



# Achieving zero deforestation in the Brazilian Amazon: What is missing?

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## Abstract

Amazon deforestation causes severe climatic and ecological disruptions, with negative consequences for the livelihood of forest-dependent peoples. To avoid further disruptions, Brazil will need to take bold steps to eliminate both illegal and legal Amazon deforestation over the short term. Amazon deforestation declined by 70% between 2005 and 2014 due to drops in commodity prices and interventions by federal and state governments, such as law enforcement campaigns and credit restrictions for landowners who deforest illegally. Despite these impressive achievements, Brazil still deforests 5,000 km<sup>2</sup> of Amazonian forests each year. How then will Brazil eliminate Amazon deforestation altogether if the country is only committed to cut illegal deforestation by 2030—as stated in its Intended Nationally Determined Contributions (iNDC) to the 2015 climate change treaty meeting in Paris? Here we provide an analysis of the major socio-economic-political threats that could constrain Brazil from achieving its current goals. We then propose six fundamental strategies to help Brazil achieve a more ambitious goal to eliminate all major legal and illegal Amazon deforestation. These strategies involve bringing social and environmental safeguards to the infrastructure plans in the region, consolidating and expanding positive incentives for the production of sustainable commodities, establishing a new policy to guarantee the social and environmental sustainability of rural settlements, fully implementing the national legislation protecting forests (the Forest Code), protecting the land rights of indigenous people and traditional communities, and expanding the existing network of protected areas, allocating the 80 million hectares of not designated public forests as protected areas or areas for sustainable use of timber and non-timber forest products. The implementation of these strategies however depends on the formulation of a new development paradigm that promotes economic growth, social justice and productive agriculture, while protecting the fundamentally important ecological services of tropical forests.

## Introduction

Tropical deforestation and land-use change are responsible for around 10% of global greenhouse gas (GHG) emissions (Le Quéré et al., 2015). It is widely accepted that tropical deforestation should be greatly reduced in order to avoid “dangerous interferences” in the global climate system, the primary objective of the United Nations Framework Convention on Climate Change (UNFCCC), stated in Article 2 (Goodman and Herold, 2014). Conversion of forests to pasture and agricultural land in the Brazilian Amazon has reached extremely high levels during the past two decades (an average of 18,165 km<sup>2</sup> from 1990 to 2000 and 19,289 km<sup>2</sup> from 2001 to 2010), releasing an average of 1.3 Gt CO<sub>2</sub> per year, according to the Greenhouse Gas Emission Estimate System (SEEG, 2015).

This historical pattern of deforestation in the Brazilian Amazon, however, has been reversed. Deforestation in the region has declined 70% from 2005 (19,014 km<sup>2</sup>) to 2014 (5,012 km<sup>2</sup>) (INPE/PRODES, 2016) in response to different strategies including law enforcement campaigns, establishment of new protected areas, and credit restrictions on land owners involved in illegal deforestation (Soares-Filho et al., 2008; 2010; Assunção et al., 2012, 2013a, 2013b; Nepstad et al., 2014; Pfaff et al., 2015). Despite this great achievement, the annual rate of deforestation since 2012 appears to be stuck at around 5,000 km<sup>2</sup> (4,571 km<sup>2</sup> in 2012,

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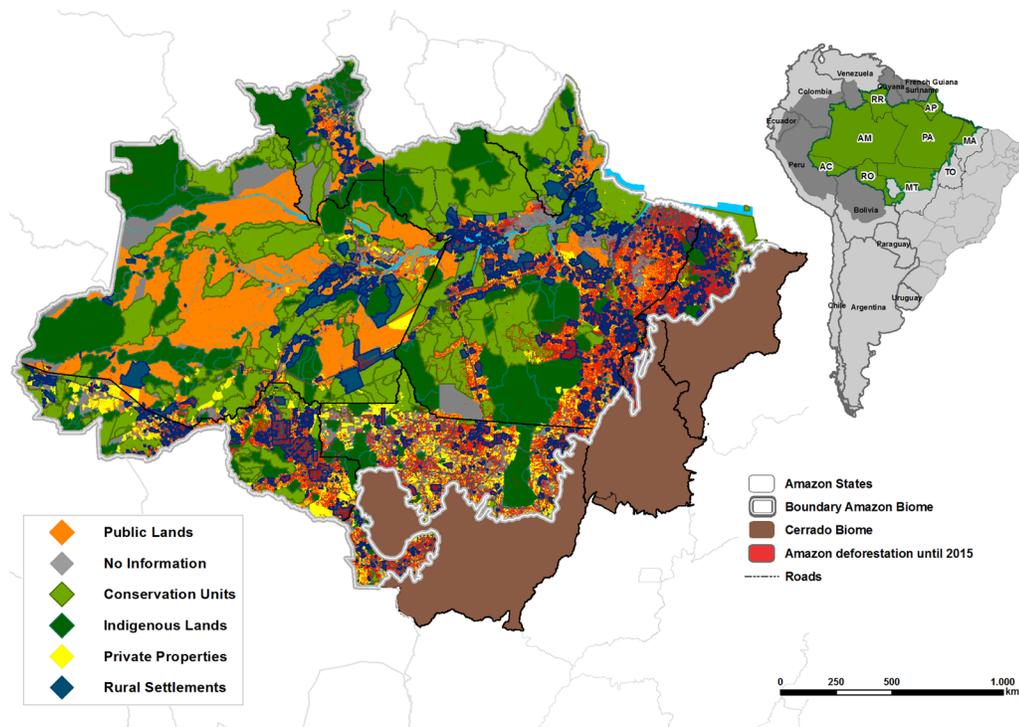
5,891 km<sup>2</sup> in 2013, 5,012 km<sup>2</sup> in 2014 and 5,831 km<sup>2</sup> in 2015; INPE/PRODES, 2016). Although this represents the lowest amount of deforestation recorded since the beginning of monitoring in 1988 by the Brazilian National Institute for Space Research (INPE), this is a major waste of resources because a large, pre-existing deforested area (6–15 million ha) has been completely underutilized (INPE/Embrapa, 2011). In addition, the combination of global climate change, deforestation - even in low rates - and fire will lead to severe changes in the local climate (Brando et al., 2014; Alencar et al., 2015; Duffy et al., 2015), as is already occurring in the southeastern portion of the Brazilian Amazon (Silvério et al., 2015). Studies also point to the risk of biological impoverishment due to the use of fire in some specific areas (Cox et al., 2004; Nepstad et al., 2001; Silvério et al., 2013, 2015). These effects are local and, depending on the dry processing of vegetation, can provoke fast impacts (Silvério et al., 2015).

