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Overview of Possible Causes of Forest Destruction in the Legal Amazon: A Literature Review

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Authors' contributions

This work was carried out in collaboration among all authors. Author JR was the creator of the review, the main guidelines and made the majority of the article. Authors VSO, JVGS and WRS worked on the Agriculture part. Authors BAS and ASL worked on Livestock part of the work. Authors JAA, AGB and MAAA were divided and collaborated with the rest of the review. All authors read and approved the final manuscript.

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ABSTRACT

The work is a literature review whose objective was to identify in the literature the approach on the main causes of forest destruction in the legal Amazon. For the discussion, scientific materials were selected whose focus includes deforestation in the region of the legal Amazon. Among the possible causes, the ones that stood out the most in the literature were livestock, agriculture, mining, mining and burning, so a discussion was made on them. It is clear, after all the surveys, that there is no single solution to destruction and deforestation in the Amazon. If the Brazilian government, with the help of the international community, does not take control of the forces of destructive development seriously, then, regardless of periods of growth and reduced deforestation, this magnificent rainforest will continue disappearing decade after decade. A series of measures is necessary, ranging from prevention to incisive combat, mainly by the government, which should expand and reinforce the activities of the entities responsible for environmental inspection in the country.

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1. INTRODUCTION

The Amazon is the most extensive forest on the planet, distributed over an area of approximately 6.3 million km², covering countries such as Brazil, Peru, Colombia, Ecuador, Venezuela, Bolivia and Guyana. The part that covers the Brazilian territory is about 5.5 million km², being known as Legal Amazon or Brazilian Amazon; the states that make up the legal Amazon are: Acre, Amapá, Amazonas, Pará, Rondônia, Roraima and Tocantins, as well as parts of Mato Grosso and Maranhão [1].

Deforestation is a practice that has been impacting the Amazon rainforest for many years. In Brazil, deforestation in the Amazon is estimated annually by the government through the PRODES-INPE Project (Project for Monitoring Deforestation in the Legal Amazon - National Institute for Space Research). According to PRODES, it is observed that, after a long period, unrestrained deforestation extended with an average rate of 2x104 km^2 $year^{-1}$, declining dramatically in recent years to previously unobserved levels, of approximately 1,4x104 km² per year, mainly due to the intensification of public policies to conserve the forest [2]. However, more recently, these rates seem to increase again, and the eastern and southern portion of the Amazon basin (known as the arc of deforestation) may continue to be a key point of deforestation in Brazil [3].

Deforestation in the Amazon has grown at a rapid pace in recent years, putting the region's fauna and flora at risk [4]. The increase in deforestation in recent years should not surprise us, since the factors underlying the destruction of forests continue to grow year after year [5]. Each year, the Amazon region becomes more populated: more roads penetrate the jungle, more investments in agriculture and livestock and more large-scale projects, such as hydroelectric dams, whose areas, for example, around the dams on the Madeira River (Santo Antônio, whose dam was filled in 2011, and Jirau, filled in 2013) and the Xingu River (Belo Monte, filled in 2015) were points of intense deforestation [1]. The same occurred on the road from Santarém to Cuiabá, which is being rebuilt to transport soy from Mato Grosso to ports with access to the Amazon River [5].

The old reasons for deforestation, such as land speculation, money laundering and land acquisition, whether obtaining the legal title to the land or occupying and preventing it from being invaded or confiscated, with or without a legal document, still exist, and all this adds up to a free economy to sell agricultural products for profit [6].

There is no single solution to the incessant destruction of the Amazon rainforest, a series of measures is necessary, divided into three categories: efforts to prevent deforestation; suspension of government actions that promote deforestation; and offering alternatives for those who depend on agriculture to survive - a group that does not include agribusiness, ranchers or “grileiros” (large illegal land grabbers) [7]. The purpose of this bibliographic review was to identify in the literature the approach on the main causes of forest destruction in the legal Amazon, in order to know through studies, the main reasons for the increasing deforestation and degradation in the biome.

2. GENERAL STUDY ON MAIN CAUSES OF DEFORESTATION IN THE AMAZON FOREST: LITERATURE REVIEW

2.1 Livestock

At the current rate of deforestation and climate change, scientists estimate that in 20 years, 40% of the Amazon will be destroyed and another 20% will lose their original features, in a process of collapse of the largest tropical forest in the world [8].

