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Research Letters

Minimum costs to conserve 80% of the Brazilian Amazon

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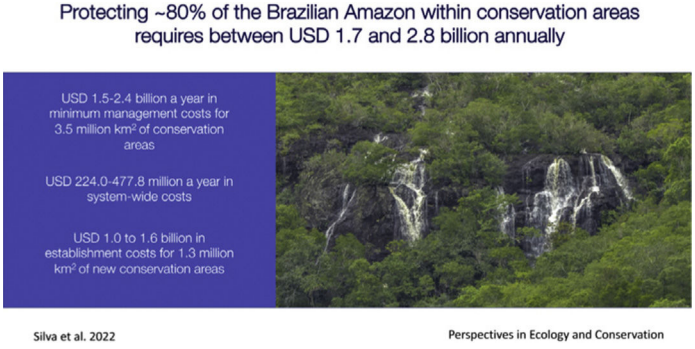
HIGHLIGHTS

- Conserving ~80% of the Brazilian Amazon is still feasible
- Conservation areas are essential for a new regional development model
- The cost of establishing.1.3 million km^2 of new conservation areas is USD 1.0–1.6 billion
- The annual cost of 3.5 million km^2 of conservation areas is USD 1.7–2.8 billion
- A new ambitious, decentralized, and agile fund mechanism is required

GRAPHICAL ABSTRACT



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ABSTRACT

The protection of the Brazilian Amazon is essential to prevent the collapse of global biodiversity and minimize the negative impacts of climate change worldwide. However, there is currently no estimate of how much it costs to conserve most of this region. We report that maintaining ~80% (3.5 million km^2) of the region within conservation areas (conservation units and indigenous lands) would minimally cost around USD 1.7–2.8 billion a year in recurrent management and system-wide costs, plus an upfront investment of USD 1.0-1.6 billion for establishment costs. Building a sustainable and definitive conservation system to maintain the socioecological integrity of the world's most biodiverse region is still possible, but the window of opportunity to achieve one of the most significant conservation accomplishments in the history of humanity can be closed soon and – given the declining resilience of the region's ecosystems – forever.

Introduction

The conservation of the Amazon is a recurrent theme of discussion in all major global conferences on biodiversity loss and climate change. This large region harbors millions of species and unique biological interactions, most of which have not yet been described by science (Mittermeier et al., 2003; Scarano et al., 2021).

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Moreover, it stores 150–200 billion tons of carbon, is responsible for global climate and hydrological regulation, and is home to at least one million indigenous people and their rich cultures and traditions (Nobre et al., 2016; Science Panel for the Amazon, 2021). Although nine countries share the Amazon, most of the global concern is focused on Brazil, which encompasses 4.3 million km^2 of the region (60%) and most of its deforestation and forest degradation (van Marle et al., 2017).

However, Brazil is not short of sound public policies designed to conserve the country's rich natural wealth. The most successful ones have been setting aside conservation areas, including public and private conservation units and indigenous lands (Silva et al., 2021b). Most of these conservation areas have been established in the last 36 years, with the end of the authoritarian regime (1985), the adoption of a new constitution (1988), and the approval of a law that regulates a national system of conservation units (2000). Currently, conservation areas in the Brazilian Amazon cover 2.2 million km^2 and comprise two large, almost continuous corridors distributed longitudinally across the region, one in the north and another in the south of the Amazon (Fig. 1). Such a conservation system has been pivotal in controlling deforestation and forest degradation and protecting the rights of indigenous and traditional populations (e.g., Gonçalves-Souza et al., 2021).

