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White Paper

Why Brazil needs its Legal Reserves

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ABSTRACT

Brazil's environmental legislation obliges private properties to retain a fixed proportion of their total area with native vegetation, the so-called "Legal Reserves". Those areas represent practically one third of the country's native vegetation and are well known for their role in biodiversity protection and in the provisioning of a wide range of ecosystem services for landowners and society. Despite their relevance, this instrument has been criticized by part of the agribusiness sector and its representatives in the Brazilian Congress. The Legal Reserve requirement is said to be too restrictive and to impede the full expansion of agricultural activities, and thus to be detrimental for the development of the country. Here, we critically analyze the arguments employed in the justification of a recently proposed bill that aims to completely extinguish Legal Reserves. We demonstrate that the arguments used are mostly unsupported by data, evidence or theory, besides being based on illogical reasoning. Further, we synthesize the principal benefits of Legal Reserves, including health and economic benefits, and emphasize the importance of these reserves for water, energy, food, and climate securities, in addition to their primary function of assisting in the maintenance of biodiversity in agricultural landscapes. We also highlight that Legal Reserves are a key-component for effective and less expensive nature-based solutions, and thus should be considered as assets for the development of Brazil rather than liabilities. Based on available sound scientific evidence and agreement on their relevance, we strongly oppose any attempt to extinguish or weaken the maintenance of Brazil's Legal Reserves.

Introduction

Brazil's environmental legislation[1] obliges landowners to maintain a fixed amount of native vegetation in parts of their property, the so-called "Legal Reserves". The main objective of these areas is to guarantee the conservation of biodiversity, the provision of multiple ecosystem services, and the sustainable use of natural resources in rural properties. Legal Reserves can be used economically as long as natural vegetation[2] is maintained or restored (see Brancalion et al., 2016). The Legal Reserve requirement in

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[1] The Native Vegetation Protection Law from 2012 (n. 12.651/2012), which substituted the Brazilian Forest Code from 1965.

[2] We use here "native vegetation" and "natural vegetation" as synonymous, including natural and semi-natural habitats.

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proportion of the property varies from 80% for forest vegetation in the Amazon to 35% in the transition between Amazon and Cerrado and to 20% in remaining regions (Atlantic Forest, Cerrado, Caatinga, Pantanal and Pampa). This obligation to protect natural vegetation in private properties exists in Brazilian environmental legislation since the Forest Code of 1934. However, it has been criticized by part of the agribusiness sector and their political representatives to be too restrictive, to impede property owners from realizing their activities and to violate property rights. This debate recently came back on the table with a bill that has been presented to the Brazilian Senate (*Projeto de Lei* n. 2362/19), aiming to remove completely the Legal Reserve requirement from Law 12.651. The bill is based, principally, on the argument that Brazil needs to expand its agricultural activities in order to stimulate economic development. Here, we analyze the risks that the extinction of the Legal Reserves would represent to biodiversity conservation and human wellbeing, and critically debate the arguments used to justify the extinction of the Legal Reserve. We also discuss an alternative scenario, where the contributions of natural vegetation to increase agricultural productivity, quality of life and economic stability of the country in the long run are valued. Although we used a specific bill to discuss the importance of Legal Reserves, we hope that our rationale also serves to pave further discussions related to conservation of natural vegetation and biodiversity in Brazil.

The risks of the bill

The immediate impact of extinguishing the Legal Reserve requirement is the increase of areas with natural vegetation that could legally be converted to other land uses. At current, an area of 103 million hectares (Mha) of natural vegetation in Brazil is not protected under Law 12.651, neither as Legal Reserves nor as Areas of Permanent Protection (APPs, areas meant to protect riparian corridors, steep slopes and other sensitive ecosystems). Thus, the conversion of these natural ecosystems to other land uses, such as agriculture, can be authorized. These areas are mostly concentrated in the Cerrado (44 Mha) and in the Caatinga (35 Mha) (Table 1, Guidotti et al., 2017). If the bill in question were approved, areas currently considered as Legal Reserves with natural vegetation could also be legally converted, which would mean an additional potential loss of 167 Mha of natural vegetation in Brazil (i.e., 29% of the remaining native vegetation). In total, the area that legally could be converted (~270 Mha) would correspond to one third of the country's area, and almost half of the remaining Brazilian native vegetation (46%). The Amazon region, where natural vegetation today covers 85%, could have natural vegetation reduced to 61%. In the Cerrado, the 57% of remaining natural vegetation could be reduced to 13%, and the Caatinga, today with 63% of native vegetation, could end up with only 3% (Table 1). All these losses of natural ecosystems would be completely legal.

Obviously, the conversion of natural areas to other types of land cover in such a magnitude, if legally authorized, will have blatant and well-known consequences (Díaz et al., 2019), including massive extinctions of endemic or already threatened species, substantial emissions of greenhouse gases, losses in recharge capacity of rivers and aquifers, erosion and loss of soil, silting of rivers and reduction of water quality, apart from reduction of other ecosystem services, including those that are directly beneficial for agricultural production, such as crop pollination or natural pest control, among others (see the "The importance of Brazil's Legal Reserves" section).

The widespread impacts resulting from the conversion and degradation of native vegetation in Brazil are already well documented. In the Amazon region, for example, according to current deforestation scenarios, 36–57% of species are at risk of disappearing (Gomes et al., 2019; ter Steege et al., 2015), including important economic species such as Brazil nut, açaí palm and cacao. The situation is even more worrisome in other Brazilian biomes, where large proportions of natural areas have already been lost (e.g. Beuchle et al., 2015; Portillo-Quintero and Sánchez-Azofeifa, 2010). Amazonian deforestation also leads to soil erosion (Fearnside, 2005), reduction of ecosystem services (Davidson et al., 2012) and altered climatic patterns (D'Almeida et al., 2007; Malhi et al., 2008). Across biomes, loss of natural ecosystems to agricultural areas will also affect the water cycle (Silvério et al., 2015), with expected negative impacts on energy production as hydroelectric power plants are responsible for more than 60% of the electric energy produced in Brazil.[3]

Conversion of natural vegetation into agricultural production areas may have overall negative impacts on agricultural productivity (see the "The importance of Brazil's Legal Reserves" section). The expected changes would add to the already deteriorating situation of biodiversity and ecosystem services worldwide. For example, according to the recently published report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), one million of plant and animal species already face extinction, and the loss of pollinators may negatively impact agricultural production in the range of hundreds of billions of US dollars annually (Novais et al., 2016b; Díaz et al., 2019).

