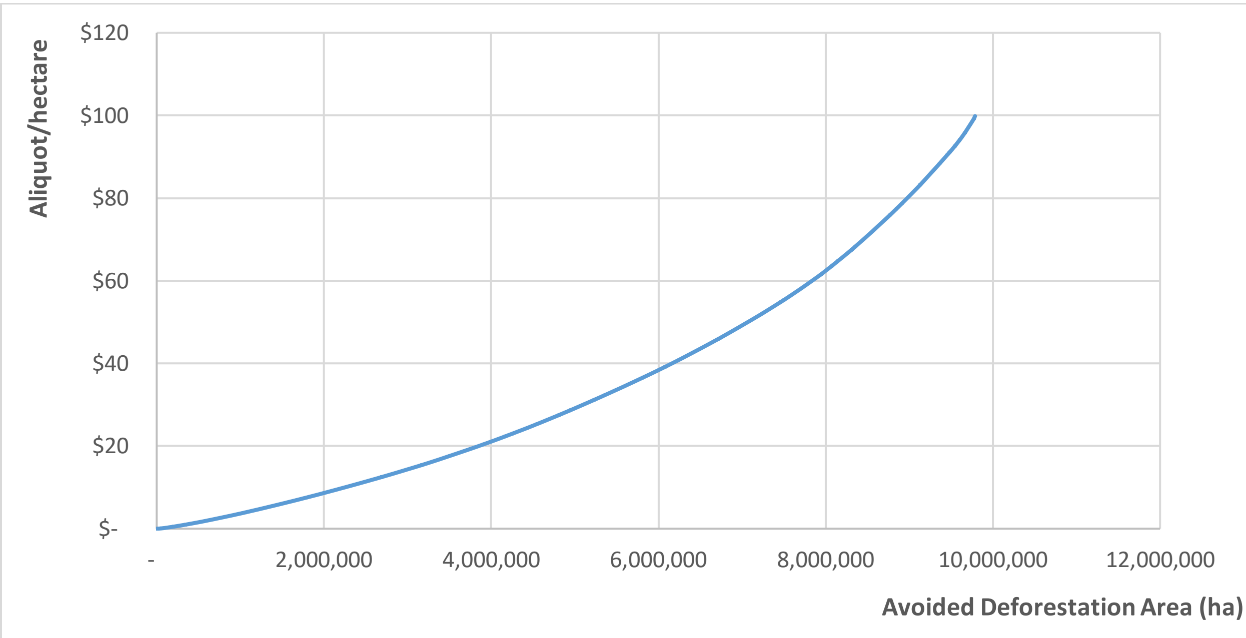
Map 2. Avoided Deforestation areas resulting from a tax of USD 25.00/hectare of forest deficit



Source: own elaboration based on *Sisgema* (n.d) *database*.

The aliquot chosen in this study is arbitrary. However, the competent authorities could pick any other value for it. However, changes in the aliquot would lead to changes on the financing capacity of this mechanism to support a PES program, and thus on the avoided deforestation area and on the stock of carbon conserved as well. Graph 6 shows how the avoided deforestation and the aliquot are related to each other. One can notices that an aliquot of approximately USD 100.00 would be theoretically sufficient to avoid all deforestation projected for the Amazon.

Graph 6. Forest Deficit Aliquot and Avoided Deforestation



Source: own elaboration based on *SISGEMA* (n.d) *database*

The fund-raising capacity of carbon taxation is estimated at USD 4.1 billion within a 15 years period. This amount of resource would be enough to pay for the conservation of 8.5 million hectares, preventing 3.1 GtCO_2e for being released into the atmosphere. The market value of the conserved carbon, in this case, exceeds USD 15.9 billion (Table 10).

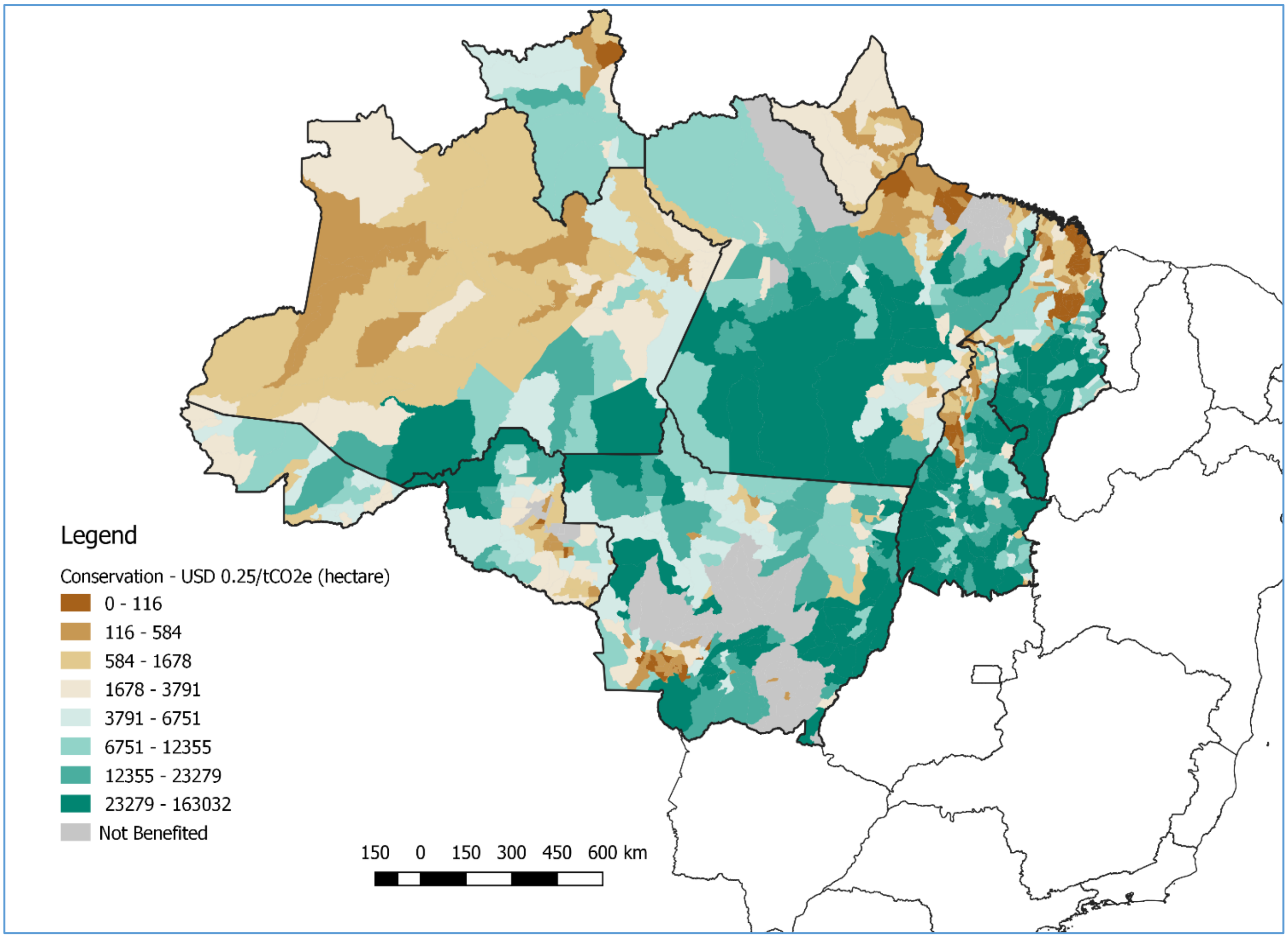
Table 10. Funding potential of Carbon taxation, avoided deforestation and stock of conserved carbon