Although vast, this system is still insufficient to maintain the region's biodiversity and ecosystem services and to safeguard the rights of indigenous and traditional populations whose lands are not yet recognized by the federal government (e.g., Ministério do Meio Ambiente, 2007, Pinto et al. 2014, Silva et al., 2019b). Being aware that the region's conservation system needs to be expanded, in 1999, the Brazilian government launched a science-based and participatory process (including scientists, businesses, local populations, and civil society) anchored in the principles of systematic conservation planning. This process was regulated in 2004 (Decree No. 5092, signed on May 21, 2004). One of the main outputs of this process was a map pinpointing new priority areas to be added to the existing conservation system. This first map with conservation priorities was published in 2004, followed by updates in 2007 and 2018 (Ministério do Meio Ambiente, 2022). These maps suggest that at least 80% of the Brazilian Amazon should be formally protected in perpetuity to avoid the environmental, social, cultural, and economic erosion associated with the loss of the region's ecosystems (Ministério do Meio Ambiente, 2007). This proportion aligns with estimates that the region can reach an irreversible tipping point in which native non-forest, impoverished ecosystems replace native forests if deforestation reaches 20-25% of its total area (Lovejoy and Nobre, 2019).

Four strategic actions are necessary to conserve ~80% of the Brazilian Amazon within conservation areas. First, maintain the integrity of existing conservation units and indigenous lands (Garda et al., 2010). Second, allocate undesignated public lands to public conservation areas (Azevedo-Ramos and Moutinho, 2018; Vieira et al., 2005). Third, create financial incentives for private landowners to convert the share of their lands that must be conserved or restored to comply with the Native Vegetation Protected Law (Law No. 12727, passed on October 17, 2012) to private natural heritage reserves (RPPNs, as in the locally used acronym). By becoming RPPNs, private lands are legally protected in perpetuity and formally integrated into the national conservation system (Silva et al., 2021b). Fourth, create a regional coordination mechanism to promote integration and synergies among the region's conservation areas (Garda et al., 2010; Silva et al., 2005; Vieira et al., 2005).

Although the four components of the strategy to protect at least 80% of the region within conservation areas are straightforward, there is currently no estimate on the costs of this endeavor. This is surprising because, as with any public policy, conservation areas need financial resources to be implemented and achieve the goals for which they have been created (Bruner et al., 2004; Cunha et al., 2016; Medeiros et al., 2011; Silva et al., 2019a). Conservation areas that are well funded and managed are much more likely to maintain the health of their natural ecosystems, provide the ecosystem services that society needs, and create opportunities for economic prosperity in adjacent areas (Bruner et al., 2001; Dias et al., 2016; Geldmann et al., 2018). This article contributes to closing this knowledge gap with the first estimate of the minimum costs of a comprehensive conservation system for the Brazilian Amazon.

Materials and Methods

We used the term "Brazilian Amazon" synonymously with the Amazon biome, such as it was delimited by the Brazilian Institute for Geography and Statistics (Instituto Brasileiro de Geografia e Estatística, 2004). To estimate the minimum costs of a comprehensive regional conservation system, the first step is to understand the individual size of its components and eliminate any overlaps between them to avoid double counting. To generate this information, we first mapped the spatial distribution of conservation units, indigenous lands, undesignated public lands, and priority conservation areas that are not undesignated public lands using georeferenced official datasets that are publicly available (Table 1). Then, we removed all overlaps between these four area groups using the following sequence of priorities: (a) indigenous lands, (b) conservation areas, (c) undesignated public lands, and (d) priority conservation areas. Finally, we estimated the size of each polygon using ArcGIS 10.5.1. We eliminated all polygons of undesignated public lands and priority conservation areas smaller than 100 km^2 from our database because this is the minimum size required for a fully isolated forest fragment to maintain its avifauna for at least one century (Ferraz et al., 2003).

The costs of conservation systems can be classified into three groups (Bruner et al., 2004): (a) management costs, which consist of all expenses associated with the actual management of conservation areas, including, for instance, site-level administration, staff salaries, fuel, infrastructure maintenance, community assistance and engagement, monitoring and evaluation; (b) establishment costs, which cover all activities required to designate new conservation areas (e.g., biological inventories, social assessments, stakeholder consultation, boundary demarcation), plus planning and infrastructure building; and (c) system-wide costs, which include all expenses associated with the management of a conservation system, such as national and regional coordination, budgeting, new site selection, and other activities required to support the conservation network.