Apart from direct economic impact in terms of reduction of productivity, effects can also be expected in terms of losses of share on the international market. A large number of actors, including traders, industries, retailers and processors, are promoting supply-chain commitments to reduce deforestation (Lambin et al., 2018). Governments can also play an important role in providing incentives or sanctions to stimulate the adoption of sustainable practices, avoiding native vegetation suppression in their supply-chains or promoting changes in agricultural practices. China, for example, is now engaging in large-scale programs that aim at making agriculture more sustainable, including reductions of greenhouse gases emissions (Cui et al., 2018, see also Bryan et al., 2018). At the international level, the United Nations are stimulating better agricultural practices by its 17 sustainable development goals. The Council of the European Union issued recently its Council Conclusions on Climate Diplomacy with a strong commitment to the Paris Agreement and related actions (Council of the European Union, 2019). In April 2019, more than 600 European scientists and representatives of 300 indigenous people called upon the European parliament to strengthen efforts toward sustainable trade that considers human rights, environmental protection, and climate change mitigation (Kehoe et al., 2019). This initiative was subsequently endorsed and supported by 56 Brazilian researchers (Thomaz et al., 2019). It thus becomes clear that any policy that blatantly disregards consequences of agricultural production on the environment and on human rights will bring the risk of economic losses to Brazil and its producers.

The false arguments behind the bill

Many of the arguments used to support the bill that aims to extinguish Legal Reserves in rural properties in Brazil are based on illogical reasoning and are mostly unsupported by data, evidence or theory, as we show point by point in the following discussion.

Is conversion necessary to increase agricultural areas?

There are no valid arguments for the immense increase of natural areas that could legally be converted to other land uses under

[3] http://www2.aneel.gov.br/aplicacoes/capacidadebrasil/OperacaoCapacidadeBrasil.cfm

Table 1
Brazilian native vegetation and agricultural cover (based on MapBiomas data, collection 3.1; A), and Legal Reserve extensions (Guidotti et al., 2017; B) for all biomes. Total native vegetation that could be legally lost is estimated considering the sum of vegetation not protected by the Native Vegetation Protection Law (Law 12.651/2012) and the potential loss of all current Legal Reserves.

A.

Biomes	Total area	Current native vegetation cover		Agriculture (crop and pasture)	
	(Mha)	(Mha)	%	(Mha)	%
Amazon	421.6	356.3	85%	53.1	13%
Caatinga	83.6	52.3	63%	30.2	36%
Cerrado	203.0	115.1	57%	85.4	42%
Atlantic forest	110.7	37.6	34%	68.9	62%
Pampa	17.7	9.8	55%	5.9	33%
Pantanal	15.0	12.5	83%	2.1	14%
Total	851.64	583.6	69%	245.6	29%

B.

Biomes	Legal Reserves (Mha)	Native vegetation that currently could be legally converted (Mha)	Total native vegetation that could be legally lost if the new bill is accepted (Mha)	Remaining protected native vegetation cover if the new bill is accepted %
Amazon	88.5	12	100.5	61%
Caatinga	14.5	35	49.5	3%
Cerrado	45.7	44	89.7	13%
Atlantic forest	12.2	0	12.2	23%
Pampa	2.6	4	6.6	18%
Pantanal	3.4	8	11.4	7%
Total	167	103	269.9	37%

the proposed bill. Recently, the former Forest Code was thoroughly revised, leading to the Native Vegetation Protection Law from 2012 (Brancalion et al., 2016). This revision already led to a reduction of Legal Reserve requirements by 37 Mha (Guidotti et al., 2017) due to an amnesty for former illegal conversion, which under the previous law would have required restoration (Soares-Filho et al., 2014). As a result, the deficit of Legal Reserves, i.e. restoration or compensation requirements, today is much smaller (11 Mha) than it had been before (48 Mha; Guidotti et al., 2017). Furthermore, different mechanisms were established to facilitate law compliance by property owners that have converted native vegetation beyond what used to be legally permitted. This includes the possibility to compensate deficits outside their own property. Additionally, it is important to mention that land set aside as Legal Reserves tends to have low suitability for intensive agriculture (Latawiec et al., 2015). Therefore, conversion of Legal Reserves would mostly lead to immediate and limited gains (e.g. from selling wood or charcoal, initially, and then with cattle grazing on former forest areas). On the long run, the result would be more degraded and unproductive lands.

Brazil already has vast areas of degraded or not efficiently used pasture lands in regions highly suitable for agriculture (Sparovek et al., 2015). Productivity of cultivated pastures, which cover 115.6 million hectares in total, has been shown to be at only 32–34% of its potential, and an increase of about 50% of the estimated potential pasture productivity, considered feasible under current patterns of regional land use, would allow meeting the demands for meat until 2040, sparing already converted land for crops, wood products and biofuels, without additional conversion of natural vegetation (Strassburg et al., 2014). Furthermore, the current trend is a decoupling of production and natural vegetation conversion (Lapola et al., 2013), since the growth of agricultural production increasingly depends on local intensification, thanks to new technologies (Abramovay, 2018). Extensive destruction of natural vegetation is therefore not a requirement for the increase of agricultural production in Brazil, just as has also been shown in an analysis at the global level (Foley et al., 2011).

Additionally, Legal Reserves can be economically exploited as long as this is done in a sustainable way and natural vegetation is maintained at least partially. For example, in Brazil, more than 469 plant species are currently used in agroforestry systems that are allowed in Legal Reserves (Joly et al., 2018). Increased consumption of fruits produced in these systems may also contribute to human health (Tilman and Clark, 2014). More than 245 species of the Brazilian flora are used for cosmetic and pharmaceutical products, and at least 36 of them have already been registered as phytotherapeutic plants (Joly et al., 2018), and all of them may be cultivated in Legal Reserves. Many exotic species of high economic interest can also be used for restoration of Legal Reserves, if combined with native species and if not covering more than 50% of the area. In natural grassland regions, such as in Pampa and Pantanal, livestock grazing is allowed in Legal Reserves: when well-managed, these areas can provide competitive economical return to farmers, while also conserving natural resources (Overbeck et al., 2007, 2015). The financial gains stemming from sustainable use of natural resources in Legal Reserves, including the implementation of agroforestry systems, can even be much higher than those from degraded cultivated pastures currently under use (Batista et al., 2017).