Tax on Carbon Emission	Total Revenue	Avoided Deforestation (Ha)	Carbon Conserved (tCO2e)	Value of the Carbon Conserved
	$4,090,395,000	8,469,288	3,122,863,348	$15,926,603,076

Source: own elaboration based on SEEG and *SISGEMA* (n.d) *database*

In this case, the PES would be effective to avoid 86,5% of the projected deforestation, and the remaining deforestation would take place only in the belt of soybean production in the center of Mato Grosso state, and in the forest planted areas in the north of Pará (Map 3).

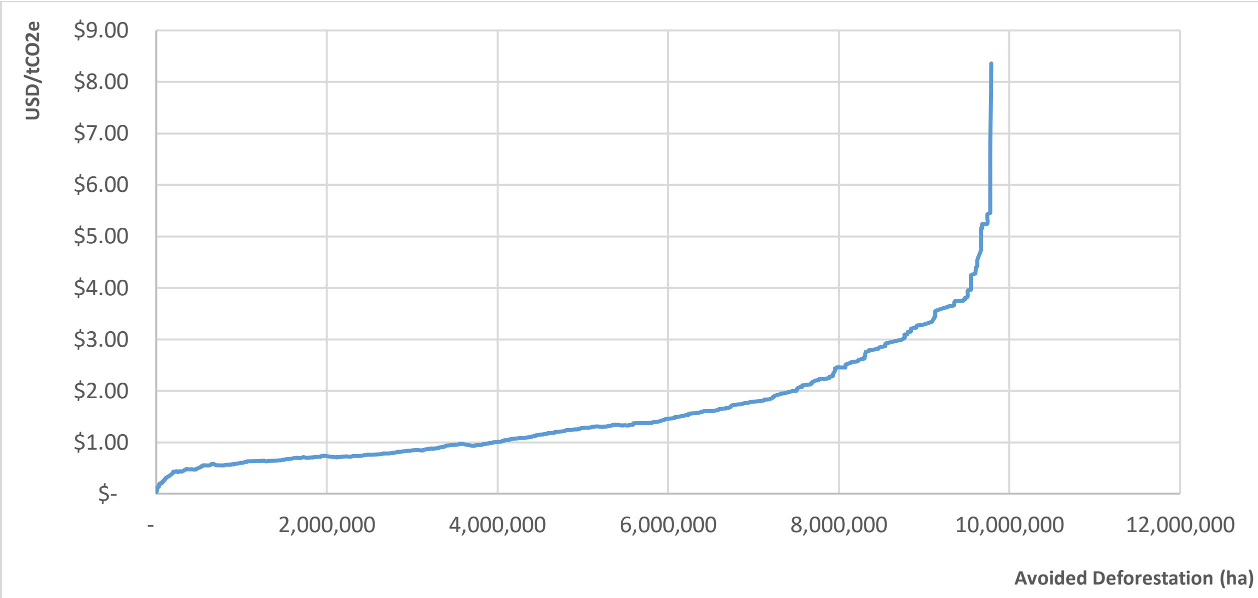
Map 3. Avoided Deforestation Areas resulting from a tax of USD 0.25/tCO_2e.



Source: own elaboration based on *Sisgema* (n.d) *database*.

Besides, REDD+ can also directly contribute to raising funds to pay for Amazon conservation. Assuming that the stock of conserved carbon can be traded in a forest carbon market, conservation might equal the monetary returns of alternative land uses, providing that the prices per tCO_2e are sufficiently high. In other words: at a certain price for the tCO_2e, the value of total conserved carbon in one hectare can be worth at least as much as the land opportunity cost. In such situations, REDD + would become a strategy at least as profitable as the alternative land uses, leading landowners to voluntarily commit themselves to conservation strategies. Graph 7 shows the avoided deforestation area as a result of a range of carbon prices.