In December 2015, the 21<sup>st</sup> Conference of the Parties to the UN Framework Convention on Climate Change met in Paris to achieve a universal agreement on climate, with the goal to keep global warming below 2° C (UNFCCC, 2015). As part of the agreement, all Parties should put forward efforts to reduce emissions through “Intended Nationally Determined Contributions” (iNDCs). Brazil has committed to eliminate deforestation in the Amazon by 2030, as announced in the Brazilian government’s iNDC (Federative Republic of Brazil, 2015). Considering the current deforestation rate in the region (~5000 km<sup>2</sup>/yr) and the ongoing changes on the local/regional climate (Brando et al., 2014, Silvério et al., 2015; Duffy et al., 2015), it is urgent to reduce deforestation to zero as soon as possible, and long before 2030.

In this paper, we provide a brief analysis of the current threats to Brazil achieving zero deforestation and propose six fundamental strategies to extinguish legal and illegal deforestation in the region over the coming years.

## Understanding the strategies to control deforestation in the Amazon

A vast literature describes the main drivers of deforestation in the Brazilian Amazon (Nepstad et al., 2001; Kaimowitz et al., 2004; Fearnside, 2005; Etter et al., 2006; Scouvar et al., 2008; Boucher et al., 2011; Guerra, 2014; Nepstad et al., 2014; Azevedo-Ramos et al., 2015). There is not yet a consensus, however, about which intervention has been most effective in causing the region’s dramatic reduction of deforestation since 2005. Instead, this reduction has been attributed to many factors such as implementation of command and control measures and expansion of protected areas (PA), including into indigenous territories, by the Brazilian government (Soares-Filho et al., 2010, 2014; Schwartzman et al., 2012; Ricketts et al., 2010; Nepstad et al., 2014; Richards et al., 2014). Currently, around 54% of the Brazilian Amazon falls under certain categories of protected areas (INPE/PRODES, 2016) (Figure 1). Deforestation reduction has also been attributed to decreases in the price of commodities in 2005 (Wunder et al., 2008; Assunção et al., 2012) and to the 2006 soy moratorium agreement (Gibbs et al., 2015). In 2007, through Presidential Decree 6.321, the federal



**Figure 1**  
Deforested area and land tenure categories in the Brazilian Amazon.

Sources: Deforestation data from National Institute for Space Research (INPE) and Brazilian Amazon Forest Monitoring by Satellites Project (PRODES) (INPE/PRODES, 2016); IL, FCU and SCU from Socio-environmental Institute (ISA, 2015); RS from the National Institute for Colonization and Agrarian Reform (INCRA, 2015); FPL and SPL from Brazilian Forest Service; PP from state database of Rural Environmental Registry from States Secretaries of Environment (Para, Acre and Mato Grosso states; reference year: 2013); NI are undefined polygons.

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government created a blacklist of the largest deforesters in the Amazon and started to monitor and control those municipalities with critical levels of illegal deforestation through embargoes and economic and development sanctions such as restricted access to credit. Deforestation decreased by 35% in this period. Also in 2007, a major deforestation control measure was implemented: the Real Time System for Detection of Deforestation (DETER). This official remote monitoring system is attributed for preventing the clearing of 59,500 km<sup>2</sup> of Amazon forest between 2007 and 2011 (Assunção et al., 2013a; Assunção and Rocha, 2014). Other promising policy instruments such as payments for ecosystem services and REDD+ initiatives are new in the region (Nepstad et al., 2014), thus have not likely to have been major drivers of this decreased deforestation. This patchwork of policies and control instruments could not prevent an increase in deforestation rates by 28% in 2013, mostly due to land grabbing of public lands and deforestation in rural settlements (Table 1). This upturn in deforestation is clearly unacceptable if it represents an easing of preventive and punitive measures.