Does Brazil protect more natural areas than other countries?

The argument that Brazil protects more natural areas than other countries, presented in the bill as one of the principal justifications for the extinction of the Legal Reserve requirement, is wrong. In Brazil, natural vegetation cover is estimated to be approximately 65–69% of the territory. In the World Bank ranked country list of forest area, Brazil holds the 30th place (with 59% of forest cover), after countries with very high socioeconomic development, such as Finland (73%) or Sweden (69%) (The World DataBank[4]). Considering natural and semi-natural lands, Brazil ranks only in the 118-122th place (with 73% of cover) from 300 analyzed countries (European Commission and Joint Research Centre, 2018).

[4] https://data.worldbank.org/indicator/

A common argument in favor of the expansion of agribusiness in Brazil is the fact that in Brazil only one third of the national territory is covered by agricultural land, which is said to be less than several developed countries. The authors of the bill explicitly refer to the United States, Australia and Canada to be countries with larger percentage of agricultural land in comparison to Brazil. However, the numbers they present are not correct. In the United States, for instance, only 22% of the total area is used for agriculture and intensive pastures (Sleeter et al., 2018) and 44% for all agricultural activities[4], i.e. including extensive rangelands, and not 74%, as stated in the justification of the bill. In Australia and Canada, the percentage of agricultural areas is even much lower (Australia: 13%,[5] Canada: 7%[4]). In Europe, agriculture cover varies from 21% to 43%, with a strong decreasing tendency (in contrast to Brazil). Maintaining those tendencies, Brazil will, proportionally, have more agricultural land than the European Union before 2030 (The World DataBank[4]).

Further, the value of 65–69% of remaining natural vegetation in Brazil is the national mean, strongly influenced by the Amazon region, where 85% is natural vegetation. In other regions of Brazil, the situation of natural land cover is worrying: in the Atlantic Forest, for example, the remaining native vegetation cover is estimated to be between 28% (Rezende et al., 2018) and 34% (Table 1). At a regional scale, many parts of the country show very low levels of natural vegetation (<20%), in particular regions with high suitability for agricultural production that have been almost completely converted (>70%), e.g. in parts of Mato Grosso, Paraná, São Paulo or Rio Grande do Sul (data from MapBiomas collection 3.1; http://mapbiomas.org). This means that the benefits of Legal Reserves for human societies (see the "The importance of Brazil's Legal Reserves" section) are very unequally distributed in Brazil.

The same reasoning applies for strictly protected areas. In total, Brazil sets apart 6% of its territory for biodiversity conservation in public areas (IUCN protected areas categories I and II), but most of it is concentrated in the Amazon region. Outside the Amazon, land under protection reaches a maximum of 3% and is only around 1% in the Pampa (Table 2). Those values represent only a small part of the international requirements of protected areas (e.g., the Aichi Biodiversity Targets from the Convention on Biological Diversity suggests the conservation of at least 17% of terrestrial ecosystems) and are low when compared with protected area extension in other countries (Pacheco et al., 2018; Battistella et al., 2019). Indeed, the Brazilian commitment to meet its National Target within the Aichi Biodiversity Targets for protecting, by 2020, at least 30% of the Amazon and 17% of each of the other terrestrial biomes, includes the Legal Reserves.[6] Without including the Legal Reserves, this target will not be met.

Does the Legal Reserve requirement impede economic development?

The authors of bill 2362/19 assume that an increase in agricultural production in areas today defined as Legal Reserves will increase production and thus increase economic development of the country. In the bill justification, authors refer to the US as a country with large agricultural production and large wealth. However, if we look at data it becomes obvious that the economic performance of the US does not stem from agricultural production. Even though the country is one of the world's largest producers of agricultural goods, agricultural activities only correspond to 5.4% of the US gross domestic product (Data from US Department of Agriculture, for 2017[7]). Clearly, the way to economic development is not based on expansion of areas for production of commodities.

Furthermore, a UN report on global commodity dependence shows that those countries in the world that highly depend on commodities actually show lower indices of human development, i.e. are poorer (United Nations Conference on Trade and Development and Food and Agriculture Organization of the United Nations, 2017). This negative link between commodity dependence and development persists even after periods of economic growth due to high commodity prices.

Is agriculture the sector that contributes the strongest to conservation?

The argument that in Brazil the agricultural sector is responsible for conservation of natural resources, also stated by the bill proposers, is heavily biased. It is true that large parts of natural vegetation are found on private lands. But if we look not at total extent of natural vegetation, but instead focus on gains (regeneration) and losses (conversion of native vegetation to other uses), Brazil turns out to be the country with highest losses of natural vegetation of the world (European Comission and Joint Research Centre, 2018; Food and Agriculture Organization of the United Nations, 2016) – and these processes occur on private land. In the past 30 years, net losses of natural vegetation on private properties were above 20%, in comparison to only 0.5% in protected areas and 5% in other public land (Azevedo and Pinto, 2019). Deforestation rates can be up to 20 times lower in protected areas or indigenous lands when compared with adjacent private lands (Nepstad et al., 2006; Soares-Filho et al., 2010, Pfaff et al., 2014). This means that a considerable part of landowners does not effectively maintain, and protect, natural vegetation. For example, an analysis of land use changes in the Cerrado region in northern Minas Gerais indicates an annual loss of 1.2% of natural vegetation from 2000 to 2015 (Espírito-Santo et al., 2016). If these tendencies continue – and the proposed bill will likely increase conversion of natural vegetation – the current stocks of natural vegetation can be rapidly dilapidated. Additionally, it is worth mentioning that effective conservation includes more than maintenance of natural vegetation. For instance, it would mean following principles of 'ecological intensification', such as reducing pesticide use and promoting better spatial arrangement of natural areas (Kovács-Hostyánszki et al., 2017; Rother et al., 2018), to give just two examples.