Graph 7. Conservation supply curve and carbon pricing



Source: own elaboration based on *SISGEMA* (n.d) *database*

There are two different ways to look at this graph. The first one is to assume that the REDD+ project would pay a unique price for the carbon ton, let's say USD 5.1/tCO2e. In this case, it would be possible to avoid around 9.7 million hectares of deforestation, and all the landowners able to profitably avoid deforestation at a price lower than USD 5.1/tCO2e would be capturing "*a 'provider surplus', i.e. the difference between the market price and their individually lower costs of supplying REDD*". (BÖRNER & WUNDER, 2008: p.504-505). And the other way is to assume that the REDD+ project would pay differentiated prices for the tCO_2e, according to the land opportunity costs in each locality. Once again, by paying up to USD 5.1/tCO2e it would be possible to conserve 9.7 million hectares, but no provider surplus would be appropriated by the landowners. As a result, even though both REDD+ projects produce the same outcome in terms of avoided deforestation and carbon emissions, the latter alternative would be cheaper than the former (Table 11)

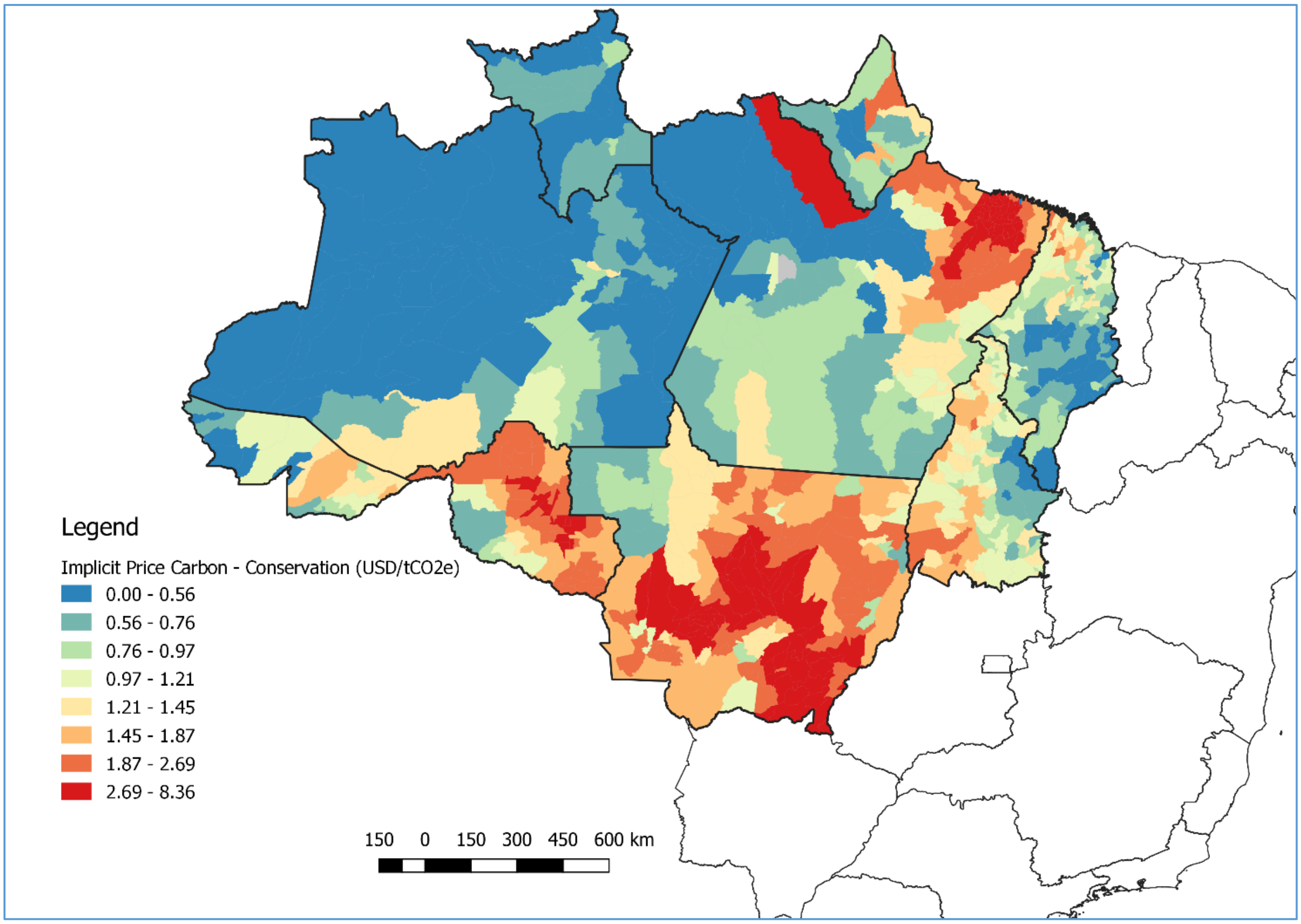
Table 11. REDD+ outcomes in the Brazilian Amazon

Carbon Pricing	Avoided Deforestation (ha)	Avoided Emissions (tCO2e)	Total Cost
Unique Price (USD 5.1/TCO2e)	9,667,146	3,381,204,915	$ 17,244,145,065
Differentiated Price (≤ USD 5.1/tCO2e)	9,667,146	3,381,204,915	$ 5,808,356,771

Source: own elaboration based on *SISGEMA database*

Finally, map 4 shows the implicit carbon prices for all the municipalities of the Brazilian Amazon. The values tend to be higher in the Mato Grosso state, not only because of the higher land opportunity costs but also because of the lower carbon density in the Cerrado enclaves there.

Map 4. Minimum carbon prices to induce conservation



Source: own elaboration based on *SISGEMA database*

V.2 Costs and benefits of a PES program for forest restoration in the Brazilian Amazon

Table 12 presents the descriptive statistics of the restoration costs per hectare in the Brazilian Amazon. The average restoration cost, in this case, is USD 4,106/hectare, while the median cost is USD 3,709/hectare. As one can notice the restoration costs are consistently higher than the costs of conservation (i.e. the NPV of the land opportunity cost) presented in the *subsection V.1*, which means that the expenses related to seedling, transporting the inputs, fencing the area, and administrating the projects are substantial.

