# The threat of political bargaining to climate mitigation in Brazil

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# The threat of political bargaining to climate mitigation in Brazil

Pedro R. R. Rochedo[1], Britaldo Soares-Filho[2], Roberto Schaeffer[1]*, Eduardo Viola[3], Alexandre Szklo[1], André F. P. Lucena[1], Alexandre Koberle[1], Juliana Leroy Davis[2,4], Raoni Rajão[4] and Regis Rathmann[1]

**In exchange for political support, the Brazilian government is signalling landholders to increase deforestation, putting the country's contribution to the Paris Agreement at risk[1]. The President of Brazil has signed provisionary acts and decrees lowering environmental licensing requirements, suspending the ratification of indigenous lands, reducing the size of protected areas and facilitating land grabbers to obtain the deeds of illegally deforested areas[2]. This could undermine the success of Brazil's $CO_2$ emission reductions through control of deforestation in the previous decade. Integrated assessment models are tools to assess progress in fulfilling global efforts to curb climate change[3,4]. Using integrated assessment models developed for Brazil, we explore 2 °C-compliant $CO_2$ emission scenarios estimating the effort needed in other sectors of the economy to compensate for the weakening of environmental governance, potentially resulting in higher deforestation emissions. We found that the risk of reversals of recent trends in deforestation governance could impose a burden on other sectors that would need to deploy not yet mature technologies to compensate for higher emissions from land-use change. The abandonment of deforestation control policies and the political support for predatory agricultural practices make it impossible to meet targets consistent with Brazil's contribution to a 2 °C world.**

Brazil is the seventh largest greenhouse gas (GHG) emitter. Between 2005 and 2012, the country's GHG emissions were reduced by 54% (ref. [5]), mostly by cutting deforestation by 78%. However, the country's recent record on land-use policies and practices has not been bright. On the one hand, by the end of 2017 some 65% of Brazil's 5.4 million rural properties have joined the rural environmental registry, a system to monitor compliance with environmental laws, and the country committed to reduce its annual emissions to 1.3 GtCO$_2$e in 2025, with an indicative of 1.2 GtCO$_2$e by 2030, in its Nationally Determined Contribution (NDC) as part of the Paris Agreement. On the other hand, since 2012, following relaxation of the Forest Code[6], there has been a reversal in the declining deforestation trend in the Brazilian Amazon, and deforestation has levelled out at high rates in the Cerrado biome, which has already lost more than half of its original vegetation[6]. Since May 2016, Brazil's presidency has deepened this negative reversal by attempting to deconstruct several successful environmental policies[7].

At the core of the current government's coalition is the powerful rural/mining caucus, which holds some 40% of the seats in Congress[8]. To avoid responding to corruption accusations, the President has proposed legislative projects and signed provisionary acts and decrees that have lowered environmental licensing requirements[9], suspended the ratification of indigenous lands[10], reduced the size of protected areas in the Amazon[11], and facilitated land grabbers to obtain the deeds of illegally deforested areas as large as 2,500 ha per farm in the Amazon rainforest[12].

Analysis of the environmental governance in Brazil helps to explain how a political crisis can be a major driver for increasing deforestation and carbon emissions in the country. Deforestation control is the result of forces arising from institutional arrangements such as enforcing the rule of law and sending signals that may, directly or indirectly, incentivize economic agents to decide whether or not to illegally deforest. The institutional arrangement can also be affected by the degree of cooperation with the international regime on climate change. By analysing these forces over the last two decades, environmental governance in Brazil can be divided into three major periods (see Supplementary Information): pre-2005, a period with very poor governance and high rates of deforestation; 2005–2011, a period with improvements in environmental governance and effective results in reducing deforestation[13]; and 2012–2017, when governance suffered a gradual erosion with the large amnesty granted to past illegal deforesters in the revision of the Forest Code[6], which led to a reversal of the deforestation reduction trend in the Amazon after 2012 and, later, to an increase in deforestation during 2015–2017.

Based on these past records, we define three environmental governance scenarios—weak, intermediate and strong—as shown in Fig. 1.