Livestock expansion is the main cause of the accelerated deforestation process in the Amazon [9]. The data is clear: about 75% of the deforested areas are occupied by cattle; more than 90% of the meat produced in the Amazon is consumed in Brazil itself; of the total meat for domestic consumption, more than 70% is consumed in the regions of greater economic power, South and Southeast [10].

The destruction of forests, to open pastures and cultivation fields to feed livestock, has several implications, such as the compromise of biodiversity and the promotion of erosion and desertification processes, and, in addition, the fires used as a mechanism for deforestation. place Brazil as the 4th largest emitter of greenhouse gases in the world. This corresponds to 75% of CO_2 emissions generated across the

country [11]. For a hectare of burnt forest, an average of 150 tons of CO_2 are emitted [10].

When studying the causality between main causes of deforestation, [12] verified that the direction of the causality of the effect of livestock on deforestation measured by the number of heads per municipality and the density of this in the area of the municipality can be thought of in a bidirectional way. On the one hand, the higher the size of the cattle herd in terms of the area occupied by the municipality and the higher its growth rate, an increase in the pressure on the conversion of the forest to pasture can be expected. On the other hand, the larger the area occupied with pasture and, therefore, the greater the deforestation already carried out, the greater the dynamization of this activity, in terms of reducing the relative cost, attracting new ranchers and intensifying this activity.

Fig. 1 shows the growth rates of the slaughtered herd for the main States that are slaughter centers in the country, in the period between 1998 and 2006, in which the performance of the States of the Legal Amazon: Mato Grosso, Rondônia and Pará can be observed.

Thus, it is clear that these States showed growth rates above the national average, with emphasis on the State of Rondônia, which, in the most recent period since 2002, has shown a high growth trajectory, exceeding the rate of 20% as from 2004 [12].

Other works found in the literature also discuss the role of livestock in deforestation in the Amazon [13,14,15].

2.2 Agriculture

Currently, soybeans correspond to about 57% of the total area sown with grains in the country [16]. Soy produced in Brazil stands out as a preeminent agricultural activity in the country, playing an important role in the growth of agriculture and the economy of several States, both in the production of grains for export and in the destination of various domestic uses, enabling the consolidation of vast agro-industrial chains [17].

The North region has been standing out as a significant agricultural frontier, registering an annual growth in the area cultivated with grains, mainly with the cultivation of soy. The success of soy is due to several factors, such as the development of research and innovative technologies adapted to the tropical region, new cultivars with greater productive potential, rational use of agrochemicals, adapted mechanization modes, direct sowing techniques, among others [18].

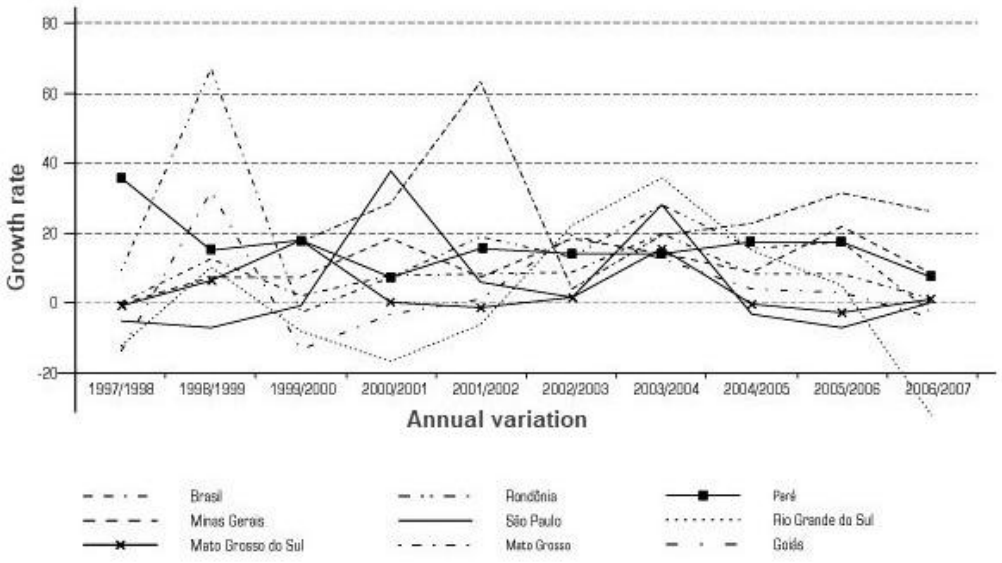

Fig. 1. Annual variation in the growth rates of the slaughtered herd in the states with the largest cattle herd in Brazil