The cost of preventing deforestation is difficult to estimate, even after successes in reducing deforestation since 2005. The cost to reduce 70–80% of deforestation in private areas of the Brazilian Amazon was estimated at less than USD 5/tCO<sub>2</sub>e or USD 7–18 billion in 10 years (Nepstad et al., 2009). The cost to maintain all protected areas in the Brazilian Amazon was estimated in USD150 billion (net present value), calculated as the opportunity cost of not converting protected areas into other land use (grains plantation and pastures) and on investments needed for their consolidation (Soares-Filho et al., 2010). Nonetheless, the cost of deforestation reduction or of forest protection will always be underestimated because the estimates do not include other related costs, for example, transaction costs. However, the Brazilian government is only willing (or able) to pay for a fraction of the efforts related to policy and enforcement to reduce deforestation. For example, from 2007 to 2014 approximately USD 500 million was allocated to the official Action Plan for Prevention and Control of Amazon Deforestation (PPCDAm).

To cover the high cost related to deforestation reduction and maintain the standing forests in the Amazon, complementary funds will be necessary over the next decades. Towards this end, the Paris Agreement signed at COP21 includes a mechanism for Reduction of Emissions from Deforestation and Degradation (REDD+) that could play an important role in compensating tropical, forest-rich countries - like Brazil - making efforts to reduce emissions from deforestation in their own territories.

## Building the path to achieving zero deforestation: What is still missing?

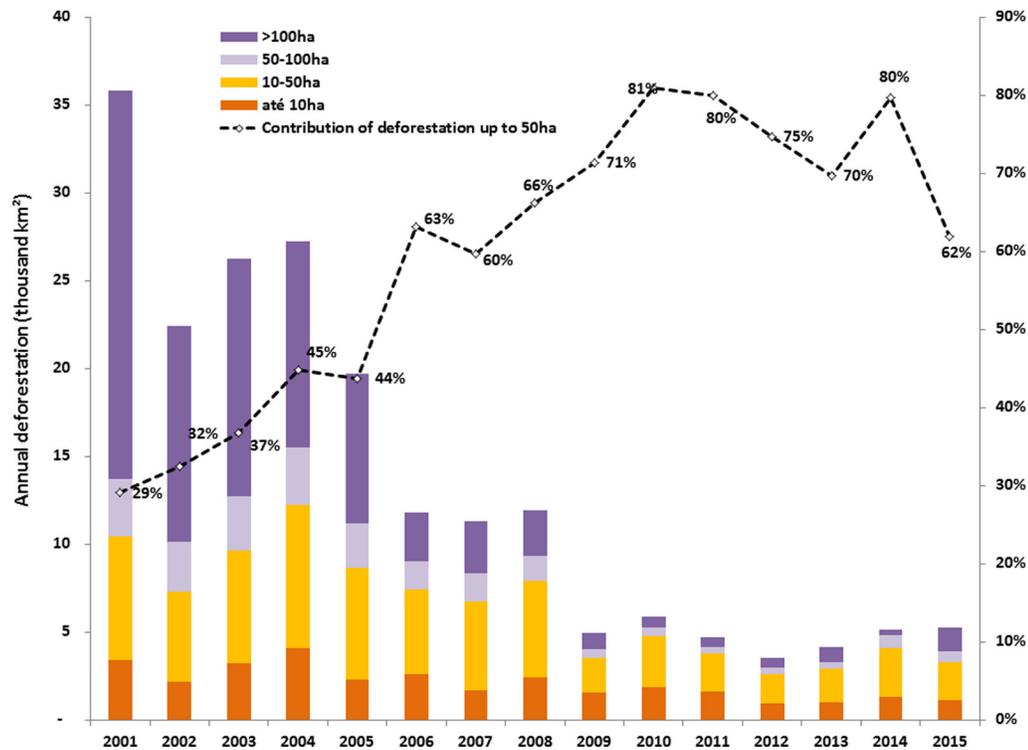
Despite the remarkable reduction in deforestation rates from 2005 to 2010, the current challenge is finding ways to reduce deforestation from an average of 5,000 km<sup>2</sup>/year to zero over the next decade. Meeting this challenge requires recognizing it to be a complex problem, involving many factors and actors that change across space and over time; and that no “silver bullet” solution – no single strategy – can eliminate deforestation alone. The historical pattern of deforestation has also changed over time, creating additional difficulties for control measures. Whereas deforestation during the 1990–2005 period involved mostly large cleared areas (> 5,000 ha) for pasture establishment on private lands, deforestation now is often characterized by small (< 500 ha) and fragmented clearing, mostly on public lands (Figure 2). Deforestation is also increasing in public forests (Table 1), thus, illegal deforestation is still being used to “legitimize” unclaimed lands and to