Because the management cost of a conservation area is dependent on the staff size needed to manage it (Vreugdenhil et al., 2003), we first estimated the minimum number of employees required to manage a conservation area. To do so, we used the following criteria: (a) all protected areas smaller than 167 km^2 must have at least five employees (Muanis et al., 2009), and (b) conservation areas larger than 167 km^2 should have at least three employees for every 100 km^2. We used three employees for every 100 km^2 because this is the median staff density found in the 15 most effective tropical parks studied by Brunner et al. (2001). The annual average wages (including benefits) in Brazil in December 2021 were USD 7,000 for the private sector and USD 11,200 for the public sector (Instituto Brasileiro de Geografia e Estatística, 2022). We used these two values to estimate the lower and upper limits of each conservation area's total staff annual costs. Finally, we multiplied the total annual staff costs by two to get the minimum recurrent annual management costs for each conservation area. We multiplied by two because Dias et al. (2016) report that staff costs are around 50% of the total annual recurrent management costs of nine

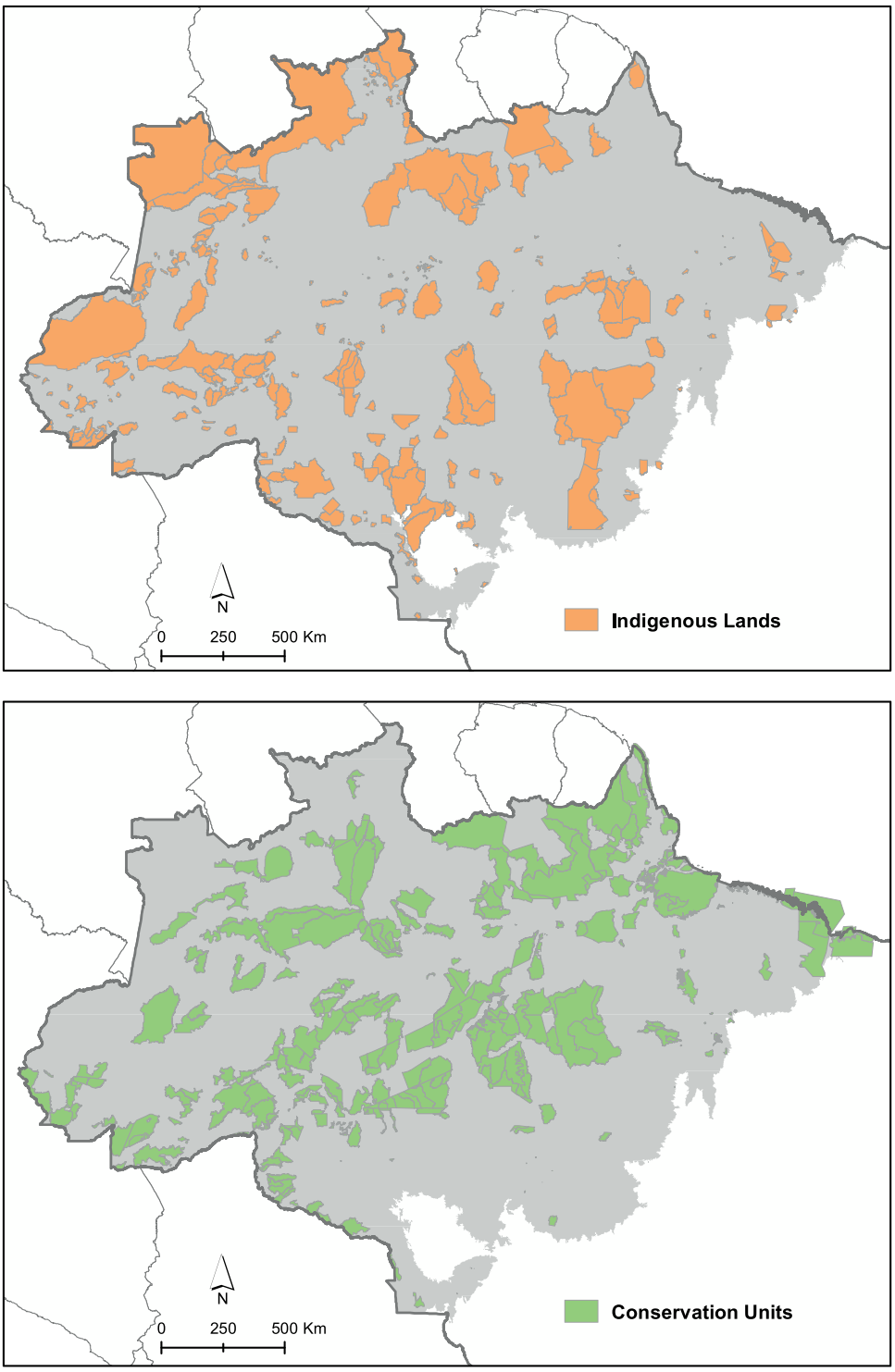

Fig. 1. Distribution of the existing conservation units (A) and indigenous lands (B) in the Brazilian Amazon.

conservation units in the state of Amapá in the Brazilian Amazon. Establishment costs were estimated as 1.8 times the yearly management costs based on the estimate provided by Dias et al. (2016). The annual system-wide costs were estimated as 15–20% of the yearly recurrent management costs (Silva et al., 2021a).

We are aware that management costs possibly vary across the region, as conservation areas in some sub-regions facing more intense human pressure have higher management costs than those facing less human pressure (Bruner et al., 2004; Kauano et al., 2017). However, we argue that each conservation area requires a minimum investment to be functional. Therefore, our effort is limited to estimating these minimum costs and providing a baseline for future studies on conservation area economics in the Brazilian Amazon at local and sub-regional levels.

Results