Fonte: PPM/IBGE

The advance of export agriculture in the Amazon produces a loss of ecosystem goods and services [19]. Some researchers suggest that much of the current deforestation is related to the expansion of soy [1], but others argue that the expansion of soy occurs on land previously used for pasture, not causing deforestation [20]. Although the expansion of livestock continues to be considered the primary vector for deforestation, the expansion of mechanized agriculture (grains) has altered the dynamics of deforestation, both increasing the conversion of forests to soy plantations and indirectly replacing pastures, moving some ranchers to others forested regions [17].

In the 2000, several policies that stimulated deforestation ended. In 2004, the Action Plan for Protection and Control of Deforestation in the Amazon (PPCDAM) was launched with the objective of continuously and consistently reducing deforestation and creating the conditions to establish a sustainable development model in the Legal Amazon. The actions contained in the PPCDAM contributed significantly to the drastic reduction in the rate of deforestation in the Amazon, as measured by the PRODES Project (Project for Monitoring Deforestation in the Legal Amazon, under the responsibility of the National Institute for Space Research - INPE / MCTI). The annual rate went from 27,772 km² in 2004 to 7,989 km² in 2016 (preliminary data), a reduction of 70% in 10 years [21].

According to several surveys [22,16], soybeans began to be cultivated in the State of Pará, including in the Santarém region, from the 1997 agricultural harvest. CONAB's annual harvest surveys (2013) reveal that cultivation of soy arrived in the State of Pará in the years 1997/1998, especially in the Santarém region (Baixo Amazonas). Today, there are two more consolidated centers for the cultivation of this legume, which are the regions of Paragominas (Northwest of Pará) and Santana do Araguaia (South of State) and Paragominas already has a cultivated area larger than the Santarém pole, as can see in Fig. 2.