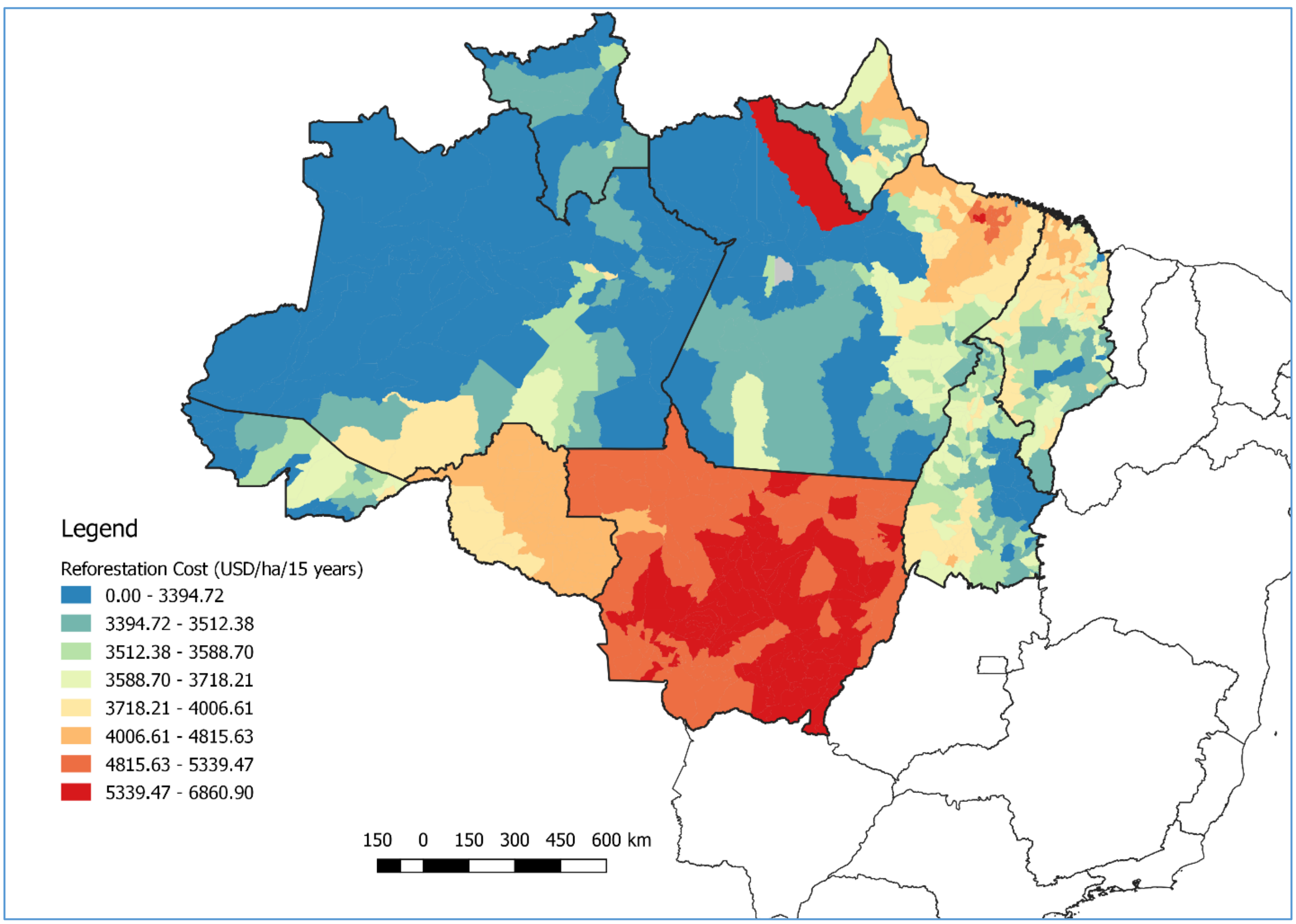
Table 12. Descriptive Statistics for the restoration costs in the Brazilian Amazon

Variable	Mean	Median	Standard Deviation
Restoration Cost (NPV in USD/ha)	$ 4,106	$ 3,709	$ 856

Source: own elaboration based on *SISGEMA* (n.d.) *database*

The spatial distribution of the costs of a 15-year restoration PES program is quite similar to the distribution of the PES program for conservation. Once again, the highest costs concentrate in the intensive grain production areas, for which the land opportunity costs are higher. Furthermore, the highest costs of labor in the state of Mato Grosso reinforce the distribution pattern (map 5).

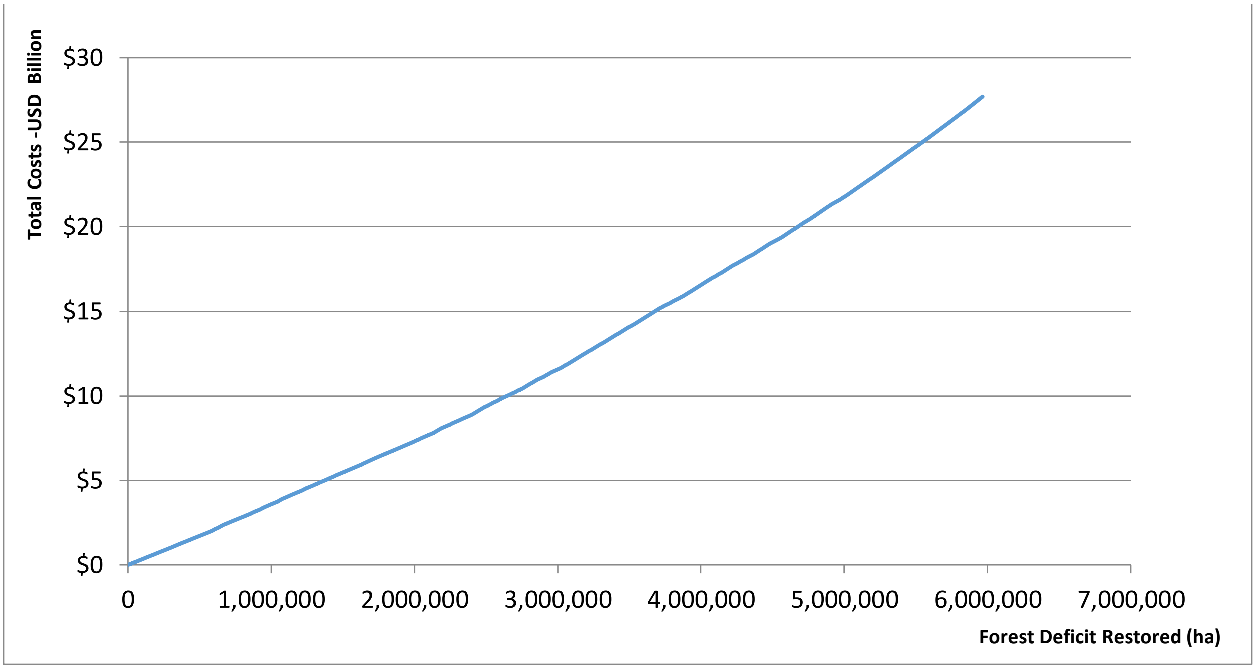
Map 5. Spatial Distribution of Restoration Costs – Net Present Value