Is conservation linked to poverty?

The proposed association between conservation of natural ecosystem and poverty is another false argument used in the bill. Conservation does not mean that populations in the region will have to live in poverty. It is true that about 40% of natural vegetation in Brazil is situated in 400 municipalities (7% of total municipalities) that are home to 13% of the economically most deprived Brazilians (Joly et al., 2018). However, the spatial relation between poverty and conservation areas in Brazil lacks a causal link. Historically, the conversion of forests or other natural ecosystems to agricultural areas has not resulted in significant increases of human well-being of local populations. On the contrary: what has been described is a boom-and-bust pattern under which different indicators of life quality rise initially as deforestation starts, but fall back to pre-deforestation values as the agricultural frontier moves on to new

[5] Australian Bureau of Agricultural and Resource Economics and Sciences, http://www.agriculture.gov.au/abares/aclump; 46% of the country's area is used for grazing in natural ecosystems. According to World Bank data (see footnote 4), total area for agricultural activities in Australia is 48%.

[6] https://www.cbd.int/nbsap/about/latest/default.shtml#br

[7] https://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=58270

Table 2
Extent of protected areas for all Brazilian biomes (source: CNUC/MMA – www.mma.gov.br/cadastro_uc).

Biomes	Strictly protected areas (Mha)	Protected areas of sustainable use (Mha)	Total protected areas (Mha)	% of strictly protected	% of sustainable use area	% of total protected area
Amazon	41.31	75.17	116.48	10%	18%	28%
Caatinga	1.41	5.82	7.23	2%	7%	9%
Cerrado	5.82	10.58	16.40	3%	5%	8%
Atlantic forest	2.19	7.73	9.92	2%	7%	9%
Pampa	0.11	0.43	0.54	1%	2%	3%
Pantanal	0.44	0.25	0.69	3%	2%	5%
Total	51.28	99.98	151.26	6%	12%	18%

forest areas (Rodrigues et al., 2009). Deforestation may generate economic growth and improvements in human development level, mainly driven by agricultural and industrial activities, but those gains can be ephemeral if producers do not stop depleting natural resources and implement more eco-efficient activities instead (Sathler et al., 2018). Furthermore, land uses adopted after deforestation in the Amazon, such as livestock grazing, only provide very low income in remote regions, while causing severe environmental degradation (Garrett et al., 2017). Recent studies in the Amazon have even shown that agriculture is negatively associated with human welfare at the local level, possibly due to the dominance of cattle-ranching as the predominant economic activity of this sector (Silva et al., 2017).

The importance of Brazil's Legal Reserves

A considerable proportion of Brazil is covered by natural vegetation, which is desirable if we consider the responsibility of the country not only to maintain its high biodiversity, but also to maintain the benefits that these areas have for the country's population, including for the productive sector. Natural vegetation provides a wide range of ecosystem services, such as pollination, water conservation, climate regulation, fire protection, regulation of pests and diseases, among others (Pascual et al., 2017). All these services contribute to food, climate, water, energy security, and human health. Due to their total extent and their wide spatial distribution, Legal Reserves are crucial for the provisioning of ecosystem services to the Brazilian population as a whole (Fig. 1), and, as a result, Legal Reserves are also a key component to guarantee the social function of private properties, as stated in Brazilian Constitution. In the following, we detail some of the main functions and services of the Legal Reserves.

Biodiversity protection

One of the critical functions of Legal Reserves is to provide the minimum conditions for the maintenance of biodiversity in productive landscapes where agricultural areas dominate and relegate remnant natural vegetation to small fragments or to narrow strips along rivers (Lira et al., 2012; Oliveira et al., 2017). Under such conditions, the risks of local extinctions are high, as the small populations of native species are submitted to stressful living conditions (few resources, edge effects, high levels of human disturbance). This results in a high probability of local extinctions, as the possibilities of recolonization from adjacent areas are limited: most of the species will not be able to transit across anthropogenic land use matrix (e.g. Hanski, 2011; Krauss et al., 2010). To allow a better balance between local extinctions and recolonization, it is necessary to increase landscape permeability, creating corridors, approximating the remaining fragments, or implementing land uses more permeable to biological fluxes, such as agroforestry systems in woodland areas (Metzger and Brancalion, 2016; Rother et al., 2018). In these situations, due to their large and widespread spatial distribution, Legal Reserves play a crucial role establishing conditions to facilitate flows, increasing thus landscape connectivity (Tambosi et al., 2014) and species recolonization rates (Mangueira et al., 2019). As Legal Reserves are habitat to many animals that contribute to seed dispersal, they also facilitate recovery and ecological restoration of degraded areas in their proximity (e.g. Paolucci et al., 2019).

Data from the Atlantic and Amazonian forests suggest that a cover of at least 30% of natural vegetation is needed to ensure the maintenance of communities with higher integrity, conserving some of the most vulnerable forest-dependent species (Banks-Leite et al., 2014; Ochoa-Quintero et al., 2015). For some species groups, this extinction threshold is even higher, around 50% (Morante-Filho et al., 2015). For the Campos Sulinos, a grassland dominated-region in the southern of Brazil, a recent study has indicated negative effects of habitat loss on plant and ant communities even under scenarios where more than 50% is still covered by natural grasslands (Staude et al., 2018). Below these thresholds, extinction rates increase exponentially and cause an impoverishment of the communities, which will then be dominated by more generalist species, while abundances and richness of species restricted to the original natural ecosystems will be greatly reduced. Without Legal Reserves, these extinction thresholds will no longer be reached in any Brazilian biome, except for the Amazon Forest (Table 1).