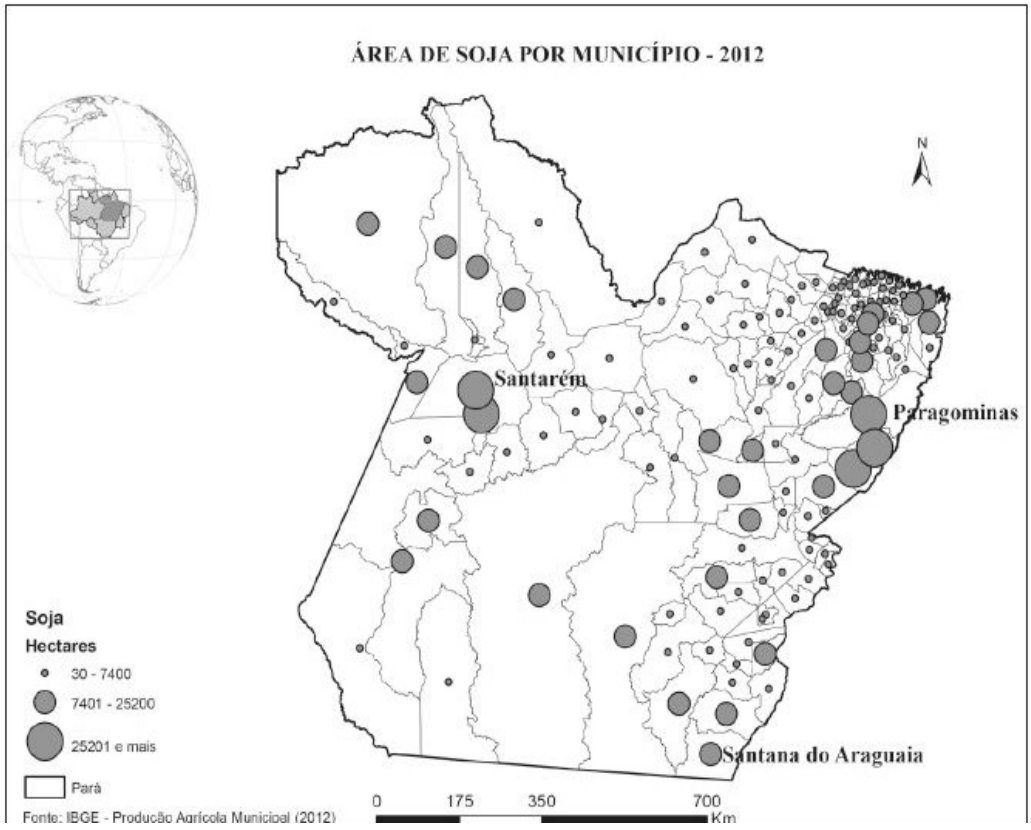

Fig. 2. Soy cultivation in the State of Pará - distribution by municipality (2012)

Source: IBGE - Municipal Agricultural Production (2014); Elaboration: Ralph de Medeiros Albuquerque - Mader / FUP

The increase in the quantity produced is directly proportional to the increase in the soybean cultivated area in the State, which jumped from 2,600 hectares in the 1997/1998 harvest, to more than 172 thousand hectares in the 2012/13 harvest [23], especially with growth from the 2002/2003 harvest. According to information in Fig. 3, there is a significant increase in the planted area since the 2002/2003 harvest, confirming the increase in production and demonstrating that the construction of the port of Cargill, in Santarém, was a decisive incentive for the expansion of soy in the region [23].

Many authors report the impacts of settlements in the region of the legal amazon, showing increasing rates of small deforestations, resulting from the diversification of productive activities related to family farming [24,25,26].

As a measure of environmental impact, [27] evaluated the dynamics of deforestation in 15% of federal settlements in the State of Pará, over five years. The results showed that there is proportionally more deforestation in the interior of the settlements than in the area that circumscribes them. However, the rate at which deforestation increases over the years is slower within the settlements, when the state's protected areas are excluded.

The study points to possible causes that contribute to the trend of deforestation in the context of settlements. Factors such as economic vulnerability, the delay in releasing rural financing, land uncertainties, lot sizes and logging in fictitious settlements are pointed out as some of the determinant causes of the pattern observed.

2.3 Mining

Artisanal mining in the Amazon is practiced on the margins of state laws and causes damage to the environment, the right of present and future generations and to indigenous societies, with severe environmental and social damage arising mainly from the use of mercury in the amalgamation of gold being known [28,29].

Garimpeiros seek opportunities in the Amazon, unexplored resources: “the areas of virgin forest, endowed with rare wood and fertile soils for agriculture and mineral deposits” [28], because “El Dorado packs dreams of wealth, of appropriation new forest and water resources, as it contains a promise of monetary wealth that has not yet been exploited” [30].