Source: own elaboration based on *SISGEMA* (n.d) *database*

The difference between restoration and conservation costs becomes even more apparent when considering the accumulated costs involved in each of these strategies. A 15-year PES program to restore all the forest deficit area of the Brazilian Amazon would cost USD 27.7 billion, showing that the demand for financial resources is much higher in this case, especially given the fact that the area to be recovered is almost half the size of the projected deforestation area.

Graph 8. Total Restoration Cost in the Brazilian Amazon – in Net Present Value

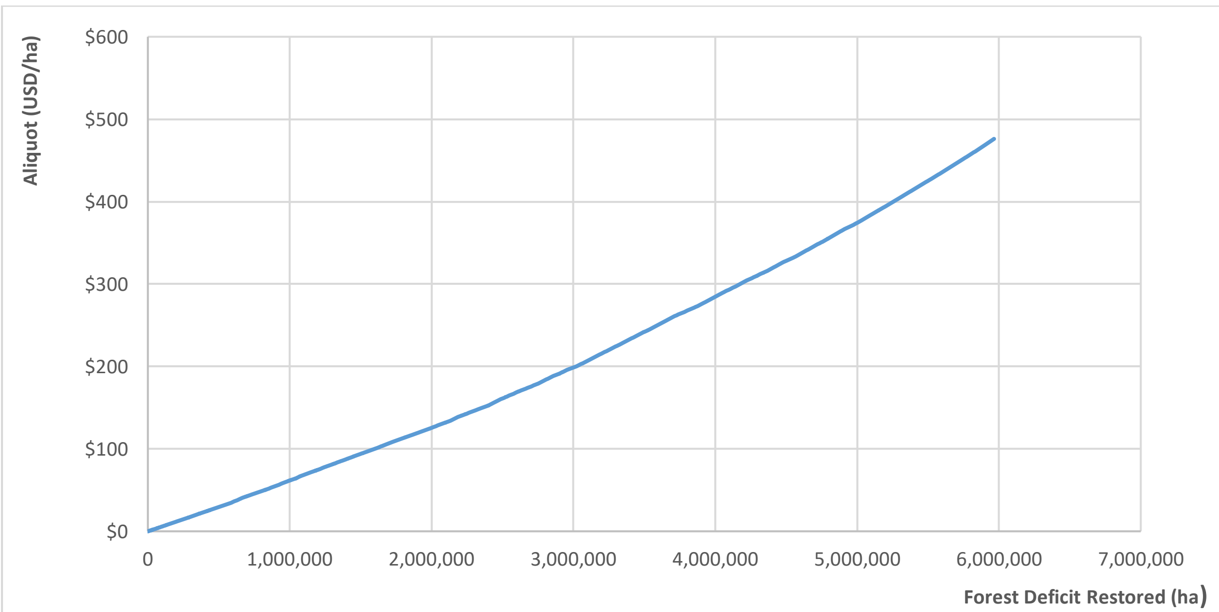


Source: own elaboration based on *SISGEMA* (n.d) *database*

In this situation, the amount collected through the taxation of Forest Deficit areas is highly insufficient to make a great difference. It is important to mention that the total forest deficit varies over time according to two opposite forces: (i) the restoration of old forest deficit areas; (ii) the share of deforestation rates that exceeds the legal limits imposed by the Forest Code (i.e. the deforestation that constitutes new deficits of Permanent Preservation Areas or new deficit of Legal Reserve). In this specific point, for simplification purpose, let's assume that these forces cancel one another, and the forest deficit remains stable. In this case, the USD 1.4 billion collected by this mechanism could only afford the restoration of 7.2% of the current forest deficit, leading to a stock of captured GHG of 0.13 $GtCO_2e$.

Of course, an aliquot could be raised in order to comprise a larger area, however in order to finance the restoration of 5.6 million hectares (the current forest deficit area) the aliquot should be set at USD 476.12/hectare/year (Graph 9), which within 15 years totals a payment of USD 4901.60/hectare (at net present value). An aliquot like this is very unlikely to be implemented, not only because of political constraints but also because the Forest Code itself provides the possibility of offsetting forest deficit areas by the acquisition of Environmental Reserve Quotas (CRA's)[21] from landowners with forest surplus in their properties. YOUNG & ALVARENGA JR. (2017) estimated the average price for 15-year quota in the Amazon biome at USD 863.25, while the average price in the Cerrado is USD 770.00. In both cases, the acquisition of Environmental Reserve Quotas would be cheaper than the payment of the forest deficit tax.

