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Environmental policy at a critical junction in the Brazilian Amazon

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Wholesale conversion of natural Amazonian ecosystems has been encouraged by Brazil's extreme antienvironmental government, and historical forest loss explains municipal-scale voting prevalence. Embracing a new administration would strengthen local-to-regional governance, suppress illegal land grabbing, deforestation, logging, and gold mining, thereby protecting the world's most species-rich forest domain and ensuring global sustainability.

Agricultural expansion into Amazonia

Agricultural expansion into tropical wildlands is the leading driver of plant and animal extinctions [1]. Agropastoral colonization of hinterlands – that are often occupied by nonagricultural societies – is arguably the most important land-use transition leading to wholesale shifts in the structure and species composition of terrestrial ecosystems. Since the invention of agriculture some 13 kya, technologically superior farmers have always displaced hunter-gatherers; a process that continues today as agricultural expansion and intensification encroaches into the last remote ice-free wilderness regions. In modern nation states, this territorial conquest often occurs through predesigned geopolitical strategies by central governments involving subsidized resettlements of millions of small farmers seeking prosperity elsewhere,

almost invariably at the expense of previously intact ecosystems and indigenous people.

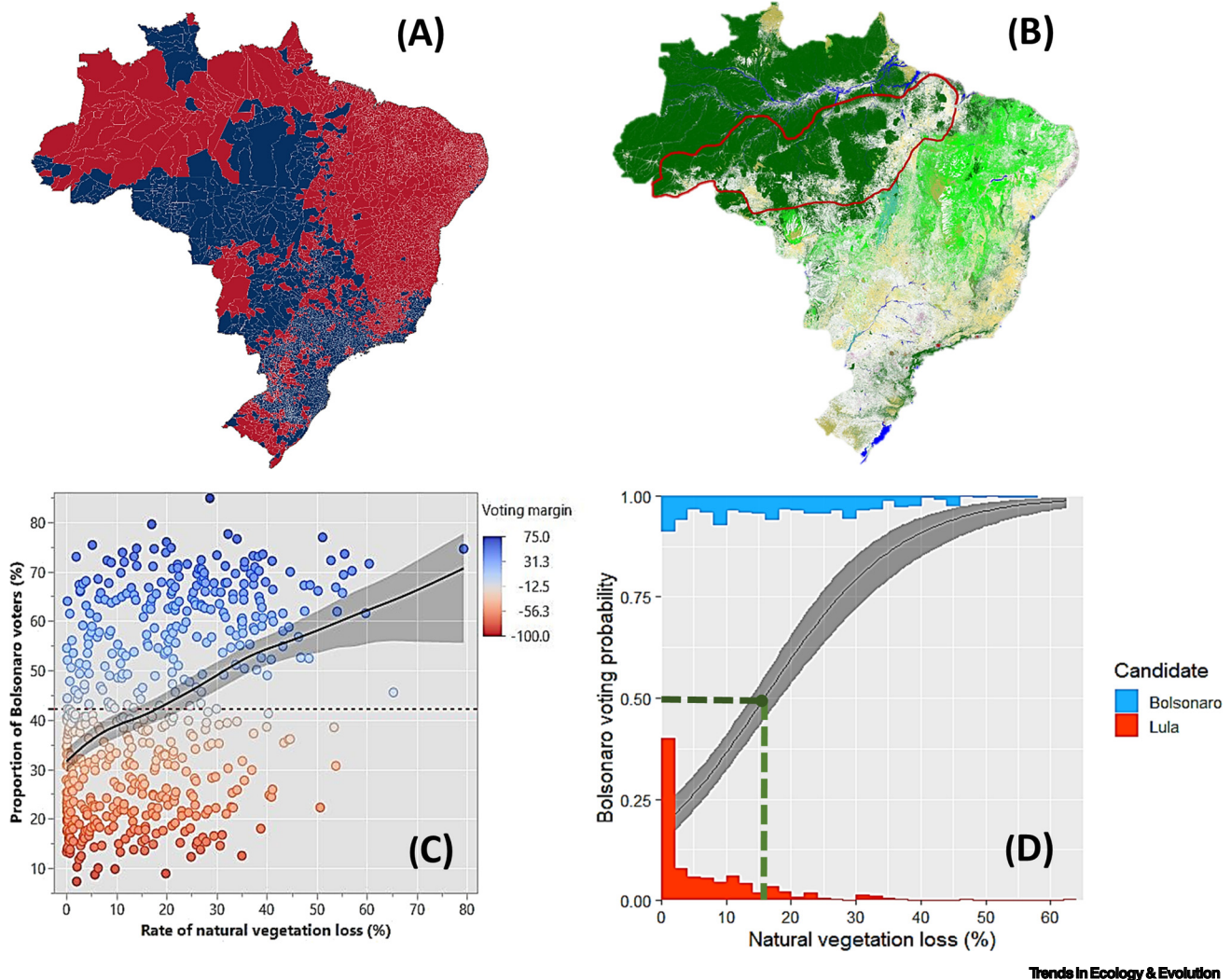
Brazil leads the world in overall ice-free wildland area still available for agricultural expansion; most of which is in Amazonia. Since the first major road linking the Amazon to the rest of Brazil (Belém-Brasília Highway, BR-010) was paved in 1970, ~94 million hectares of natural Amazonian vegetation (including forests and wooded savannahs) have been clear-cut. Over the 1985–2021 period, total agricultural area further rapidly increased to 43.5 Mha (cattle pastures ~36.3 Mha; croplands ~7.2 Mha) [2]. Yet, the world's largest agricultural frontier will continue to expand, posing serious questions on the fate of Earth's most biodiverse region and one of the five major climate tipping points [3]. Brazil currently faces a critical juncture in terms of the overarching nexus between rural development and conservation of natural ecosystems, which has been illustrated by the results of the first and second rounds of presidential elections (October 2 and 30, 2022). Here, we show how municipal-scale voting prevalence relates to the history of natural vegetation loss, and what this means to the fate of the Amazon in a profoundly divided country in decades to come.