To protect around ~80% of the Brazilian Amazon within conservation areas, it will be necessary to incorporate 594,924 km^2 of

Table 1
Definition of conservation units, indigenous lands, undesignated public lands, priority conservation areas, and the sources of the datasets used to map their distribution within the Brazilian Amazon.

Groups	Definition	Source
Conservation units	All public and private conservation areas recognized in the region by all government levels.	https://antigo.mma.gov.br/areas-protegidas/cadastro-nacional-de-ucs/dados-georreferenciados.html
Indigenous lands	All indigenous lands recognized by the federal government	https://www.gov.br/funai/pt-br/atuacao/terras-indigenas/geoprocessamento-e-mapas
Undesignated public lands	All polygons of undesignated public lands above 100 km^2 recognized by the federal government	https://www.florestal.gov.br/cadastro-nacional-de-florestas-publicas/127-informacoes-florestais/cadastro-nacional-de-florestas-publicas-cnfp/2050-cadastro-nacional-de-florestas-publicas-atualizacao-2020
Priority conservation areas	All priority conservation areas recognized by the federal government that have not been classified as undesignated public lands	http://areasprioritarias.mma.gov.br/2-atualizacao-das-areas-prioritarias

Table 2
Estimated costs (in million USD) for maintaining the existing conservation areas (indigenous lands and conservation units) and creating new conservation areas in the undesignated public lands and priority conservation areas that are not undesignated public lands.

Groups	Area (km^2)	Annual management costs	Establishment costs	System-wide costs	
				15%	20%
Indigenous lands	1,088,149	461.8–738.8			
Conservation units	1,119,021	474.6–759.3			
Undesignated public lands	594,924	251.4–402.2	452.5–724.0		
Priority conservation areas	780,416	305.6-488.9	550.1–880.0		
Total	3,582,510	1,493.2–2,389.2	1,000.6–1,604.0	224.0–358.4	299.7–477.8

undesignated public lands and around 780,416 km^2 of conservation priority areas that are not undesignated lands into the existing regional conservation system (Fig. 2). Adding these two groups of areas to the conservation system under different management categories will increase the coverage of the region's conservation areas to around 3.6 million km^2 or 83.3% of the region (Table 2).