## Weak environmental governance

The weak environmental governance (WEG) scenario assumes the abandonment of current deforestation control policies, as well as strong political support for predatory agricultural practices. In practice, by 2025 this scenario represents the annulling of governance gains achieved since 2005. This represents the worst-case scenario and should be understood as a complete deconstruction of environmental governance in Brazil, with severe impacts on deforestation rates, which could potentially return to pre-2005 levels. Such a return of deforestation rates to the peak levels of the last decade would lead to annual losses of more than 27,000 and 18,000 km$^2$ of the Amazon and Cerrado biomes, respectively, by 2025. Cumulative $CO_2$ emissions from deforestation could escalate to 23.1 GtCO$_2$ from 2010 to 2030.

## Intermediate environmental governance

The intermediate environmental governance (IEG) scenario assumes the maintenance of current deforestation control policies, while,

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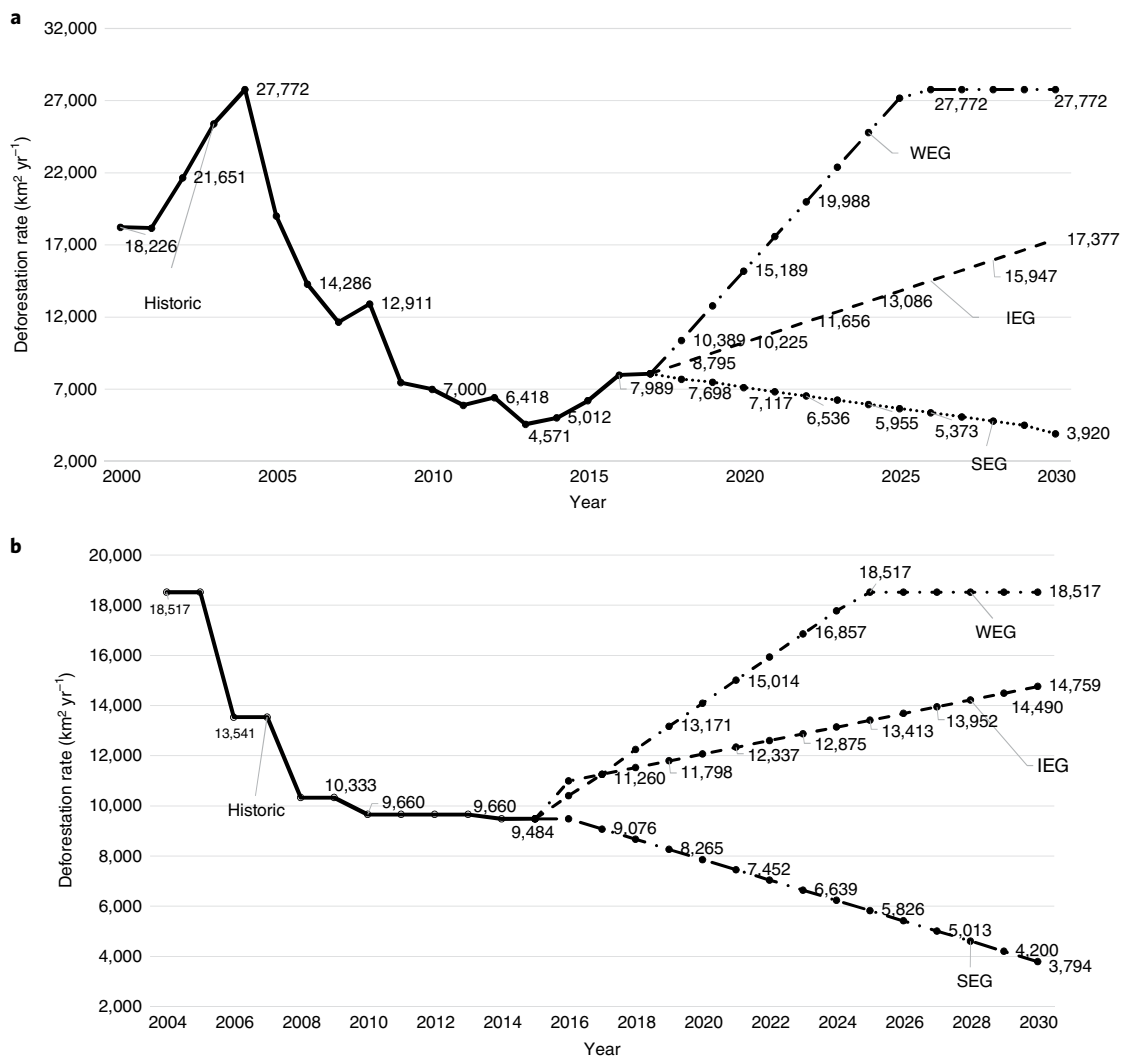
**Fig. 1 | Deforestation rates. a,b,** Deforestation rates for the Amazon (**a**) and Cerrado (**b**) biomes.