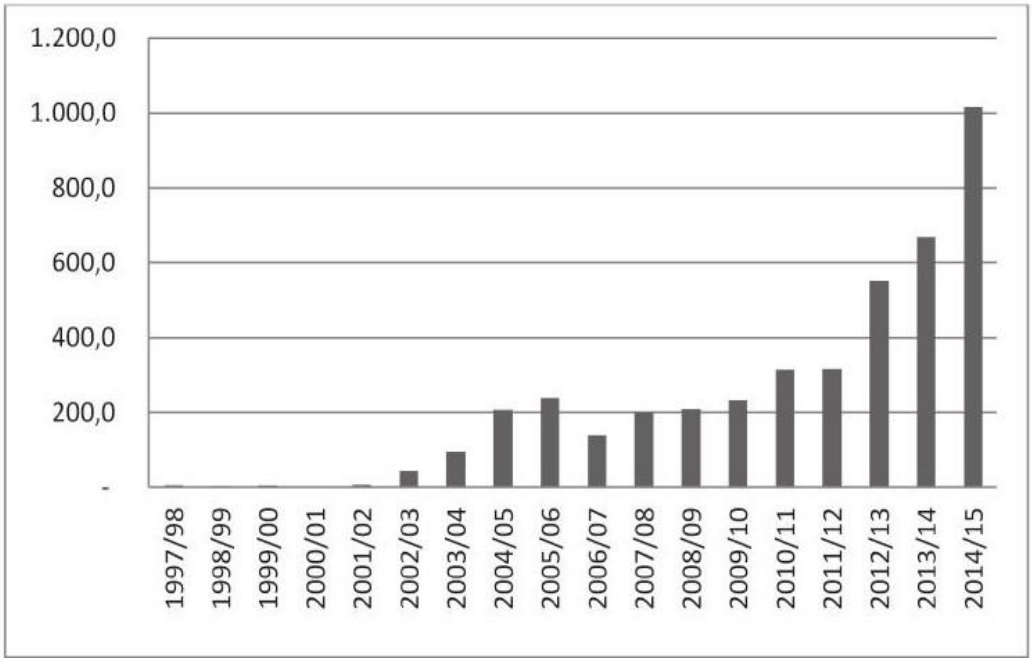

Fig. 3. Soy production in the State of Pará (in thousand tons)
X axis: Historical series (1997/98 – 2014/15); Y axis: Soy production (in thousand tons).
Source: Historical series: soybeans - 1997/98 to 2014/15 harvests - CONAB (2016).
Elaborated by: Sérgio Sauer and Pedro Sérgio Vieira Martins

When studying the expansion of mining in indigenous lands in the eastern Amazon and the socioenvironmental impacts, [31] made a study regarding the expansion of mining processes required and active in indigenous lands in the Amazon in 4 scenes, referring to the years 1990, 2000, 2010 and 2019, as shown in Fig. 4.

Mineral extraction, despite being considered in the Amazon paradigm as a synonym for economic growth, configures economic activity with a high potential for environmental impacts and its expansion poses serious threats to indigenous lands and everything they represent [32]. It is known that mining must continue and grow in the foreseeable future to ensure mineral inputs for the production and consumption of final goods. However, there must be a more responsible path for mineral exploration with more just and conscious environmental practices [32].