Decisive 2022 election

We reviewed yearly data on absolute vegetation loss (including both forest and cerrado savannah areas) between 1985 and 2021 for all 558 municipal counties within Brazil's ~522 Mha Amazon region, plus neighbouring counties in adjacent biomes. We also recorded the number and proportion of valid votes per county (excluding blank/null votes and non-voters) for each candidate [4], and derived a log-ratio of municipality-level voting prevalence (i.e. $\ln \left[\frac{\% \text{votes}(JB)}{\% \text{votes}(LS)} \right]$), where JB = the extreme right wing Jair M. Bolsonaro and LS = the center-left

Luis I. Lula da Silva). The presidential election was narrowly decided in late October 2022 following a bitter contest between these candidates who represent opposite views in terms of command-and-control measures against environmental misconduct, including illegal deforestation, land grabbing, predatory logging, gold mining, and land-use conflicts within protected areas, including indigenous territories and state-controlled forest reserves, all of which have occurred with impunity. Bolsonaro has systematically dismantled and starved all environmental law-enforcement agencies, explicitly or implicitly incentivising all forms of illegal deforestation, forest degradation, and wildfires, including arson of seasonally dry public lands, whereas Lula promises to re-establish law and order and bring deforestation under control as in his 2003–2010 administration.

Rates of vegetation loss for all Amazonian counties since 1985 and the election results show a remarkable spatial overlap between high deforestation and Bolsonaro-leaning counties (Figure 1A–C). County-scale cumulative vegetation loss in the 1985–2021 period is positively related with pro-Bolsonaro voting intent ($R^2 = 0.25$; Figure 1C), whether we consider the overall proportion of votes or the log-ratio of voting prevalence between the leading candidates. This is particularly the case of major agricultural states in Southern Amazonia (Mato Grosso and Rondônia), and increasingly in Southern/Eastern Pará, Northern Tocantins, and Roraima, which are now largely occupied by new settlers who migrated from elsewhere in Brazil since the late 1970s. Bolsonaro increased his voting majority in nine of the ten municipalities experiencing the highest deforestation rate since January 2019 (mean forest loss = 486.5 km², $n = 10$). High-deforestation municipalities also experience few employment opportunities, most frequently filled by the informal wage-labour sector including illegal logging, land grabbing, and uninsured chain-saw operation. Low-income workers thus



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Figure 1. Presidential voting prevalence by Amazonian municipal county in which Bolsonaro and Lula majority wins are indicated by blue and red polygons, respectively (A), and remaining natural vegetation cover, including both forest and cerrado vegetation (in dark and pale green areas, respectively) by December 2021 throughout the ~522 Mha Brazilian Amazon and elsewhere in the country (B). Red line (in B) delineates the expanding Deforestation Arc of the Brazilian Amazon. Positive relationship between county-scale proportion of pro-Bolsonaro votes and cumulative deforestation rates (C), in which circles are colour-coded as in (A). A logistic regression (D) further shows that deforestation rates are strongly predicted by whether or not a county swung towards either Bolsonaro or Lula as indicated by the upper (blue) and the lower (red) histograms, respectively.

most likely voted for the candidate least likely to suppress these activities. Conversely, most Lula-leaning counties remain largely intact and are primarily occupied by traditional and native Amazonians, whose communal territories have been increasingly encroached upon by successive waves of new settlers. Bolsonaro won the election in 265 Legal Amazon counties accounting for 70% of all 1985–2021 deforestation (mean per county = 19.9%). In

contrast, Lula won in 499 more sparsely settled counties accounting for 30% of all deforestation over the same period (mean = 6.3%). Not surprisingly, a logistic regression model shows that history of natural vegetation loss over three decades explains most of the county-scale variance in voting prevalence. Residents were 2.6 times more likely to vote for Bolsonaro within counties that had experienced a deforestation increase of just 10%, and

only counties with a history of deforestation lower than 16% were more likely to elect Lula (Figure 1D). In particular, pro-Bolsonaro counties include those within both the consolidated agribusiness belt of southern Amazonia, where soybean croplands have been rapidly replacing low-yield cattle pastures, and in the expanding deforestation frontier immediately north of the former Deforestation Arc of the Brazilian Amazon (Figure 1B).