**Table 1.** Deforested area (km<sup>2</sup>) in the Amazon by land title category from 2010 to 2015<sup>a</sup>

Land title category	Year					
	2010	2011	2012	2013	2014	2015
Indigenous Lands (IL)	305	227	168	170	71	62
Federal Conservation Unit (FCU)	179	131	175	187	120	184
State Conservation Unit (SCU)	126	150	117	175	174	233
Environmental Protection Areas (EPA)	265	209	124	228	202	245
Rural Settlements (RS)	1,851	1,766	1,239	1,518	1,269	1,437
Private Properties (PP)	1,502	1,355	986	1,009	883	1,113
Federal Public Lands (FPL)	690	698	574	743	584	670
State Public Lands (SPL)	64	30	15	31	0	7
No information (NI)	1,497	1,072	982	1,222	1,047	1,306
Total Km <sup>2</sup>	6,479	5,637	4,381	5,282	4,350	5,256

<sup>a</sup>Sources: Deforestation data from National Institute for Space Research (INPE) and Brazilian Amazon Forest Monitoring by Satellites Project (PRODES) (INPE/PRODES, 2016); IL, FCU and SCU from Socio-environmental Institute (ISA, 2015); RS from the National Institute for Colonization and Agrarian Reform (INCRA, 2015); FPL and SPL from Brazilian Forest Service (CENF, 2013); PP from state database of Rural Environmental Registry (SEMA-MT, 2013; SEMA-PA, 2013; Governo do Estado do Acre, 2010); NI are undefined polygons.

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**Figure 2**  
Annual deforestation rate in the Brazilian Amazon.

The colors on the bars (deforestation rate) indicate the proportion of categories of deforested area sizes (red: < 10ha; yellow: 10-50 ha; blue: 50-100 ha; purple: >100 ha). The dotted line shows the percentages of small deforested areas (<50 ha). Data source: PRODES 2015.

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profit as the price of cleared land increases. Additionally, major infrastructure projects such as hydroelectric dams, highway paving and port construction still represent important drivers of deforestation (Soares-Filho et al., 2006; Stickler et al., 2013; Alencar et al., 2015). The current deforestation pattern can also be attributed to changes in environmental regulations. The new Forest Code approved in 2012 allows legalization of a significant portion of land illegally deforested in the past, creating expectations that new illegal deforestation in the future also may be amnestied (Soares-Filho et al., 2014). Other factors seem to be involved in the increased pressure to clear land after 2013, such as the unsustainable rural settlement policies (Alencar et al., 2015) and lobby of agribusiness at the National Congress (Crisostomo et al., 2015).

We present a list of the six main current threats and corresponding strategies to deal with each in Table 2. The first relevant threat still driving deforestation is Brazil's Growth Acceleration Plan (PAC). Launched in 2007 and renewed in 2011, this plan's goal is to accelerate Brazilian economic growth. The plan consists of investments in more than forty thousand infrastructure projects such as roads, dams and waterways, most of them in the Amazon region (May et al., 2010), with an estimated investment of USD 270 billion for 2015–2018. The cumulative impacts of these projects on deforestation are high, especially because these projects follow the old economic paradigm of growth based on the lobby of powerful economic groups and lack socio-environmental controls (Pfaff et al., 2008; May et al., 2010). A strategy of mitigating the negative impacts of infrastructure investments by the PAC is crucial to establishing effective controls over how these infrastructure investments affect forest lands. Such mitigation efforts should go beyond the routine reporting of environmental impacts and consultation through public hearings that are required to obtain the mandatory environmental licenses to implement these infrastructure projects.

Indeed, establishing environmental protocols and socio-environmental safeguards for infrastructure investments is fundamental for healthy development (*Strategy #1*, Table 2). Currently, efforts in this direction are being made by several governmental and non-governmental organizations, such as the new initiative coordinated by the World Bank's International Financial Corporation (IFC) and the Getúlio Vargas Foundation (FGV) that aim to establish a social and environmental standard protocol for infrastructure projects in the Amazon. Additionally, several NGO campaigns have publicized technical steps and evaluation methodologies for improving implementation of infrastructure projects in the region (GvCes, 2015; ISA, 2015). These processes include improvements in socio-environmental compensatory measures, guarantees for real civil society participation in strategies to mitigate impacts, and investments in local governance prior to project installation. Unfortunately, none of these protocols or safeguards has been adopted yet by the government or by project implementers. Impacts on health, education and housing should also be taken into account and mitigated because large infrastructure enterprises stimulate in-migration of people into the vicinity of these projects, searching for jobs and congregating in impoverished municipalities. For those who remain in rural areas, pressure to extract timber and other natural resources is huge and an additional source of deforestation.