contradictorily, considering growing political support for predatory agricultural practices. This includes legal support for land-grabbing practices, the creation of fewer protected areas and the downgrading, downsizing and degazettement of key protected areas together with lax enforcement of the Forest Code. IEG represents the current business-as-usual scenario in Brazil, according to which the increasing deforestation trend observed in the Amazon since 2013 is extended until 2030. As a result, annual deforestation would reach some 17,000 and 15,000 km$^2$ in the Amazon and Cerrado biomes, respectively, by 2030. This implies cumulative emissions from deforestation of 16.3 GtCO$_2$ for the same 2010–2030 period.

**Strong environmental governance**

The strong environmental governance (SEG) scenario assumes the expansion of current deforestation command-and-control policies and full political support for the environmental agenda in the country, including full implementation of the Forest Code alongside economic incentives for forest conservation. Annual deforestation in the Amazon and Cerrado biomes would be reduced from 7,989 and 9,483 km$^2$ in 2016 and 2015[14], respectively, to under 4,000 km$^2$ by 2030. Associated cumulative emissions from deforestation reach 9.6 GtCO$_2$ from 2010 to 2030.

For these environmental governance scenarios we estimated the resulting land-use CO$_2$ emissions. We then evaluated the level of

effort and cost to other sectors of the economy to compensate for higher emissions if Brazil is to meet its commitments under the Paris Agreement and contribute to a 'below 2 °C' world.

Recent studies[15–20] indicate a cumulative budget of ~24.0 GtCO$_2$ for Brazil between 2010 and 2050 in a 'below 2 °C' world. These studies adopt different allocation criteria (least-cost, population metrics, economic and social development, historic emissions, per capita emissions) in analyses performed using global integrated assessment models (IAMs). This is the cumulative amount of CO$_2$ Brazil should emit in a worldwide effort to be likely to keep the global average temperature increase below 2 °C by 2100 (66–100% probability). Other GHGs are also considered (see Supplementary Information). In 2010–2016, some 4.6 GtCO$_2$ were emitted in Brazil, so there remain 19.4 GtCO$_2$ to be emitted from 2017 to 2050.

If Brazil is to contribute to a 'below 2 °C' world, the remaining emissions budget for other economic sectors (agriculture, livestock, energy production and consumption, waste and industrial process emissions) will depend on the cumulative emissions from deforestation. The higher the emissions from deforestation, the greater will be the effort required to reduce emissions elsewhere to help the world reach the below 2 °C target. Based on the budget that would remain for the other sectors under the modelled deforestation scenarios, we simulated cost-optimal mitigation strategies that maintain the overall Brazilian contribution within the 2 °C target.
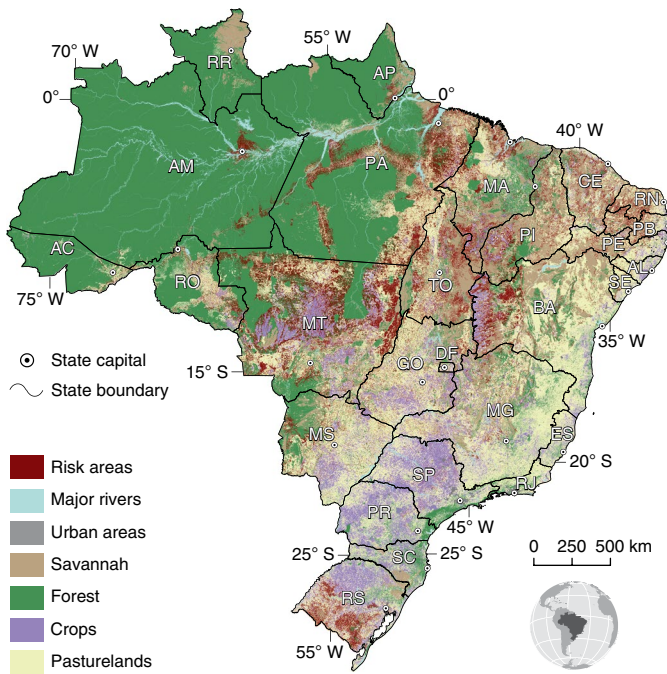
**Fig. 2 |** Land use and deforestation risk areas in the WEG scenario by 2030.