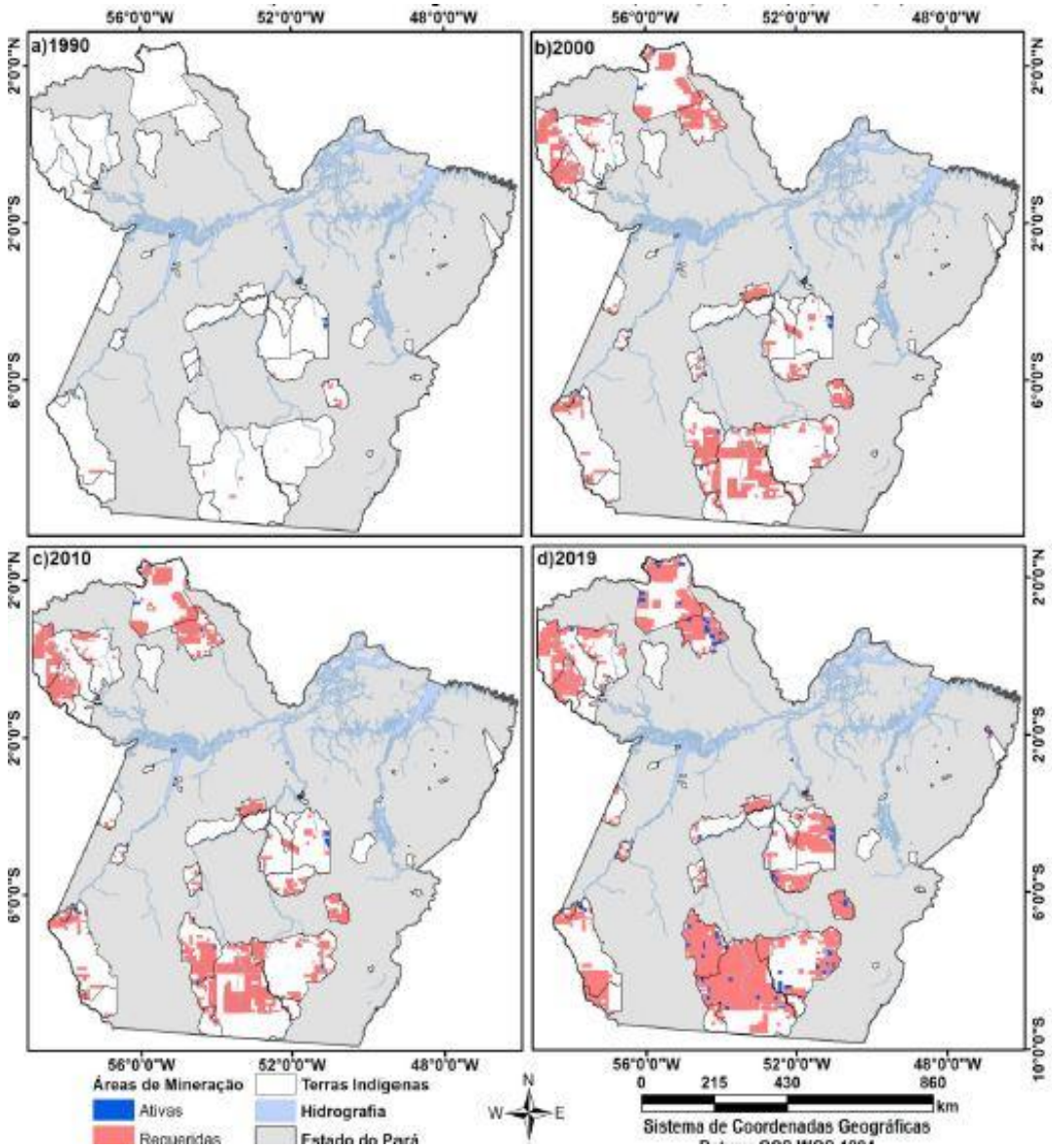

Fig. 4. Active and required mining areas on indigenous lands: a) 1990; b) 2000; c) 2010; d) 2019
Source: Ribeiro et al. (2019), adapted from IBGE (2017), FUNAI (2017), ANM (2019)

2.4 Forest Degradation

A mosaic of protected areas is defined by the National System of Conservation Units (SNUC, Law nº 9.985 of 2000 art. 26) as:

[...] a set of conservation units of different categories or not, close, juxtaposed or overlapping, and other public or private protected areas, constituting a mosaic, the management of the complex must be done in an integrated and participatory way, considering its distinct conservation objectives, in order to reconcile the presence of biodiversity, the valorization of sociodiversity and sustainable development in the regional context [33].

Currently, in Brazil there are 15 mosaics with integrated management formalized by the Ministry of the Environment (MMA), including the "Mosaic of the West of Amapá and Norte do Pará" (MMA Ordinance No. 4 of 2013), the only one to integrate the management Conservation Units (UC) and Indigenous Lands (TI). The "Mosaico Gurupi" is not yet legally recognized, but in this context, the term "mosaic" was used due to the process that started in 2014, bringing together different actors with the intention of consolidating its formalization [33].

Between 2007 and 2015, the degraded forests of the "Mosaico Gurupi" totaled 2,200 km², which represents 14.4% of the remaining forests in the protected areas (Table 1). Forest degradation reaches 45% of the remaining forests in TI Arariboia. At the Alto Rio Guamá TI, a pilot radar monitoring study detected the cutting of 9,731 trees in 2014 [34]. According to [34], tropical forests subjected to degradation become a source of carbon for the atmosphere and no longer a sink.

According to data provided by the Maranhão State Department of the Environment and Natural Resources (Sema), there are currently only four logging enterprises with a valid operating license in the municipalities of the mosaic. In the past two years, Sema has suspended the Sustainable Forest Management Plan (PMFS) authorizations for this region. However, it authorized the deforestation of 205 km^2 between 2014 and 2017, which generated a volume of about 540 thousand m^3 of wood, 95% of which was firewood and waste and 5% of stake and log. According to IBGE (2014), Maranhão is the largest charcoal producer in the Legal Amazon [35].

Studies such as those carried out by [36] and [37] demonstrate the damage that deforestation causes in the region of the legal Amazon, with the destruction of an extremely important biome for Brazil and the world.

2.5 Burns

In addition to the increase in the outbreaks of burning during the 2019 drought, which declined in September, deforestation in the Legal Amazon, according to INPE's Deter system, grew. In August 2019, the Amazon lost 1,698 km^2 of vegetation cover against 525 km^2 relative to August 2018, an increase of 222%. Data from the last 8 months of 2019 show that deforestation was 6,404 km^2, that is, it registered a growth of 92% [37].