Table 2. Six threats to deforestation reduction and six strategies to achieve zero deforestation

Six Threats to Deforestation Reduction	Context and Perspectives	Six Strategies to Achieve Zero Deforestation	Ideal Perspectives
1. Brazil's Growth Acceleration Plan (PAC).	<ul style="list-style-type: none"> <li>Infrastructure projects do not dialogue with environmental preservation efforts.</li> <li>There are few to no environmental safeguards for infrastructure projects. Protected Areas Downgrading, Downsizing and Degazettement (PADDD) phenomenon from infrastructure projects</li> </ul>	<p>1. Socio-environmentally-friendly investments in infrastructure:</p> <ul style="list-style-type: none"> <li>Environmental safeguards established;</li> <li>Prior plan for mitigating impacts implemented;</li> <li>Environmental compensation finances mitigation actions;</li> <li>Investments in local governance;</li> <li>Strategies to increase sustainable income opportunities.</li> </ul>	<ul style="list-style-type: none"> <li>Creation and implementation of compensatory mechanisms.</li> <li>Enforcement of societal participation and choice.</li> </ul>
2. Growing demands for commodities (beef and grains).	<ul style="list-style-type: none"> <li>The same threat as always. There are also other commodities such as sugar cane, timber, etc.</li> <li>Low Carbon Agriculture Program (ABC Program): despite the government providing R\$4.5 billion in 2014 for this program, the initiative exists only on paper. More actions are needed to expand this initiative. The program expired in June 2015.</li> <li>Land access to cattle ranching activities</li> </ul>	<p>2. Expanding sustainable commodities production:</p> <ul style="list-style-type: none"> <li>Credit for low carbon agriculture (ABC Program);</li> <li>Intensify cattle-ranching activity (from &lt;1 head/ha to 1.5 head/ha);</li> <li>Expanding production on already deforested lands;</li> <li>Business opportunities in the green market;</li> <li>Compliance with the Forest Code as purchasing and financing criterion for (large) producers.</li> </ul>	<ul style="list-style-type: none"> <li>ABC Program increased and extended above regular credit lines.</li> <li>Agricultural credit criteria promote the use of already deforested land.</li> <li>Small producers better informed about legal requirements, sustainable production and credit lines</li> </ul>
3. Unsustainable rural settlement policies.	<ul style="list-style-type: none"> <li>Rural settlements require better control and means for sustainable livelihoods.</li> <li>National Institute for Colonization and Agrarian Reform (INCRA) still does not have an effective policy for sustainable rural settlements.</li> </ul>	<p>3. Sustainable Settlements:</p> <ul style="list-style-type: none"> <li>Technical assistance program.</li> <li>Payment for environmental services</li> <li>Sustainable agricultural credit policy.</li> <li>Solid social organizations</li> </ul>	<ul style="list-style-type: none"> <li>Establish a policy to guarantee the sustainability of rural settlements and the permanence of producers on their sites.</li> <li>Expand credit for environmentally-friendly activities to small producers.</li> </ul>
4. Less than full implementation of the Brazilian Forest Code.	<ul style="list-style-type: none"> <li>The rural lobby of the National Congress is developing a strategy to remove restrictions on forest clearing on private land.</li> <li>Article 41 (compensating providers of environmental services) of the BFC has not yet been implemented.</li> </ul>	<p>4. Full implementation of the Forest Code:</p> <ul style="list-style-type: none"> <li>Rural Environmental Registry (CAR) implemented;</li> <li>Economic incentives of the Forest Code devoted to the regions with highest deforestation risk and/or areas critical for restoration;</li> <li>Reducing Emissions from Deforestation and forest Degradation (REDD) initiatives.</li> </ul>	<ul style="list-style-type: none"> <li>Implement PES projects.</li> <li>Promote benefits for properties with CAR.</li> <li>Create mechanisms to monitor, verify and report</li> <li>REDD initiatives.</li> <li>Better define international financial resources for supporting the development and consolidation of REDD in Brazil.</li> <li>Develop fair benefit sharing mechanisms.</li> </ul>
5. Agribusiness lobby in the National Congress.	<ul style="list-style-type: none"> <li>PEC 215, under analysis in the Congress, intends to transfer to the legislative branch the power to establish new protected areas and to alter the size of existing protected areas.</li> </ul>	<p>5. Public forests as protected areas and for protection of people rights:</p> <ul style="list-style-type: none"> <li>Protect the rights of indigenous and traditional communities;</li> <li>Make people aware of the effects of climate change and deforestation on food production.</li> </ul>	<ul style="list-style-type: none"> <li>Demonstrate the negative effects of deforestation and climate change on regional rainfall and crop production.</li> <li>Guarantee that protected areas already created will not be reduced in size nor will there be a change to their use category designation.</li> </ul>
6. Lack of land tenure and the existence of undesignated public forestlands.	<ul style="list-style-type: none"> <li>The lack of secure land title causes insecurity and drives smallholders to exhaust their land as quickly as possible.</li> <li>There are still 80 million hectares of undesignated public forests that could be designated for protection in coming years but today are open to unscrupulous use.</li> </ul>	<p>6. Land Governance:</p> <ul style="list-style-type: none"> <li>Expand protected areas;</li> <li>Allocate undesignated public forests to some legal category. Secure land titles for consolidated smallholders;</li> <li>Guarantee landscape and development planning in new development frontiers.</li> </ul>	<ul style="list-style-type: none"> <li>Create new protected areas.</li> <li>Allocate still undesignated public forestlands, preferably in accordance with conservation and sustainable use goals.</li> <li>Distribute land titles on old Amazon development frontiers and improve land governance on new frontiers.</li> </ul>

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Thus, sustainable livelihood and employment opportunities need to be incorporated into planning for large infrastructure projects.