**Fig. 3 |** $CO_2$ budget and cost analysis.

To do this, a comprehensive methodological procedure was established by combining two well-proven models developed in, and for, Brazil: the spatially explicit land-use model OTIMIZAGRO[21,22] and the optimization model for national energy and land-use systems, BLUES (Brazilian Land Use and Energy System)[23].

The results for the SEG scenario place most of the country's effort to reduce $CO_2$ emissions on avoiding further deforestation and increasing energy efficiency and the use of biofuels. This indicates that Brazil succeeds in upholding the conservation gains obtained between 2005 and 2011, and can meet its NDC targets and go beyond, contributing its share to a below 2 °C world. In this case, the country's cumulative $CO_2$ emissions for the 2010–2050 period split between deforestation (9.6 $GtCO_2$) and other sources (14.4 $GtCO_2$).

In the IEG scenario associated with growing political support for predatory environmental practices, our analyses indicate that Brazil could still meet its share in the world effort to reach the 2 °C target. In this case, for the 2010–2050 period, cumulative $CO_2$ emissions from deforestation reach 16.3 $GtCO_2$, while cumulative $CO_2$ emissions from other sources total 7.7 $GtCO_2$.

Although with the IEG scenario Brazil may still manage its $CO_2$ budget, emissions from deforestation under the WEG scenario fall close to the cumulative $CO_2$ budget of 24.0 $GtCO_2$. Cumulative emissions from deforestation reach 23.1 $GtCO_2$, and there is no way other sectors can compensate for the emissions associated with the loss in forest coverage (Fig. 2). Even using a set of advanced and costly technologies—some of which are not fully deployed commercially yet (such as carbon capture in advanced biomass conversion (BECCS); diesel, bunker and jet fuel from biomass; ethanol-powered buses; electric and hydrogen-powered buses, trucks and cars; to cite but a few)—the BLUES model was not able to compensate the WEG trend in deforestation to keep the country's emissions within its 2 °C budget. Indeed, an intermediate deforestation rate scenario (IEG) already saturates the climate change options in Brazil.

The investment costs of the energy system almost double under the IEG scenario when compared to the investment costs of the SEG scenario, reaching US$$_{2010}$2.0 trillion. Additional investments are concentrated in the energy sector, considering both power and fuel
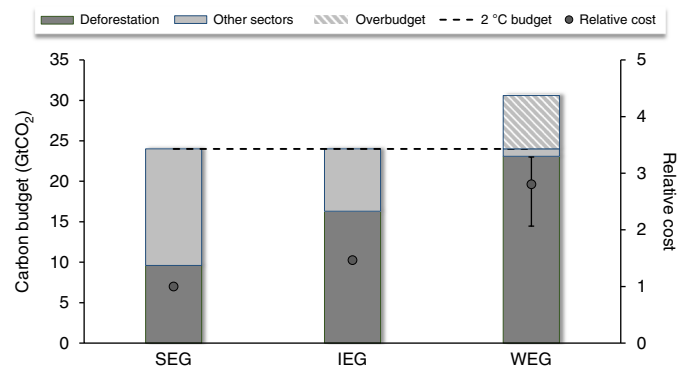
production. This means that, to contribute to the world's 2 °C path, other sectors of the Brazilian economy would need to pay a high cost for the setbacks in deforestation control policies.