Graph 9. Forest Deficit Aliquot and Restored Area

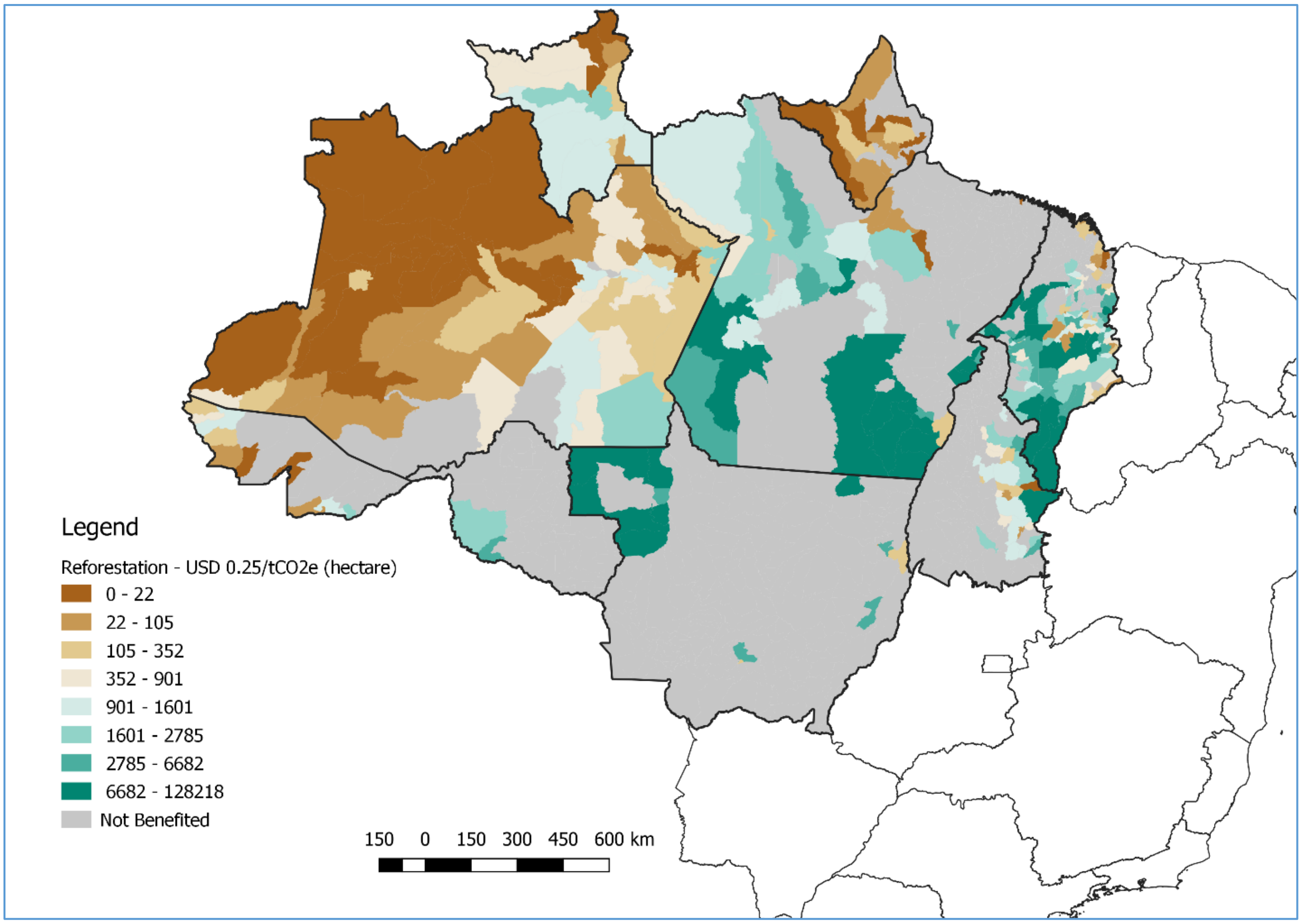


Source: own elaboration based on *SISGEMA* (n.d) *database*

The tax on carbon emissions seems to be more promising to finance a PES for restoration. At USD 0.25/tCO_2e it is possible to pay for restoring 1,1 million hectares, with most of this area taking place in the Pará, Maranhão and Amazonas states (Map 6.)

[21] CRA is title representing one hectare of existing native vegetation or native vegetation in the process of recovery that "may be transferred, onerously or free of charge, to an individual or legal entity governed by public or private law, upon an agreement signed by the CRA holder and the acquirer" (BRAZIL, 2012).

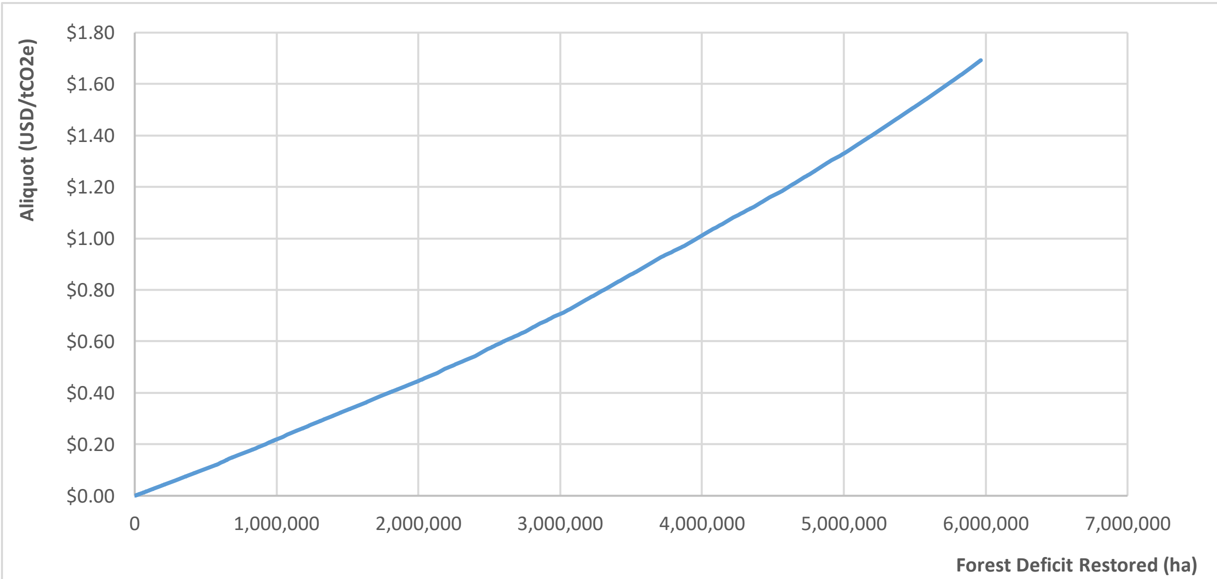
Map 6. Forest Deficit restored areas resulting from a tax of USD 0.25/tCO_2e.