All of these pressures from developmental policies are affecting the preservation of forest through a phenomenon called Protected Areas Downgrading, Downsizing and Degazettement (PADDD) (Mascia and Pallier, 2011). PADDD implies a change of boundaries and status of protected areas, related to the competition for space for large infrastructure projects such as dams, roads and hydro ways (Bernard et al., 2014). The phenomenon increased in the Amazon since 2008 and affected, in the whole Brazil, more than 5.2 million ha of protected areas (Bernard et al., 2014).

The second threat impeding deforestation reduction in the Amazon is related to growing demands for commodities, especially beef and grains. According to Loman (2014), recent economic growth in Brazil is based on two main pillars: the external demand for commodities and the growth of domestic consumption. Moreover, recent industrialization of China has increased the global demand for food and other commodities. Over the past 30 years, China's GDP has grown around nine percent per year. In 2010, China was Brazil's largest trading partner, accounting for more than 15% of exports. Exports from Brazil to China are based on natural resources, especially iron ore and soybeans (Jenkins, 2012). The good news for the Amazon is that, since 2005, the strong association between deforestation and crop and beef production has diminished (Macedo et al., 2012; Nepstad et al., 2014). This decoupling is mainly explained by intensification of cattle ranching (Macedo et al., 2012), the soy moratorium effect (Gibbs et al., 2015), and law enforcement campaigns. However, high demand for commodities, particularly by China (Fearnside and Figueiredo, 2015), combined with the lobby in the National Congress to expand crop production in forested areas, continue to threaten the recent gains in controlling deforestation. The combination of this demand for commodities and the congressional lobby for agriculture expansion also explain, in part, the illegal deforestation that still takes place in the region, preventing achievement of zero deforestation. The proportion of deforestation in the whole Amazon that is illegal seems to be high (>80%), although this is difficult to estimate (Hummel, 2016). For example, a recent study conducted by the Amazon Environmental Research Institute-IPAM (Tiago Reis, personal communication, February, 2016) estimated that 91% of deforestation ongoing in private properties of Mato Grosso state is illegal.

Positive incentives for production of sustainable commodities (*Strategy #2*, Table 2) must expand to reverse the high rates of illegal deforestation. Innovative financial incentives for sustainable agriculture, such as the Low Carbon Agriculture Program (ABC Program, MAPA/ACS, 2012), need to be consolidated and expanded. But traditional and official credit programs available for agriculture must also incorporate environmental criteria. For example, the "Safrá Plan", the most important Brazilian credit program for agriculture, will offer around USD 46 billion (R\$ 187,8 billion, converted to a rate of 1 USD ~ BRL 4,02 on Jan 11, 2016), during 2015–2016, as credits for farmers without requiring any additional measures of environmental protection (MAPA, 2015). Contrast this funding level with that of the ABC Program, which offered a volume of credit around USD 1 billion between July 2014 and May 2015 (Observatório do Plano ABC, 2015). The amount of credit provided by these two programs needs to be inverted.

Including environmental criteria in existing tax systems could also offer an economic advantage to land owners or even jurisdictional entities (municipalities or states) for preserving their forests. A successful example of a green tax in the Brazilian Amazon is one operated by Pará State called the Green ICMS (ICMS is a tax on the movement of goods and services among states). The state government distributes 25% of ICMS tax revenue to municipalities, taking into consideration the proportion of preserved forests in their territory and/or their efforts to reduce deforestation. From 2013 to the end of 2017, around USD 35 million will be distributed to 107 municipalities (Green Municipality Program, 2013).

Market campaigns can also play an important role, demanding commodities free of deforestation and illegality (i.e. compliance with the Forest Code) as purchasing and financing criterion (Gibbs et al., 2015; Azevedo et al., 2015). The soy moratorium is a good example of the role of buyers in reducing deforestation (Gibbs et al., 2015). In 2006, NGOs identified that soybeans were being harvested from illegally deforested properties and, thus, contaminating global supply chains. Traders (particularly Cargill) and companies selling directly to consumers (e.g. McDonalds) played an important role calling for a moratorium, urging others to purchase grain only from deforestation-free production. The two major soybean trade associations (ABIOVE - Brazilian Vegetable Oil Industry Association and ANEC - Brazilian Grain Exporters Association) responded by announcing that they would not purchase soybeans produced on farms deforested (legally or illegally) after July 24, 2006 (a date later changed to 2008). As a result, the area of soy planted in deforested areas from 2007 to 2012 amounted to only 0.7% of the deforestation in the Brazilian Amazon states of Mato Grosso, Pará and Rondônia (Gibbs et al., 2015). However, the challenge to keep the soy supply chain free of illegality still remains (Azevedo et al., 2015).