A new dawn for Brazilian Amazonia?

Although the boom-and-bust cycle of Amazonian rural development fuelled by forest exploitation and conversion [5] has been challenged on the basis of the human development index [6], this metric of human welfare is wholly inadequate for semisubsistence indigenous peoples and traditional communities who largely operate outside the market economy. Traditional forest dwellers can align their social aspirations with biodiversity conservation in natural ecosystems that remain largely intact [7], whereas immigrant neocolonial farmers and their analogues largely cannot. This is essentially because these newcomers have neither the know-how nor the willingness to extract prosperity and food security from standing natural forests and floodplains, and instead often take advantage of perverse government subsidies to clear the forest, thereby converting natural capital into commodities that are measured in regional to national economies. Yet, some 13% of the Brazilian population has been moved into >2200 agrarian reform settlements distributed throughout the Amazon over a 35-year period [8]; most of which cannot be defined as successful in terms of household economics and long-term land tenure. Bolsonaro came to power in 2018 while promising the farming community amnesty for any previous environmental violations, and legislative immunity and relaxed law enforcement against future ones. This has been reinforced during his current administration, which has been rewarded with an even higher voting prevalence in Amazonian counties dominated by livestock or cropland agribusiness and now rampant illegal appropriation of public lands. The potential for further agricultural expansion into currently protected and unprotected lands is daunting. New breeds of soybean can rapidly colonise roughly two-fifths of the Amazon [9], and palm oil monoculture is a climatically and edaphically suitable option in nearly half of the Brazilian Amazon [10]. In addition, the

current balance of government incentives and disincentives, including new infrastructure, rural credit, and titling of public lands, clearly favours a model in which hundreds of thousands of new immigrants seeking rapid financial gains continue to pour into the Amazon. This balance depends on centralised strategic planning, sound fiscal policies, and a willingness to strike an optimal trade-off between conservation and development. So here lies two different pathways for rural development in Amazonia, which we briefly elaborate next.

The Amazon perhaps hosts over >20% of the world's plant, invertebrate, and vertebrate species [11], and an immense sociocultural diversity including myriad agricultural systems coupling complex landscape management strategies with other livelihood activities such as hunting, fishing, and extractivism that can benefit regional markets [12]. Successful examples include community governance systems based on no-take areas and fishing agreements between subsistence and commercial fisherfolk along the Juruá, Purus, and Solimões (Upper Amazon) rivers [8,13]. These systems integrate nature conservation and local livelihoods while markedly raising local living standards and providing essential global-scale services such as carbon stocks and water cycling. However, these systems are threatened by haphazard agribusiness expansion, unregulated timber extraction, and proliferation of small-scale to industrial mining interests. The agribusiness model erodes both biological and cultural diversity, and can lead to rural poverty, high rates of rural violence, and slavery [14]. Uncontrolled agricultural expansion and other environmentally harmful activities have been recently weaponised by the Bolsonaro administration, leading to a new spate of land conflicts, human rights violations, land invasions, illegal deforestation, and murders [15]. Furthermore, part of the Brazilian

agribusiness lobby finances a growing number of ruralist policy-makers, who have created new laws that facilitate unregulated agricultural expansion, indiscriminate pesticide use, mining within indigenous territories, and relaxation of environmental law enforcement by government agencies. This includes severe budget cuts to the Protected Areas Agency (ICMbio), Environmental Protection Agency (IBAMA), National Policy on Climate Change, Federal Conservation Management and Implementation Program, Environmental Agency Inspection and Control Program, and Environmental Inspection, Prevention and Control of Forest Fires. Bolsonaro's aggressive anti-environmental agenda had a significant international impact leading to retaliatory withdrawal of funds committed to the Amazon Fund by donor countries, thereby subtracting ~US\$20 billion in funds [16], further hindering environmental protection in the Amazon.

The continued existence of the Amazon, as we know it, undoubtedly clashes with political and private sector interests aligned with the Bolsonaro administration, which in a second term would have become even bolder. Fortunately, Lula rekindles hope of environmental protection and reopens the door to international cooperation while giving voice to a broad spectrum of scientists and NGOs to rebuild a robust multilateral conservation agenda. However, there are several huge challenges to overcome, given a hostile National Congress majority, strict limits on investments in environmental and social projects, vigorous local opposition, and a global economy heading in the wrong direction. Defeating Bolsonaro was therefore essential but not yet a triumph to steady the ship of Amazonian environmental conservation, and fulfil international policies on biodiversity conservation, socioenvironmental justice, and sustainable development, ensuring a brighter future everywhere on Earth. This will require perseverance to overcome the 49.1% voting opposition, international cooperation,

substantive funding, and clever policies. Only time will tell if Lula will truly honour the support he had from environmentalists, artists, educators, indigenous peoples, and local leaders. Lula's speech after a narrow victory promised an ambitious zero deforestation plan. Let us hope his vows come true and that once again, as he optimistically professed, 'it will be possible to generate wealth without destroying the environment'.

Declaration of interests

No interests are declared.

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