Annual management costs of the existing conservation units and indigenous lands are estimated at USD 474.6–759.3 million and USD 461.8–738.8 million a year, respectively (Table 2). Converting undesignated public lands to public conservation areas requires USD 452.5–724.0 million in establishment costs and USD 251.4–402.2 million a year in management costs. Creating private or public conservation areas in all priority conservation areas that are not within undesignated public lands requires USD 550.1–880.0 million in establishment costs and USD 305.6–488.9 million in annual management costs. The estimated system-wide costs for the entire conservation network range between USD 224.0 and 477.8 million a year (Table 2). In summary, protecting ~80% of the Brazilian Amazon within conservation areas under different management categories would minimally cost USD 1.7–2.8 billion a year in management and system-wide costs, plus an upfront investment of USD 1.0–1.6 billion in establishment costs for new conservation areas (Table 2).

Discussion

We demonstrated that protecting ~80% of the Brazilian Amazon within conservation areas is feasible. Achieving this goal requires a mix of three types of interventions: disincentive-based, incentive-based, and enabling instruments (Börner and Vosti, 2013). Allocating undesignated public lands to public conservation areas is a disincentive-based strategy. It takes land out of the future market and reduces the incentives for those actors aiming to obtain profits from deforestation and land-grabbing (Vieira et al., 2005). On the other hand, supporting landowners to create and maintain RPPNs is an incentive-based strategy. Local actors receive financial incentives in exchange for protecting a significant portion of their lands in perpetuity (Silva et al., 2021b). Finally, building an integrated management system to promote synergies among conservation areas across different political levels, from local to national, is a critical enabling instrument that does not exist currently in the region. To implement such interventions requires USD 1.7–2.8 billion a year (adjusted for inflation) in management costs in perpetuity plus USD 1.0–1.6 billion in upfront investments over the time needed to establish all new protected areas. This value is more than twice higher than the amount governments (from local to national) have historically spent on forest policies in the region (Cunha et al., 2016). On the other hand, the estimated values are modest compared to the value of some of the ecosystem services generated by the region's native ecosystems (Strand et al., 2018; Young and Medeiros, 2018). Conserving most of the Brazilian Amazon per hectare is cost-effective. For instance, the estimated costs are 2.5 times less expensive than safeguarding 1.2 million km^2 of protected areas important for lion conservation in Africa (Lindsey et al., 2018) and 6.8 times less costly than maintaining 1 million km^2 of conservation areas within the boundaries of the European Union (Gantioler et al., 2014).

Currently, the conservation costs of the existing conservation system in the Brazilian Amazon are mainly covered by the government budget with some support from international collaboration initiatives, such as the Amazon Region Protected Areas Program (ARPA) and the Amazon Fund. However, these resources are insufficient, and there is a considerable funding gap across all types of conservation areas (Medeiros et al., 2011; Silva et al., 2021a). In recent years, successive governments have reduced investments in the region's conservation. The main reasons are recurrent severe economic and political crises (Medeiros et al., 2011; Silva et al., 2021a) as well as the anti-environmental attitude of the current government (Barbosa et al., 2021; Ferrante and Fearnside, 2019; Werneck et al., 2021). Nevertheless, the resources needed to protect the Brazilian Amazonia are within Brazil's reach considering the size of the regional (USD 100 billion in 2018) and national (USD 1.8 trillion in 2018) economies, the size of the federal public budget (USD 910.5 billion), the profits generated by the country's 500 major corporations in 2020 (US$ 63 billion), the high return on investment of the federal conservation units to the national econ-