Also, according to INPE database of fires, released by the press, fires in the Amazon biome in August totaled 3,901 outbreaks, the worst since August 2010. They burned an area 29,944 km², four times greater than the registered in August 2018, which reached 6,048 km². Between January and August 2019, 71,497 outbreaks were recorded, more than double in the same period last year [38]. Fires and deforestation have a negative impact on the Amazon Forest, one can scientifically question whether the forest is the “lung of the world”, but its role may be even more important as a climate regulator. This issue is detailed in the report “The Climate Future of the Amazon” [39].

The so-called “green ocean” of the Amazon Forest demonstrates that it is a unique system in the world and points out 5 factors that contribute to regulating the climate: i) ability to maintain air humidity for kilometers and advancing across the continent; ii), it allows the condensation of water vapor that maintains the humidity of the forest, iii) the capacity to bring moisture from the ocean to the continent in the form of rain; iv), avoids extreme weather events, with each tree evaporating more than a thousand liters of water per day; and v) draining winds through the treetops, which prevent extreme weather events [36].

Other works address the influence of fires in the Amazon region [40,41,42,43] They are extremely important, relevant so that the problem of fires in the region can be raised and resolved.

Table 1. Deforestation, forest degradation, pastures, secondary vegetation and hot spots in the Protected Areas and the Influence Area of the "Mosaico Gurupi", in eastern Pará and western Maranhão

Protected Area	Area in km^2					Heat spot ****
	Total area	Accumulated deforestation *	Degraded Forest **	Pasture***	Secondary Vegetation ***	
Alto Turiaçu Indigenous Territory	5.239,4	425,1 (8,0%)	69,0 (1,4%)	93,0 (21,9%)	225,3 (53,0%)	158
Caru Indigenous Territory	1.708,9	166,8 (9,8%)	6,1 (0,4%)	25,7 (15,4%)	47,3 (28,3%)	33
Awá Indigenous Territory	1.167,7	423,4 (36,3%)	4,9 (0,7%)	229,1 (54,1%)	81,9 (19,4%)	132
Araribóia Indigenous Territory	4.138,3	246,2 (6,0%)	1.751,9 (45,0%)	88,9 (36,1 %)	110,8 (45,0%)	2.116
Pindaré Indigenous Territory	155,1	86,8 (56,0%)	-	17,2 (19,8%)	66,9 (77,0%)	18
Alto Rio Guamá Indigenous Territory	2.823,4	941,4 (33,3%)	157,5 (8,4%)	374,6 (39,8%)	393,4 (41,8%)	437
ReBIO Gurupi	2.712,0	797,6 (29,4%)	159,4 (8,3%)	264,2 (33,1%)	208,7 (26,2%)	307
'Gurupi Mosaic'	17.998,8	3.087,4 (17,2%)	2.148,9 (14,4%)	1.092,7 (35,4%)	1.134,2 (36,7%)	3.201
Other areas *****	28.387,7	23.163,1 (81,6%)	1013,2 (19,4%)	12.105,3 (2,3%)	5.478,8 (23,7%)	5.501
Influence Area of the 'Gurupi Mosaic'	46.386,5	26.244,7 (56,6%)	3.162,2 (15,7%)	13.197,9 (50,3%)	6.612,9 (25,2%)	8.702

*Adapted from Celentano et al. (2017); * Accumulated deforestation until 2016. Source: Projeto Prodes (INPE, 2017); ** Degraded forest from 2007 to 2015. Source: Projeto Degrad (INPE, 2017). Percentage of degraded forest area calculated over remaining forest area; *** Pasture and secondary vegetation in 2014, pasture includes clean pasture, dirty pasture and pasture regeneration. Source: Terra Class Project (INPE / Embrapa, 2016). Percentages calculated on deforested areas; **** Heat spots from 2015 to 2017 (10/19/2017). Source: Queimadas Project (INPE, 2017); ***** Other areas include private land and 108 agrarian reform settlements (7,200 km2), where the Legal Reserve (RL) and Permanent Preservation Areas (APP) areas must be protected*

3. FINAL CONSIDERATIONS

From 2000 onwards, there was an economic dynamism in the Legal Amazon, due to the growth of agriculture, logging and the industrial pole of Manaus. In particular, agriculture has expanded in terms of occupied area, volume of production and high prices, mainly meat in international markets [44].