Because Brazil would not be able to stay within its $CO_2$ budget requirement in the WEG scenario, a non-commitment cost for Brazil failing to comply with its $CO_2$ budget could be considered. One possible narrative is that, under this scenario, the rest of the world would need to reduce its emissions to compensate for Brazil not accomplishing its part. Nevertheless, Brazil could still fulfil its commitment by supporting third parties to reduce emissions in its place, although this would not be a least-cost solution for the world to reach the 2 °C target. We estimate this additional cost using an implicit carbon price from trajectories consistent with a below 2 °C world. Using a mean value of US$370 per $tCO_2$ and the range of carbon prices available in the literature, as detailed in Supplementary Fig. 1 (US$162–505 per $tCO_2$), the total cost in the WEG scenario between 2010 and 2050 would be 2.0 to 3.3 times the total cost in the SEG scenario, with a mean value of 2.8 times (or US$$_{2010}$5.2 trillion). Despite having an overall investment cost very similar to that of the IEG scenario, by accounting for the penalty cost in the WEG scenario the total cost greatly exceeds the costs of all other scenarios (Fig. 3).

It is worth noting that there are many uncertainties associated with the assumed Brazilian carbon budget for a below 2 °C world. In the basic runs (SEG, IEG and WEG), an average value of the literature for the Brazilian carbon budget was used. To assess the role of uncertainty in the budget, two additional cases are proposed: a low budget case (LB), set according to the 25th percentile (equal to 16.5 $GtCO_2$ up to 2050), and a high budget case (HB), set according to the 75th percentile (equal to 35.5 $GtCO_2$ up to 2050). Although
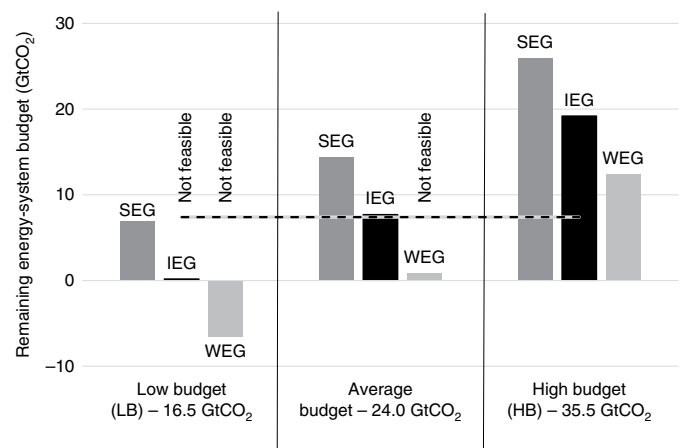


**Fig. 4 |** Sensitivity analysis of different carbon budgets for Brazil.

under a high budget all three deforestation scenarios are theoretically compatible with a national budget for a below 2 °C world (*SEG_HB, IEG_HB, WEG_HB*), a low budget (*SEG_LB, IEG_LB, WEG_LB*) would be compatible only with the strong environmental governance scenario, *SEG-LB*, but at a much higher cost than the one found for the original SEG scenario (Fig. 4).

Clearly, Brazil's NDC is at a high risk under the current political crisis, as the Government's attempt to dismiss successful environmental policies leads to greater deforestation pressure in the Amazon and Cerrado biomes. Paradoxically, to cope with higher $CO_2$ emissions ensuing from this 'particularistic short-term predatory' politics, Brazil would have to rely heavily on twenty-first-century advanced technologies, many of which are not yet mature nor available, to curb emissions. This would imply too large a cost for the domestic economy, and hence it is likely that the country will not honour its commitments to reduce emissions and help the world fulfil the ambitions of the Paris Agreement. Indeed, reducing deforestation is, by far, the lowest-cost option for Brazil to achieve its pledges to the Paris Agreement and the ultimate goal of meeting the below 2 °C target.

The bottom line is that, either other sectors within the Brazilian economy will have to pay a tremendously high cost to compensate for deforestation, or part of Brazil's emissions reduction bill will fall to other countries. Furthermore, the Amazon and Cerrado biomes, which provide many important ecosystem services at national and global scales, are in danger.

## Methods

Methods, including statements of data availability and any associated accession codes and references, are available at https://doi.org/10.1038/s41558-018-0213-y.

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## Author contributions

A.S., A.F.P.L. and R.S. performed the basic integrated modelling and conceived the methodological procedure. A.K. and P.R.R.R. were responsible for the energy system modelling and the final writing of the Supplementary Information. B.S.-F., J.L.D. and Ra.R. performed the land-use modelling and contributed to writing the manuscript and the Supplementary Information. E.V. developed the political analysis and contributed to writing the manuscript and the Supplementary Information. Re.R. was responsible for the review of the land-use results.