Importantly, Areas of Permanent Protection (APPs) cannot substitute Legal Reserves. As clearly defined in law 12.685, Legal Reserves and APPs are located in different environmental and disturbance regime conditions: APPs are situated (and required) at steep slopes or along rivers, while the Legal Reserves may be placed over the full gradient of environmental conditions. It is thus not possible to replace the functions of Legal Reserves with APPs, or vice versa: the two categories of conserved areas complement each other in the landscape, they protect different functions (Tambosi et al., 2015) and contribute to the maintenance of distinct groups of species. Apart from providing ecosystem functions, they work together to make agricultural landscapes more suitable and permeable to species flows, also connecting larger protected areas, such as Biological Reserve, National Parks, and Ecological Stations. Without the protection of natural vegetation in private land through Legal Reserves and APPs, many protected areas would be totally isolated within agricultural landscapes. This would also, in the long term, increase the risks of extinction in large biodiversity refuges, in spite of their formal protection (DeFries et al., 2005). As a result, natural vegetation in private properties is also important to the maintenance of biological diversity in protected areas.

Finally, processes of land use conversion in many developed countries, such as in Europe, occurred in landscapes with lower biodiversity, and began thousands of years ago (Roberts et al., 2018), which enabled the adaptation of many species to the new conditions of low intensity farming. This process led, for instance, to the development of semi-natural grasslands that are nowadays protected under the European law (Veen et al., 2009). In fact, Europe spends billions of Euros annually in order to promote biodiversity friendly agriculture and to maintain semi-natural grasslands

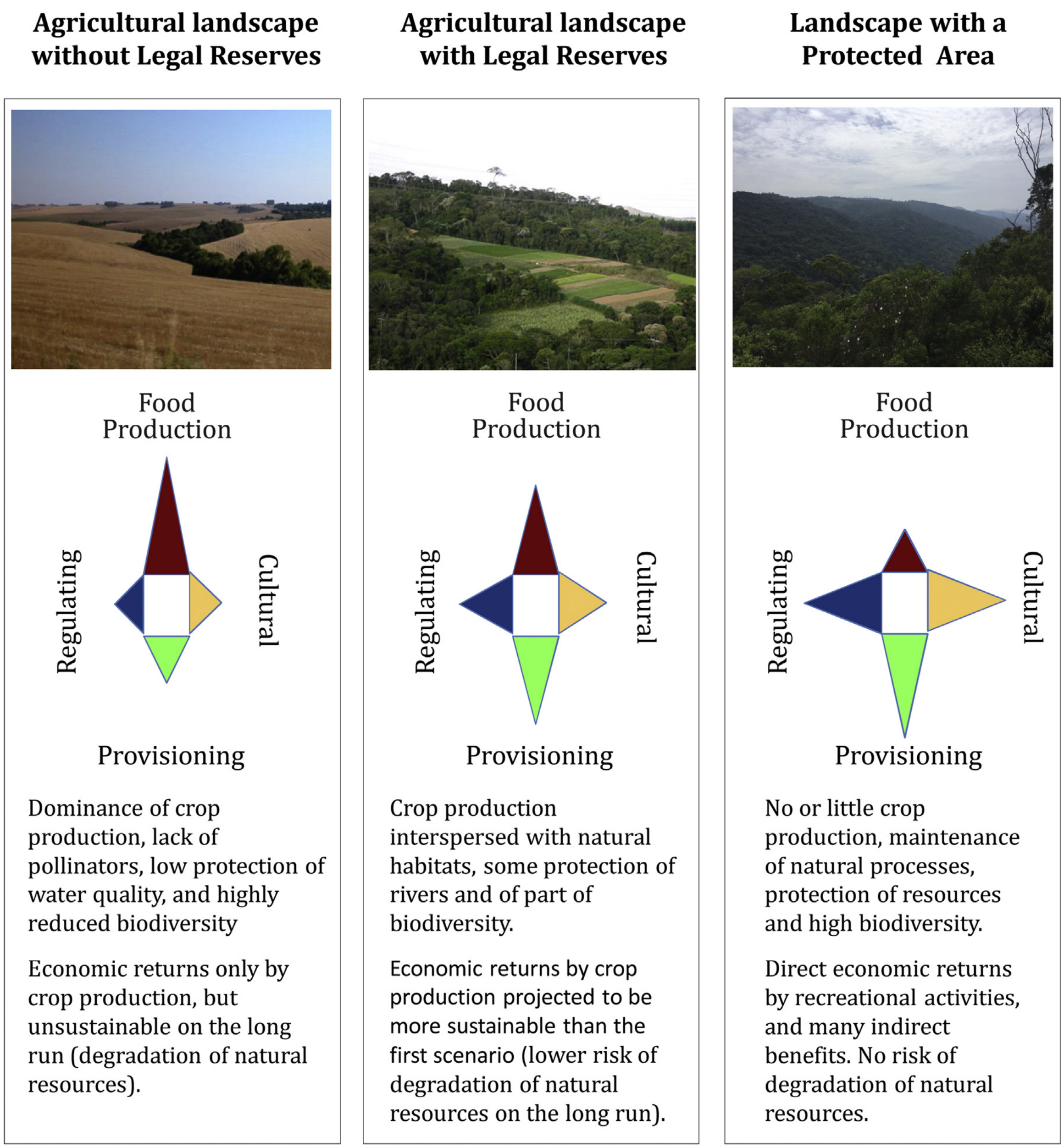

Fig. 1. Contribution of landscapes with different levels of native vegetation protection to the provision of ecosystem services.

(De Castro et al., 2012; Kleijn and Sutherland, 2003). In contrast, conversion of forest and non-forest native vegetation in Brazil has occurred mainly in high-biodiversity landscapes, along the last 200 years, and more rapidly in the last 50 years, which has not allowed species adaptation, and consequently has been accompanied by extreme extinction levels (Pimm et al., 2014).