According to data from the Municipal Livestock Survey and the Municipal Agricultural Survey (IBGE), the municipalities of the Legal Amazon concentrated 32.53% of the soy planted area and 37.38% of the national cattle herd in 2012. With regard to the priority municipalities, these percentages were 8.95% and 5.7% respectively, between 2005 and 2011, the Gross Domestic Product in the municipalities of the Legal Amazon and in the municipalities of Arco Verde grew on average 14.8% and 14.9% respectively, while the National GDP grew 11.62% [45].

As of 2004, the year in which the deforestation rate reached its highest historical value, the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm) came into force. The PPCDAm is an instrument for the operation of the Federal Government's strategic plans for the Amazon region and is coordinated by the Casa Civil in partnership with 13 ministries, its goals are part of the National Climate Change Plan (PNMC), which provides for a reduction of 80% of deforestation in the Legal Amazon by 2020, starting with the 19,500 km^2 deforested in 2002 [46]. It is likely that the Plan will achieve its goal, since between 2002 and 2014 deforestation dropped 73.7%, from 19,500 km^2 in 2002 to 5,100 km^2 in 2013 [40].

The solution to the incessant destruction of the Amazon rainforest is complex. A series of measures is needed, divided into three categories: efforts to prevent deforestation; suspension of government actions that promote deforestation; and offering alternatives for those who depend on agriculture to survive - a group that does not include agribusiness, ranchers or “grileiros” (large illegal land grabbers) [7].

The value of the region's environmental services is a potential source of funds. These services include: maintaining biodiversity, avoiding global warming and recycling the water provided by the rains not only in the Amazon, but also in São Paulo and in the neighboring countries of Brazil. However, despite some progress, this alternative to the current destructive economy, necessary to change the course of development, is still at an early stage [7].

It is an urgent priority to establish protected areas, and these must be created immediately, before settlers and investors reach the regions hitherto untouched. However, instead of creating reserves, the government and its rural allies are reducing and revoking them. An example of this is the state of Amazonas, where representatives of Congress are currently working to cancel parts of a mosaic of reserves in the south of the state, which is one of the most important points of deforestation [47].

The Ministry of the Environment and other agencies need reinforcements, financial aid and political support, and the failure to obtain this is one of the reasons that explain the current resurgence of forest clearing. The Ministry of the Environment is always among the last priorities when resources from the scarce state budget are allocated. This reduced inspections of illegal deforestation and hampered efforts to create and defend protected areas, but the problem is more complex. Responding to bad news about deforestation always means passing the problem on to the Ministry of the Environment, while the rest of the Government remains unmoved, but a plethora of government actions leads to further deforestation, and these actions must be recognized and stopped [48].

The Government subsidizes deforestation by offering low-interest loans for agriculture and livestock (and forgiving debts when problems arise), creating settlements, exempting export taxes without worrying about damage, providing extensions and research to expand the cultivation of soy, cattle grazing and unsustainable forest “handling”, as well as building and maintaining roads and other infrastructure to transport these products. The opening of roads inevitably sets in motion a chain of land invasion, land speculation and deforestation that quickly escapes government control. A clear example of this is the planned reopening of the abandoned Manaus to Porto Velho road, which, together with the existing and planned connecting roads, would open approximately half of what remains of the Amazon rainforest in Brazil to soy producers, ranchers, loggers and other participants in the infamous “arc of deforestation”, which extends along the region's southern border [49].

4. CONCLUSION

Therefore, the response to intensified deforestation should include the cancellation of some important infrastructure projects, with great potential to catalyze further clearing of forests. Unfortunately, stopping these development projects is not the current trend, which is characterized by an explosion of legislative proposals to weaken or abolish environmental licenses in favor of “strategic” infrastructure projects, such as roads and dams [50].

The Brazil has the Environmental Law (Law nº 9.605/98) that is quite severe in theory, but it does not work very well in practice, since most the offenders receive a fine, however, this fine is not paid and the environmental organs do not put into practice its power.

If the Brazilian government, with the help of the international community, does not take control of destructive development forces seriously, then, regardless of periods of growth and reduced deforestation, this magnificent rainforest will continue to disappear decade after decade [49].

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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