The third threat identified as a constraint to ending deforestation in the Amazon is the role of unsustainable settlements (Table 2). As a consequence of the reduction in deforestation driven by large farmers and ranchers, a significant proportion (10–30%) of the ~ 5000 km<sup>2</sup> deforested every year is now attributed to smallholders, particularly in settlements established by the Brazilian government (Figure 1) (Schneider and Fearnside, 2005; Tourneau and Burztnyn, 2010; Alencar et al., 2015; Peres, 2015). But, there is no basis to

support the contention that settlers are deforesting more now than before (Alencar et al., 2015). Currently, 50% of deforestation attributed to settlers in the region occurred in only 2% (58) of 2,200 settlements sampled (Alencar et al., 2015). Nevertheless, reducing the region's deforestation to zero requires transforming settlements into socio-environmentally sustainable initiatives (*Strategy #3*, Table 2). The ideal precondition for sustainable settlements would be to provide settlers with the means to retain productivity on their lands while preserving their forests (Soave Jr. et al., 2014). This will require combining a set of innovative and already existing strategies, such as: a) providing technical assistance to intensify agricultural productivity in already deforested areas; b) promoting land tenure regulation; c) expanding credit for environmentally-friendly producers; d) strengthening smallholder representative organizations; and finally e) compensating settlers for the environmental services they provide, such as forest protection (Martins et al., 2010; Soave Jr. et al., 2014). These strategies are being piloted in Pará State by IPAM and its partners with support of the Amazon Fund, and have inspired a public policy called the "Green Settlements Program", currently operated by INCRA, the Brazilian agrarian reform and land tenure regularization agency (Alencar et al., 2015).

The fourth threat is resistance to and skepticism about implementation of the new Brazilian Forest Code (Law N<sup>o</sup>. 12.651/2012) by the National Congress and agriculture sectors. Full implementation of this new law is essential to discourage additional deforestation (*Strategy #4*, Table 2). If well implemented, the Forest Code opens possibilities to protect forests and reduce deforestation to zero through innovative market mechanisms (REDD-PAC Project, 2015; Soares-Filho et al., 2014). For example, the Environmental Reserve Quota predicted by the Forest Code could create a trading market of forested areas that would give landowners the incentive to prevent deforestation on properties where they still have the right to deforest legally (Soares-Filho et al., 2014). Farmers and ranchers in the Amazon biome with surplus of legal reserve (i.e. more than 80% of forested area preserved on their properties as established by the Forest Code) could use this trading mechanism to offset the legal reserve debt (< 80%) on another property. This innovative market approach could potentially offset 56% of the legal reserve deficit in the country (Soares-Filho et al., 2014). The use of the Environmental Reserve Quota, however, still needs to be fully implemented and depends on implementation of another Forest Code mechanism - the Rural Environmental Registry (CAR), a geo-referenced map of rural properties (SICAR, 2015). This involves developing an electronic registry of every rural property in the country, finally making possible the integration of environmental and landowner information. When fully implemented, the national system of CAR will represent a powerful tool to prevent illegal deforestation.

A market mechanism for compensation for forest protection could also emerge from the National Policy for REDD+ (Moutinho et al., 2012). In 2014, the Brazilian government, under coordination by the Ministry of Environment, submitted to the UNFCCC its reference levels for Amazon deforestation (MMA and MCTI, 2014), allowing the country to register reduced emissions and to capture financial compensation through the Reduced Emissions from Deforestation and Forest Degradation (REDD+) mechanism. The REDD+ mechanism currently being discussed by the UNFCCC works on a multi-level system (global-national-local) and guarantees financial compensation for those countries engaged in conserving their forest carbon stocks and reducing emissions from deforestation. In parallel to the REDD+ mechanism at UNFCCC, Brazil has received more than USD 1 billion from Norway since 2008 through the Amazon Fund, the most successful REDD experience in the world. Expansion of this program in the context of the UNFCCC and its REDD+ initiative could create new incentives to end deforestation in the Amazon because it financially compensates both stakeholders avoiding deforestation and those historically preserving forest, such as indigenous people and traditional communities.

The fifth threat is related to the strong agribusiness lobby in the National Congress pushing for expansion of agricultural and mining activities in protected areas (RAISG, 2012), including indigenous lands. The proposal to change the Brazilian Constitution (called the acronym PEC 215), and currently under debate by the National Congress, intends to transfer responsibility for the establishment of new protected areas - indigenous lands, biological reserves, national parks, and also "*quilombola*" (escaped slave community) areas - or to change (reduce) the size of existing protected areas - from the federal executive branch to the Congress. The *bancada ruralista* (rural caucus) constitutes the strongest lobby group in the Congress, representing increased risk of jeopardizing the land rights of forest dwelling people (Crisostomo et al., 2015). Additionally, the current composition of political representatives at the Congress strongly supports the agribusiness sector and exerts much political pressure against environmental policies, arguing that those policies are a barrier to agriculture (Soares-Filho et al., 2014) and infrastructure expansion. For example, bills already under discussion at the Congress against the halting deforestation include: (1) delays to implement the forest code; (2) the proposal of the law project PL 654, which aims to promote more flexibility in granting environmental licensing for large infrastructure projects; and (3) threats to the recognition of indigenous territories (law project PL 215). However, this political scenario could change if there is effective communication (*Strategy #5*, Table 2) regarding the scientific knowledge about negative effects of deforestation and climate change on regional temperature (Silvério et al., 2015) and, consequently on rainfall and crop production in the Amazon and surrounding areas.