Climate regulation

Legal Reserves are essential for climate regulation as they provide carbon storage in natural vegetation. These reserves hold around 21.5% of Brazil's aboveground carbon stocks (Freitas et al., 2018). This corresponds to 11.1 Gt of carbon, distributed across small (4.2 Gt), medium (1.8 Gt) and large farms (6.6 Gt) across all the Brazilian biomes, but with vast majority (8.6 Gt) of these carbon stocks located in Amazonian farms (Freitas et al., 2018). A scenario of broad scale deforestation resulting from the elimination of Legal Reserves would release vast amounts of carbon into the atmosphere.[8] Furthermore, there would be a missed opportunity for substantial carbon uptake in the country (Bustamante et al., 2019), if restoration of Legal Reserve deficits were no longer mandatory. The resulting carbon emissions would have strong impacts on regional and global climate, with cascading effects, such as further erosion, droughts, floods and potentially irreversible changes to natural ecosystems (Marengo et al., 2018; Nobre et al., 2016). Additionally, it has been shown that natural vegetation cover exerts an important influence on local-scale climate, due to effects on evapotranspiration and albedo (see e.g. Silvério et al., 2015; Prevedello

[8] For comparison: 11.1 Gt of Carbon corresponds to 38 years of 2015 total carbon dioxide emissions from fuel combustion in France; see https://www.ucsusa.org/global-warming/science-and-impacts/science/each-countrys-share-of-co2.html

et al., 2019). Legal Reserves thus play a key role in climate regulation and climate change mitigation and adaptation.

Energy and water security

Water is one of the crucial resources for humanity, be it for direct consumption, agriculture or energy production. While the use of groundwater resources in Brazil is rising, the major part of water used in Brazil is from surface water resources: the water withdrawn from natural ecosystems sums up to 74.830 million m^3; 60% for agriculture and livestock; 23% for municipalities, and 17% for infrastructure (ANA, 2012). Additionally, more than 60% of the electricity consumed in the country comes from hydroelectric plants[9] that rely on sufficient water flow to continue operating. The relationship between water quantity in rivers and land use and land cover is well established in the literature, even though climate change adds to the complexity (e.g. Ukkola et al., 2016; Wei et al., 2018). Concisely, natural vegetation cover promotes the decrease in runoff and increases in interception and soil infiltration during storm events, while it keeps the streamflow in dry seasons. In a case study in the Upper Xingu basin, Dias et al. (2015) found that conversion of forest to soybean led to substantial increases of streamflow, but to reduction of evapotranspiration, which has consequences for regional soil-vegetation-atmosphere water fluxes and thus precipitation patterns (Silvério et al., 2015). Spera et al. (2016) show similar processes for the Cerrado. Different agricultural production options have consequences for future water availability: continued reduction in natural vegetation cover, which is accompanied by reduced water vapor supply to the atmosphere could also affect terrestrial ecosystems that rely on precipitation for ecosystem functioning (Davidson et al., 2012, Spera et al., 2016), while dry season water consumed in intensified livestock and irrigation systems could impact aquatic ecosystems downstream (Lathuillière et al., 2018). Reduced water flow in rivers can increase the already high vulnerability of human population in many large Brazilian cities, as evidenced in the 2014 and 2015 water crisis in southeastern Brazil (Dobrovolski and Rattis, 2015; Nobre et al., 2016). The high levels of transpiration and evapotranspiration of the Amazon forests are thus important not only to sustain the forest itself, but also to maintain the rainfall in the Cerrado and key recharge areas (Fernandes et al., 2016), and also further south, including several countries in the La Plata basin (Lovejoy and Nobre, 2018). Without this vegetation, the water and energy security to the south of the Amazon region are threatened.

The relationship between presence of natural vegetation and water quality (in reservoirs, rivers and aquifers) is also widely recognized (Zhang et al., 2010). Agricultural and urban land uses lead to degradation of water quality, while natural vegetation cover plays a significant role in keeping water clean (Mello et al., 2018), reducing water treatment costs by about 100 times (Tundisi and Tundisi, 2010). This has led many countries or cities to invest in conserving native vegetation and in adopting low-impact land agricultural practices to avoid high water treatment costs for human consumption; prominent examples are New York, USA, and Munich, Germany, where municipal water organizations developed programs to pay farmers for farming practices that reduce negative impacts on water resources, such as organic farming (Grolleau and McCann, 2012).

A review on water quality in the Brazilian Cerrado shows the widespread presence of pesticides in groundwater, in some cases with high concentrations (Hunke et al., 2015), in consequence of intensive agriculture. Similar findings exist for other regions (e.g. Northeastern Pantanal Basin, Laabs et al., 2002). While APPs along rivers are to provide a buffer zone for immediate protection of water resources (though sufficiency of current requirements has been questioned based on data; e.g. Valera et al., 2019), Legal Reserves, due to their spatial extent, may be a much more important instrument to conserve water resources and the ecosystem services they provide. Consequently, water resources, in terms of quality and quantity, depend on land use in the watershed, not only on protection strips adjacent to water resources (Mello et al., 2018). Representing practically one third of Brazil's natural vegetation, Legal Reserves thus play a crucial role for the country's water and energy security.

Pollination, biological control and food security

Of a set of 141 agricultural crops analyzed in the country, 85 (60%) depend on animal pollination (Giannini et al., 2015). The diversity of pollinator species is fundamental to the effectiveness of pollination of agricultural crops (Garibaldi et al., 2016) and the maintenance of natural vegetation close to cultivated areas can guarantee this diversity and foster crop productivity (Wolowski et al., 2018; Joly et al., 2018). For example, pollination services are estimated to contribute to an increase in coffee productivity by 12–28% (De Marco and Coelho, 2004; Saturni et al., 2016), which represents a benefit of R$ 1.9 to 6.5 billion a year in Brazil (Giannini et al., 2015). However, this service only occurs in areas adjacent to natural vegetation, generally within a distance of less than 300 m from the border, which requires that natural elements be well spread in the landscape, creating more interfaces between crops and natural vegetation (Saturni et al., 2016).

The importance of pollination services by the surrounding forests was also demonstrated for the açaí palm in the Amazon river delta. Pollination of this plant has a contribution of US$ 149 million for the Brazilian economy a year (Campbell et al., 2018). The loss of pollination services for 29 of the major Brazilian food crops would reduce production by 16–51 million tons, which would translate into 5–15 billion dollars per year decrease, and reduce the contribution of agriculture to the Brazilian gross domestic product by 6.5–19.4% (Novais et al., 2016b). According to the same study, family farmers (74% of the agricultural labor force) would suffer the most from these impacts. Due to their lower income and direct or even exclusive dependence on this ecosystem service, poorer and more rural classes would mostly feel the main effects of a pollinator decline, accentuating social inequality in Brazil.