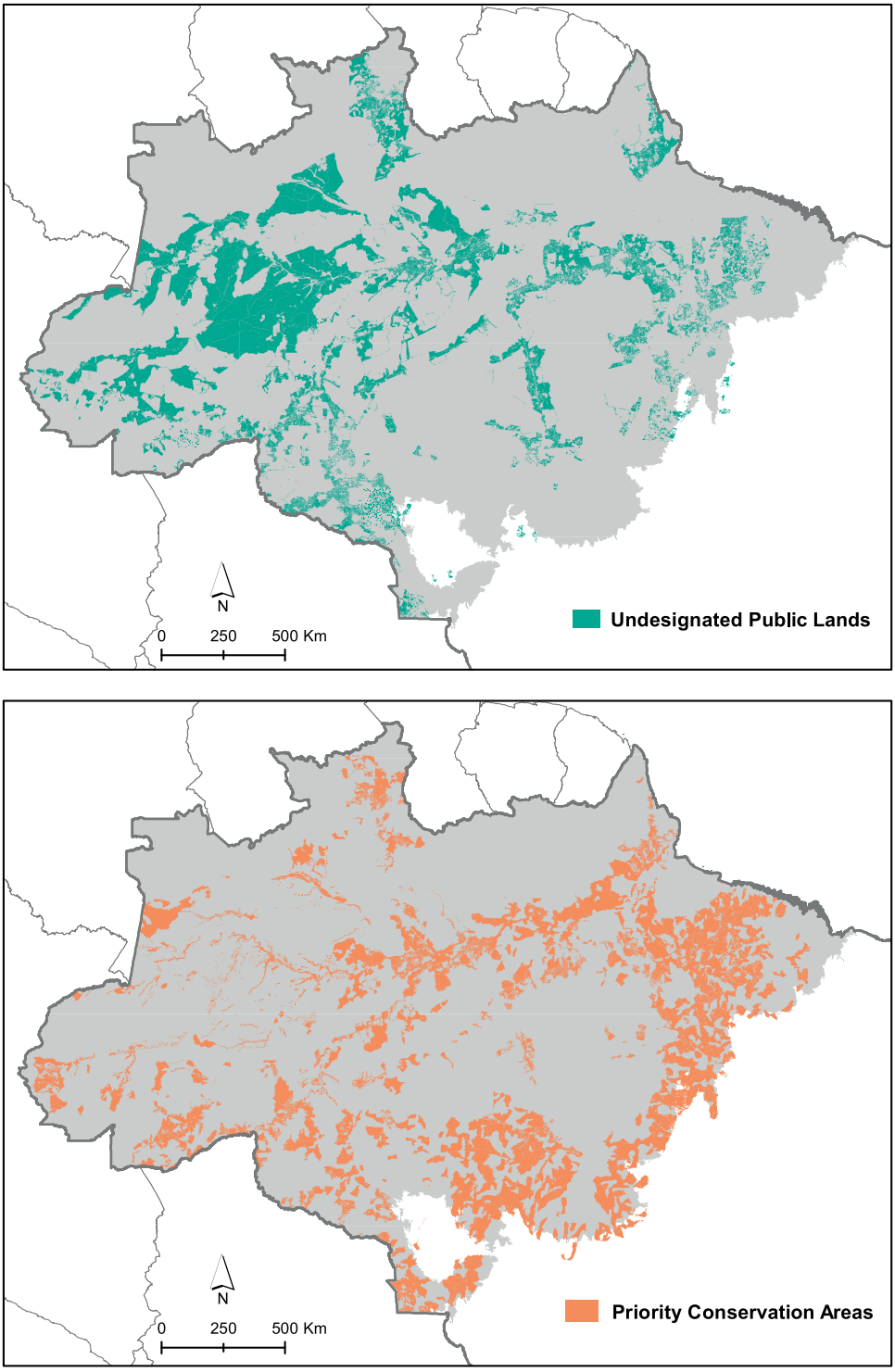

Fig. 2. Distribution of the undesignated public lands (A) and priority conservation areas that are not undesignated public lands (B) in the Brazilian Amazon.

omy (Medeiros et al. 2011), and the positive impact that investing in conservation areas can have on the country's most economically distressed regions (Dias et al., 2016; Kasecker et al. 2018).