The "thermostat" function of forests over regional climate was clearly demonstrated by recent analysis of deforestation's effect on atmospheric temperature in the Xingu region, which maintains a large portion of

pristine forest protected by indigenous populations. From 2001 to 2010, the temperature in the agricultural areas surrounding the Xingu Indigenous Park increased 0.5°C. The temperature in these deforested areas was 4–6°C higher than the temperature inside the Park (Silvério et al., 2015). Also, the Xingu Indigenous Park contributed up to 29% of the total evapotranspiration in the basin in 2010 even though it covers only 19% of the Xingu River watershed (Silvério et al., 2015). Scientific evidence from the Xingu basin indicates that, without protecting large portions of forests at the local and regional level, a future scenario of more droughts and higher temperatures for the region predicted by global climate change models (Duffy et al., 2015, Lewis et al., 2011) could be even worse (Silvério et al., 2015).

Insecure land tenure is the sixth critical threat to achieving zero deforestation, as well as the origin of the predatory nature of economic activities in the Amazon. The lack of clear land titles precludes a long-term approach to investment in land management, perpetuating extensive and extractive economies. In addition, almost 80 million hectares of public forests are still not allocated to some official use category (CNFP, 2013; Zarin et al., 2015), therefore opening up these land areas to unscrupulous use and land grabbing. Thus, *Strategy #6* (Table 2) involves promoting effective land governance by expanding land rights and allocating remaining public forests to some appropriate legal use category (e.g. protected areas, rural settlements, indigenous lands) that would convey greater protection and public accountability. Since 2009, the main goal of a federal program called Terra Legal (Law 11.952/09) has been distribution of land titles to smallholders in the Amazon. The target is to distribute land to 150 thousand smallholders (MDA, 2015), and up to 2014, the government granted 6,500 land titles covering over 6,000 hectares. At this pace, the federal government would need 115 years to complete the land titling mission. This does not even take into account smallholders on state lands in the Amazon and land tenure conflicts on larger properties. This shows the urgent need for an expedited process with appropriate safeguards to exclude land grabbers in order to bring governance to Amazon land areas where it is absent today. Likewise, approximately 80 million hectares of undesignated public forests in the Amazon (Figure 1) need to be allocated as protected areas, production forests, indigenous lands or other categories of use. This allocation of undesignated public forests could also preserve a stock of 10 billion tons of forest carbon and contribute significantly to the conservation of biological diversity of the region (SFB and IPAM, 2011). Moreover, land designations would benefit from efficient and flexible agreements between the government and land users, given the recent evidence that flexibility of some use rights for smallholders can increase achievement of conservation goals (Pfaff et al., 2013).

Interactions between different policies can exacerbate this complex mosaic of threats to achieving zero deforestation. As one example, we can end up with large availability of land for cattle production if the state does not follow suggestions on creating protected areas (threat #6). Indeed, studies already indicate that, in spite of efforts to intensify productivity of cattle farming, there is no guarantee that producers will not search for more lands (Bowman et al., 2012).

Apart from all of these threats, we have had to deal with an economic and political crisis since 2014 that led to the impeachment of the current President (Dilma Rousseff). The internal crisis may jeopardize the past advancements of Brazil's deforestation and climate change policies, mostly due the lack of resources and investments in forest protection (Guimarães and Schwartzman, 2016). On the other hand, there is now more evidences on the benefits of a zero-deforestation approach than can bring together opposite sides. For instance, some studies have shown that the decline in agricultural and pasture productivity was related to a local increase in temperature and reduction of rainfall caused by an increase in deforestation (Lawrence and Vandecar, 2015; Silvério et al., 2015).

## Conclusion

The future of the Amazon depends on halting deforestation as soon as possible while continuing to expand forest protections in the region. Despite the success of reversing the historical pattern of deforestation in the Brazilian Amazon by 70% over the past decade, deforestation rates have remained at around 5,000 km<sup>2</sup>.y<sup>-1</sup> since 2012 (INPE/PRODES, 2016). This is still high enough to aggravate the local climate in the Amazon and to jeopardize the ecological balance of the region. Additionally, deforestation of 20% of the total area of the Brazilian Amazon did not result in better development or quality of life for the inhabitants of the region. Therefore, it is important to achieve the ambitious goal of zero deforestation within the next decade. The six threats and their corresponding strategies to achieve zero deforestation discussed here call attention to what policies and actions are still missing, without exhausting all possible measures. These changes, however, do not depend only on the implementation of policies and strategies to control deforestation. A new paradigm needs to be developed for the Amazon and for other tropical countries that promotes economic growth, social justice and productive agriculture while preserving forests to maintain fundamental ecosystem services. Political leaders and decision makers must realize that socioeconomic development cannot be achieved without preserving the forest's capacity to generate ecosystem services. It is time to understand that preservation is easier and cheaper than restoration.

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- Drafted and/or revised the article: PM, RG, CA-R
- Approved the submitted version for publication: PM

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#### Competing interests

The authors have declared that no competing interests exist.

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