Agricultural production also depends heavily on the control of pest damage (Oerke, 2006). Crop pests are responsible for large economic losses that affect substantially not just producers' budgets but also food security (Barbosa et al., 2012). Only in Brazil, insect pests cause an average annual loss of 7.7% in production, which translates into a reduction of 25 million tons of food, fiber, and biofuels and a total annual economic loss of US$ 17.7 billion (Oliveira et al., 2014). It is particularly well established that pest population outbreaks in crops are avoided by the presence of vertebrate and arthropod predators and parasitoids (i.e. natural pest enemies; Biddinger et al., 2009; Swinton et al., 2006), leading to increased yield and income in economically important crops such as coffee, corn and cacao (Karp et al., 2013; Maas et al., 2013; Classen et al., 2014; Maine and Boyles, 2015). These organisms move from natural and semi-natural habitats to feed within adjacent plantations, a process called "spillover effect" (Tscharntke et al., 2011). The link between the presence of these fundamental pest enemies in agricultural land and the existence of natural vegetation in the immediate surroundings has been widely demonstrated worldwide (Aviron et al., 2005; Barbosa et al., 2012; Billeter et al., 2008; Boesing et al., 2017; Tscharntke et al., 2005) and also for Brazilian agricultural areas dominated by soybean (Cividanes et al., 2018),

[9] http://www2.aneel.gov.br/aplicacoes/capacidadebrasil/OperacaoCapacidadeBrasil.cfm

maize (Cividanes et al., 2018), coffee (Aristizábal and Metzger, 2019; Librán-Embid et al., 2017; Medeiros, 2019; Pierre, 2011), and cacao (Novais et al., 2016a, 2017; Sperber et al., 2004), among many others. Natural enemies depend on fragments of natural vegetation for shelter, nesting sites and alternative prey and cannot exist without them (Landis et al., 2000). Just as with the other ecosystem services, Legal Reserves, due to their extent and distribution patterns, are crucial for the widespread provision of pollination and pest control services in agricultural landscapes, contributing to the country's food security.

Control of zoonotic diseases and human health

Natural vegetation cover plays a key role not only in controlling the transmission risk of zoonotic diseases (Chaves et al., 2018; Prist et al., 2016, 2017a, 2017b), but also in providing better conditions for human health (Pienkowski et al., 2017). For instance, conversion of forest and non-forest natural vegetation to agricultural areas, especially sugarcane, increases the risk of Hantavirus Cardiopulmonary Syndrome, a disease that leads to death in 50% of infected people (Prist et al., 2016). A recent study shows that the expansion of sugarcane in São Paulo state that is expected under the current legal framework would increase in 20% the number of people at risk for this disease (Prist et al., 2017b), while landscapes with a percentage of natural vegetation cover greater than 30% could maintain Hantavirus transmission at low risk (Prist et al., 2017a). Therefore, converting Legal Reserves to agricultural uses could greatly increase Hantavirus transmission risk, and potentially the risk for other zoonotic diseases. For yellow fever, the scenario seems to be similar, with virus occurrence and dispersion occurring in landscapes dominated by forest cover loss and agricultural use (P. Prist, pers. communication). Also, in the Brazilian Amazon forest, deforestation increases the risks and incidence of malaria (Chaves et al., 2018; Terrazas et al., 2015; Olson et al. 2010): for each square kilometer of deforested land, 27 new malaria cases are produced (Chaves et al., 2018). Each person infected with malaria costs to public health more than 22 US dollars, considering ambulatory visits, blood tests, hospitalization and treatment (Akhavan et al., 1999). This does not take into account the costs of control programs, which represents 85% of government total costs with malaria (Akhavan et al., 1999). As a consequence, deforesting 88.5 Mha of Legal Reserves in Amazon will boost the number of malaria cases and have a giant negative impact not only in human health, but also for public health policies, and for the country's economy.

These few examples show that decreasing deforestation is the best effective measure for controlling zoonotic diseases as malaria, hantavirus, yellow fever, among others, and that the massive loss of natural vegetation cover can have huge impacts not only for human health but also for public health economy. The Legal Reserve thus plays a key role for human health security.

Economic value of Legal Reserves

The ecosystem services provided by Legal Reserves, as described above, have a huge economic value for society, on top of the direct economic benefits they bring to landowners. Based on mean values from around the world, one hectare of tropical forest can generate an estimated benefit of US$ 5382/ha/year (about R$ 21,000/ha/year) by the provision of 17 different types of ecosystem services, including climate regulation, water management, erosion control, pollination, biological control, cultural and recreational services, among others (Costanza et al., 2014). For natural grasslands and rangelands in general, the global average is US$ 4166/ha/year (about R$ 16,000/ha/Year). Other ecosystems can be even more valuable, such as mangroves (>R$ 700,000/ha/year) or floodplains (ca. R$ 100,000/ha/year; Costanza et al., 2014); these kinds of ecosystem are particularly important for the protection of coastal zones and for flood regulation, respectively. If we simplify and assume that the Amazon, Atlantic Forest and Caatinga are composed exclusively of forest, Cerrado and Pampa by grassland/rangelands, and Pantanal by floodplains, the loss of 270 Mha of unprotected native vegetation (including 167 Mha of Legal Reserves) will thus result in losses of around R$ 6 trillion per year.

More accurate and local estimations of specific ecosystem service values have been provided for the Brazilian Amazon forest, using spatially explicit economic values (Strand et al., 2018). Considering a range of ecosystem services, including food production (Brazil nut), raw material provision (rubber and timber), greenhouse gas mitigation (absorption of CO_2) and climate regulation (losses to soybean, beef and hydroelectricity production due to reduced rainfall), Strand et al. (2018) estimated that the value of the forest could attain US$ 737/ha/year (or almost R$ 3000/ha/year). In any of the above scenarios, the replacement of native vegetation areas by cultivated pastures or low-income crops seems to be totally irrational and inappropriate.