Ecosystem services, such as the climate regulation provided by the Brazilian Amazon, are also relevant to the well-being of societies beyond the Brazilian borders (Science Panel for the Amazon, 2021). Thus, it is fair that Brazilian society expects substantial contributions from other countries to maintain a significant portion of the world's most biodiverse region within a well-managed network of conservation areas (Balmford and Whitten, 2003). Accordingly, the urgency to protect the Amazon was highlighted at the Conference of the Parties #26 of the Climate Convention in Glasgow. The Glasgow Climate Pact recognizes that the current provision of climate finance for adaptation remains insufficient to respond to worsening climate change impacts in developing countries and urges developed countries to significantly scale up their provision of climate finance, technology transfer, and capacity-building for adaptation to respond to the needs of developing countries as part of a global effort (UNFCCC, 2021). More specifically, the Glasgow Leaders' Declaration on Forests and Land Use, signed by

more than 140 country leaders, reaffirmed global commitments to significantly increase finance and investment in forest conservation and restoration as well as support for indigenous peoples and local communities (UNFCCC COP26a, 2021). However, despite the rise in recent commitments and pledges (UNFCC COP26b, 2021), funding for the region remains insufficient. Therefore, a concerted international effort is also required to close the financial gap to conserve the Brazilian Amazon in addition to Brazilian efforts. We suggest that both ARPA and the Amazon Fund can provide suitable lessons and perhaps even serve as backbones or inspiration for creating a new ambitious, decentralized, more inclusive, systemic, and agile funding mechanism that includes contributions from governments and corporations, individuals, and foundations.

Despite previous assessments questioning the long-term viability of conservation areas for protecting the Brazilian Amazon's ecosystems (e.g., Nepstad et al., 2009), conservation areas have been, despite limited funding, the primary mechanism used to combat the loss of biodiversity and ecosystem services across the region during the last decade (Cabral et al., 2018; Walker et al., 2020). Setting aside ~80% of the Brazilian Amazon as conservation areas is feasible politically if the current financial bottleneck is removed. There are four main reasons for this statement. First, Brazil has the enabling policies and technical capacity to implement a diverse and polycentric conservation system with multiple management categories (Silva et al., 2021b). Second, conservation areas do not hinder local economic development across the region, and, if implemented correctly, they can generate significant social benefits for local populations (Campos-Silva et al., 2021; Kasecker et al., 2018; Kauano et al., 2020). Third, local populations, both rural and urban, support conservation areas as mechanisms to protect the region's ecosystems (Cunha et al., 2019). Finally, there is a political movement embraced by local and state governments, the private sector, and civil society proposing a nature-based regional development strategy (Nobre et al., 2016; Vieira et al., 2005), which, in turn, cannot be sustained without a large, comprehensive, stable, and well-managed regional conservation system.

Implementing an urgent and ambitious conservation program for the Brazilian Amazon cannot wait any longer because the adverse effects of human activities across the region are expanding as never before (Boulton et al., 2022; Science Panel for the Amazon, 2021). For instance, in 2021, deforestation reached the highest annual rate (13,235 km^2) of the last ten years (INPE, 2021). Around three-quarters of the deforestation takes place within undesignated public lands (Moraes et al., 2021), the region's recurrent hotspots of land speculation and social conflicts. By giving a clear designation to these areas and integrating them into a national conservation system, Brazil could potentially slash illegal deforestation and achieve world-class conservation targets. Moreover, despite all the conservation efforts carried out across the region in the last decades, none have been able to meet the true magnitude of the challenge. The timing for a global convergence towards a sustainable and definitive conservation system to maintain the socioecological integrity of the Brazilian Amazon is now; otherwise, the window of opportunity to achieve one of the most significant conservation accomplishments in the history of humanity can be closed soon and – given the declining resilience of the region's ecosystems – forever.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

Declaration of Competing Interest

The authors report no declarations of interest.

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