Source: own elaboration based on *SISGEMA* (n.d) *database*

By increasing the aliquot up to USD 1.00/tCO_2e that would result in a USD 16.4 billion in tax revenue in 15 years, which is enough to pay for restoring around 4.0 million hectares of forest deficit in the Brazilian Amazon. In order to restore all the forest deficit areas, the tax on carbon should be implemented at an aliquot of 1,69/ tCO_2e (Graph 10), which is still feasible in view of carbon market prices.

Graph 10. Carbon tax aliquot and Restored Area



Source: own elaboration based on *SISGEMA* (n.d) *database*

Table 13 summarizes the fund-raising capacity, the potential restoration area, as well as the amount and value of the captured carbon for each of these aliquots.

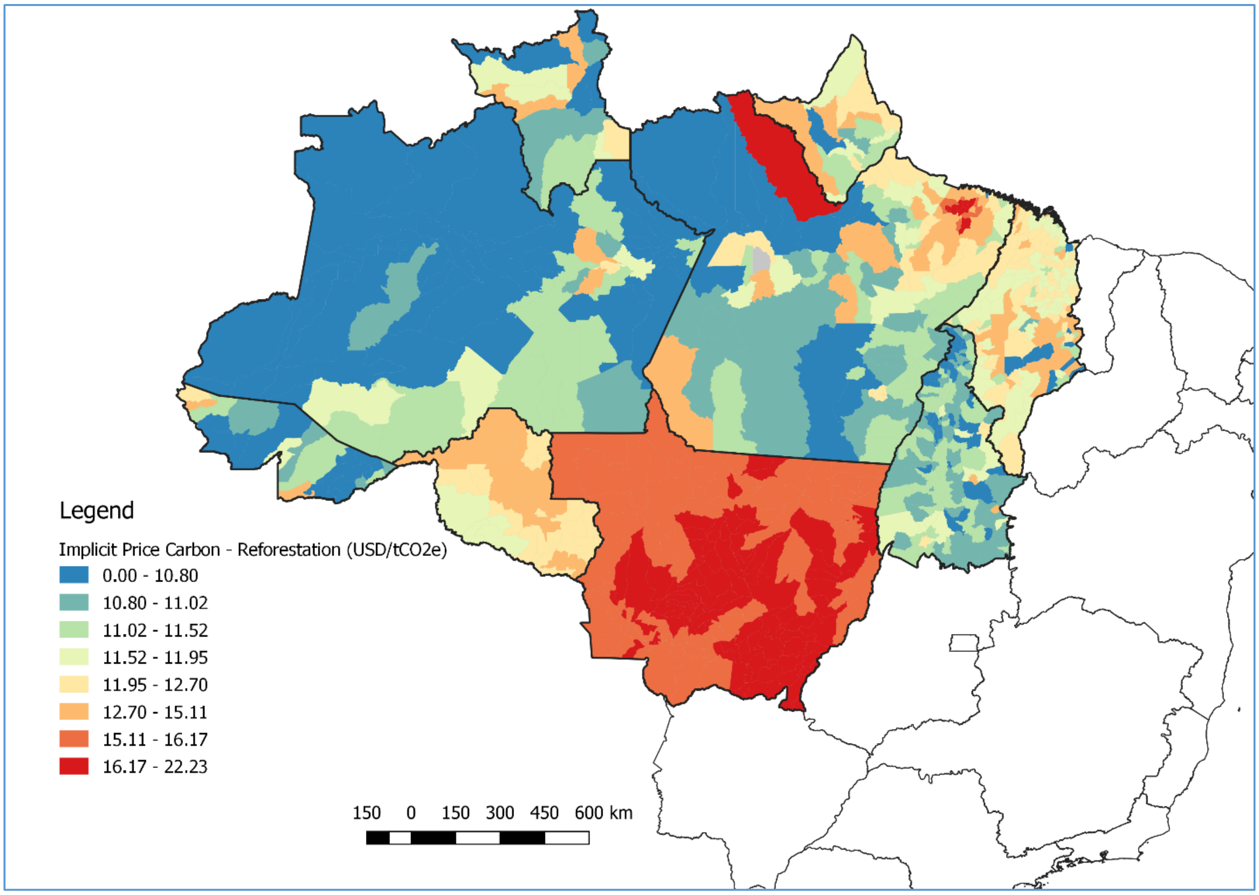
Table 13. Carbon Taxation outcomes in the Brazilian Amazon

Aliquot	Tax Revenue (15 years)	Restored Area (ha)	Carbon Captured (ton)	Value of the Carbon Captured
USD 0.25/tCO2e	$ 4,090,395,000	1,132,383	363,571,891	$ 1,854,216,647
USD 1.00/tCO2e	$ 16,361,580,002	3,964,440	1,316,398,585	$ 6,713,632,782
USD 1.69/tCO2e	$ 27,695,093,117	5,965,522	1,841,332,372	$ 9,390,795,097

Source: own elaboration based on *SISGEMA database*

Finally, REDD+ could also assist in the provision of financial resources for forest restoration. The graph 11 reveals at what price the ton of carbon captured from forest deficit restoration should be transacted in order to cover all the restoration expenses. The values range from USD 7.64/tCO_2e, in the interior part of the Amazonas state, up to USD 22.22/tCO_2e in the north of Pará. On average, the state of Mato Grosso requires the highest prices for carbon in order to pay for the forest restoration.