Social function of Legal Reserves

In Brazil, land ownership has always represented political power, and the occupation and distribution of land in the country have been associated with conflicts and tensions in rural regions. In its genesis, property rights were seen as absolute, but more recently, since the last century, the social attribute of a property began to be highlighted. The Brazilian Constitution of 1934 required landowners to use their land and available natural resources in a rational and adequate way, preserving the environment, complying with labor regulations, and favoring the well-being of owners and workers. The most recent Brazilian Constitution, from 1988, ensured in its article 170 the right to ownership of land provided that it fulfills its social function, which should include the conservation of its biodiversity, ecosystem functions and services. In accordance with this principle, native forests and other forms of vegetation have been considered of common interest to all the inhabitants of the country since the Forest Code of 1934 and, therefore, conditions to property rights should apply in those areas. This social function does not revoke ownership, but imposes on the owner social duties, which are impossible to fulfill without observance of environmental protection (Santilli, 2010). The Native Vegetation Protection Law values property insofar as it emphasizes the long-term conservation of innumerable ecological functions, and thus their contributions to collective well-being (Valadão and Araujo, 2013). Importantly, similar provisions exist in other countries, such as in Germany where the *principle of social responsibility of property* is guaranteed by constitutional law, which even grants free access to forests in private or public lands (Badura, 1976; Sievänen et al., 2013).

In considering the collective well-being, the social function of land is not only a legal concept, but also an economic one, with deep social repercussions. By definition, and as extensively presented above, Legal Reserves together with APPs have crucial roles for biodiversity protection and for assuring the wide spatial access of the benefits provided by their ecosystem services, with clear implications for a sustainable and healthy economic development. Without those areas that protect native vegetation in private properties, the social function of the land is not anymore assured.

An alternative future scenario supported by ecosystem services

The multiple functions of Legal Reserves make it clear that native vegetation and its biodiversity are assets for the development of Brazil rather than liabilities, especially under changing global environmental conditions. The Legal Reserve requirement is crucial for protecting the remnants of native Brazilian vegetation in private properties, impeding its further conversion to intensive land use (Sparovek et al., 2012). In most cases, much more will be gained by conserving or restoring (see MMA et al., 2017) these areas than by converting them.

The increasing demands of the market and the need for environmental preservation and human well-being improvement tend to value the maintenance of native vegetation and the enjoyment of the ecosystem services provided by these areas. There is widespread recognition that nature-based solutions, which take advantage of ecosystem services, have lower costs and greater benefits, both in environmental, social and economic terms (Cohen-Shacham et al., 2019). These solutions, which could be promoted by a wide range of public policies or management interventions (including payment for ecosystem services, biodiversity-based product value chains, protected areas, community-based management), allow the creation or maintenance of more resilient land use systems and landscapes (European Commission, 2016), integrating and balancing the needs of distinct actors (Primmer et al., 2015).

Ecosystem-based adaptation strategies are one example of nature-based solutions, which stand out as a significant opportunity for addressing the risks of climate change (Scarano, 2017). Through these strategies, biodiversity management can improve water flow and quality and reduce vulnerability to natural disasters and their consequent impacts (Munang et al., 2013). The effects of forests on water and climate at local, regional and continental scales provide also a powerful adaptation tool ("climate-proof landscapes") that, if wielded successfully, also has globally-relevant climate change mitigation potential (Ellison et al., 2017). Ecosystem-based adaptation, while conserving or recovering natural resources and sequestering and stocking carbon, also has the potential to reduce poverty (Joly et al., 2018).

Investing in conservation and restoration of biodiversity, ecosystems and their associated services represents a basis for a new social and economic development that can create jobs, reduce poverty and reduce socioeconomic inequality (Bustamante et al., 2019). Biodiversity and native ecosystems are fundamental elements for coping with national and global socioeconomic crises, as they bring new opportunities for development. For example, Kennedy et al. (2016) showed that compliance to the Native Vegetation Protection Law in the case of commercial sugarcane expansion in the Brazilian Cerrado can generate significant long-term benefits in terms of biodiversity conservation, carbon sequestration, and water purification, at a relatively small cost to business. In the Mississippi valley, studies quantifying and monetizing ecosystem services in restored wetlands found that the value of social well-being ranges from US$ 1435 to US$ 1486 ha/year, greenhouse gas mitigation ranges from US$ 171 to US$ 222 ha/year, and nitrogen mitigation is estimated at US$ 1248 ha/year (Jenkins et al., 2010). This example demonstrates that landscape-level mitigation provides cost-effective conservation and can be used to promote sustainable development that also has the potential to contribute to poverty reduction.[10] The concentration of poverty in municipalities with large remaining native vegetation cover represents thus a great opportunity to reconcile nature conservation with human development.

The equitable use and access to natural capital (Costanza et al., 1997) are fundamental elements for overcoming inequality in Brazil. They are also the guarantee of permanence of the multiple ways of life and social and ecological systems that represent the cultural and ethnic diversity of the country. As outlined above, Legal Reserves are an indispensable part of nature-based solutions, as they are crucial to Brazilian economy, ensuring our water, energy, food and climate security, while at the same time contributing to human well-being and biodiversity protection.

[10] https://www.cepf.net/sites/default/files/povertyreduction_atlanticforest_nov05.pdf

Conclusion

Brazil's enormous natural capital provides the necessary conditions to transform the conservation and sustainable use of its environmental assets into opportunities for development, making the country capable of successfully facing a changing climate and, at the same time, promoting socio-economic prosperity on the long run. The potential for economic production (present and future) of the country depends on the conservation of natural resources and associated ecosystem services. The benefits of Legal Reserves to society, in terms of biodiversity preservation and benefits for people and the economy, cannot be fulfilled by APPs and public Protected Areas, which have distinct objectives and functions from that of Legal Reserves. Due to their extent and spatial distribution across all biomes and regions, Legal Reserves are of crucial importance for the wide provision of ecosystem services through the landscape, and to the healthy and sustainable growth of Brazil.

In view of the enormous risks associated with the loss of Legal Reserves, the lack of solid arguments to justify such a measure, the multiple benefits they have to human well-being, and the opportunity to use these areas for the sustainable development of the country, we strongly oppose the proposal for the extinction of Legal Reserves presented in bill n. 2362/19 or to other attempts to weaken this important instrument.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.pecon.2019.07.002.

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