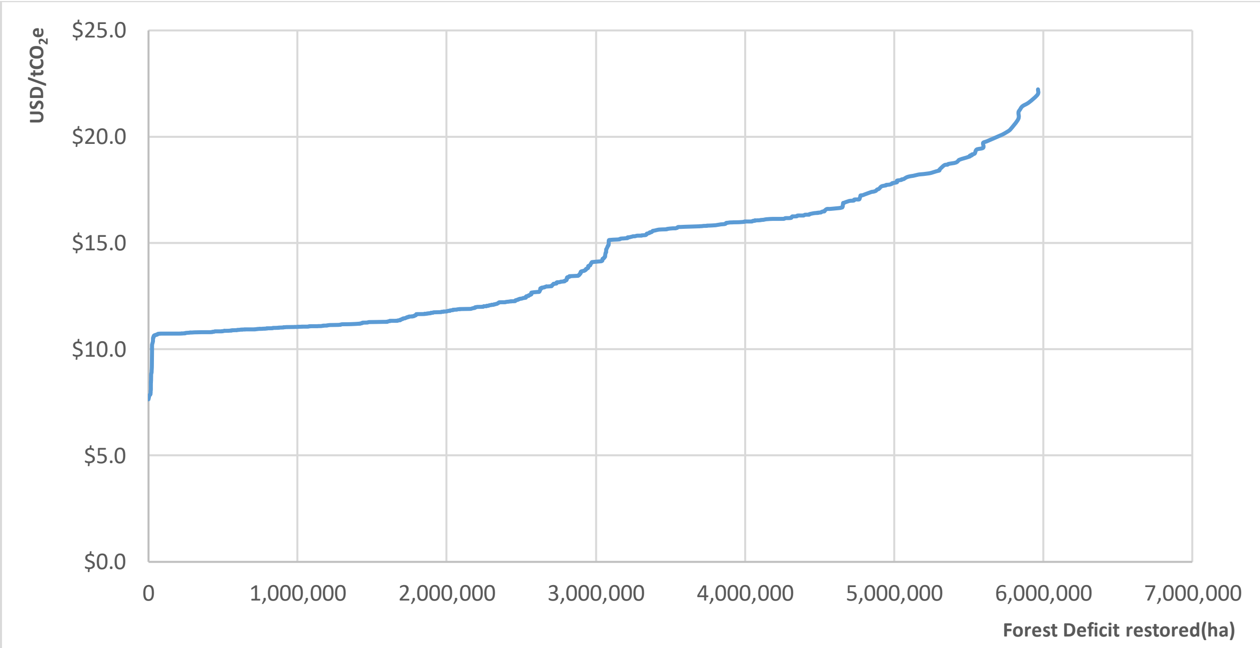
Map 7. Minimum carbon prices to induce forest deficits restoration



Source: own elaboration based on *SISGEMA* (n.d) *database*

At the price of forest carbon reported on the **State of the Carbon Markets**, no restoration would be possible. As mentioned in the previous paragraph, the bottom limit for the carbon price is around USD 7.64/ tCO_2e. However, at a price of USD11,90/ tCO_2e, it would be possible to meet the restoration costs of half of Amazon municipalities, leading to a restored area of 2.1 million hectares and a total of captured carbon of 0.4 $GtCO_2e$. In order to clear all the forest deficit, the carbon price should be transacted at USD 22.22/ tCO_2e.

Graph 11. Restoration supply curve and carbon pricing



Source: own elaboration based on *SISGEMA database*

VI. CONCLUSION REMARKS

This article proposed two PES programs as a means of strengthening conservation and restoration policies in the Brazilian Amazon in a context of deep fiscal crisis, that has been deepening the historical trend of insufficiency of public resources for funding the environmental policies. The great advantage of implementing a PES program in such scenario derives from the possibility of funding it through multiple sources of financial resource.

The cost of the PSA program for conservation for the Legal Amazon has been proved to be relatively inexpensive, largely reflecting the predominance of extensive land use in that location. With approximately USD 5.8 billion dollars it would be possible to avoid all the 9.8 million of deforestation and the release of 3.4 $GtCO_2e$ projected until 2030. The required financial resources could be collected by establishing an aliquot of USD 99.95/hectare of forest deficit or an aliquot of USD 0.35/ tCO_2e emitted, or at a price of USD 8.36/tCO_2e conserved to be traded in an eventual REDD + market.

The costs of PES for restoring the 5.9 million hectares of forest deficit were estimated at USD 27.7 billion by 2030, resulting in a captured carbon stock of 1.8$GtCO_2e$ over the 15-year period. This costs involved in the PES for restoration is about 4.8 times the cost of the conservation PES, although the restored area is 41% smaller than the avoided deforestation area. Funding for this program could also be provided by the suggested financial mechanisms, although the taxation of the deficit area proved to be ineffective as a source of funds. Estimates have pointed out that it is possible to restore the whole forest deficit area in the Brazilian Amazon by applying an aliquot of USD 1.69/ tCO2e emitted, or at a price per ton of carbon dioxide captured of USD 22.22.

Furthermore, it is important to stress the difference between the PSA costs of conservation and restoration. On the one hand, this difference represents a proxy for ecosystem services lost through forest conversion, on the other, it reveals the cost of inaction regarding the expanding deforestation. In other words it is consistently cheaper to pay for conserving today, than spending on restoration in the future.

Finally, the results found in this paper has shown that the value of the benefit (conserved carbon) derived from the PES for conservation largely exceeds the cost of implementing such a program. This is not true for the PES for restoration, at least given the current carbon market prices. However, this does not mean that this program should not be implemented. It only means that the value of the captured carbon is not sufficiently high to compensate for the costs of implementing the program. The decision, in this case, needs to be supported by a more comprehensive analysis regarding the positive outcomes in terms of other ecosystem services that were not mentioned here, such as biodiversity, soil protection, water provision, pollination, rain regulation and so on.

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