## Competing interests

The authors declare no competing interests.

## Additional information

**Supplementary information** is available for this paper at https://doi.org/10.1038/s41558-018-0213-y.

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## Methods

In this Letter we assess the implications of the $CO_2$ emissions expected for different levels of environmental governance with respect to land-use change, in Brazil. The first link of our methodological causal procedure is from politics to land-use governance. The politics/land-use governance link drives the second link, which is related to land-use change scenarios. Finally, these land-use change scenarios drive the causal link between energy, land-use and $CO_2$ emissions.

Based on the analysis of environmental governance in Brazil in the past two decades, this study elaborated three scenarios (for more details see main text):

- weak environmental governance (WEG)
- intermediate environmental governance (IEG)
- strong environmental governance (SEG)

From these environmental governance scenarios, we estimated the associated land-use scenarios in a spatially explicit land-use model, as well as the derived $CO_2$ emissions. Then, by running an IAM, we estimated the level of effort and investment costs required from other economic sectors to compensate for higher emissions from deforestation if Brazil is to meet its commitment under the Paris Agreement to keep the average surface temperature increase to below 2 °C by 2100.

We initially describe how the total Brazil $CO_2$ budget was established by IAMs, assuming an optimal global least-cost effort to curb emissions to reach a below 2 °C world. The total $CO_2$ budget for Brazil used in this Letter was derived from the results of different global IAMs and international studies. These IAMs were applied in an international collective modelling effort called CD-Links (www.cdlinks.org). For this study, we adopted the rounded average of the results from the literature, which equals ~24.0 Gt$CO_2$ for Brazil from 2010 to 2050. To limit the emissions of non-$CO_2$ gases an emission cost was applied to those gases only. There is a spread of values for the $CO_2$ budget allocated to Brazil in a below 2 °C world. This uncertainty is discussed in the Supplementary Discussion, where two sensitivity analyses were performed: one related to the role of technologies with net negative $CO_2$ emissions (BECCS) and the other related to the Brazilian $CO_2$ budget for keeping the global temperature increase below 2 °C (for more details, see Supplementary Information).

We model the impacts of lower levels of environmental governance on land-use change (basically deforestation) and land-use $CO_2$ emissions in the spatially explicit land-use model OTIMIZAGRO. This model has national coverage, and simulates land use, land-use change, forestry, deforestation, regrowth and associated carbon emissions under various scenarios of agricultural land demand and environmental policies. OTIMIZAGRO simulates nine annual crops (soy, sugarcane, corn, cotton, wheat, beans, rice, manioc and tobacco), including single and double cropping, five perennial crops (Arabica coffee, Robusta coffee, oranges, bananas and cocoa), and plantation forests. The model framework, developed using the Dinamica EGO platform, is structured into four spatial levels: (1) Brazil's biomes, (2) Instituto Brasileiro de Geografia e Estatística (IBGE) micro-regions, (3) Brazilian municipalities and (4) a raster grid with 25 ha spatial resolution. Future demand for crops, and deforestation and regrowth rates, are exogenous to the model. When the available land in a given micro-region (or other specified spatial unit) is insufficient to meet the specified land allocation, OTIMIZAGRO reallocates the distribution of remaining land demands to neighbouring regions, creating a spillover effect. The probability of deforestation is a function of spatial determinants, such as distance to roads and previously deforested areas. To account for net emissions from land use, land-use change and forestry (LULUCF), the model focused on the gross emissions from deforestation and removals from native vegetation regeneration.

$CO_2$ emissions from deforestation reduce the remaining budget for the other economic sectors. In other words, cumulative emissions from deforestation from 2010 to 2030 were subtracted from the total $CO_2$ budget allocated to Brazil by global IAMs. This provided the remaining budget for the rest of the Brazilian economy through 2050, compatible with a global below 2 °C scenario. Given the deforestation pathways established by the causal chain from politics to land, and their related $CO_2$ emissions, a significant share of the national budget for the energy system is already compromised.

Finally, we model the optimization of Brazil's energy system (including industrial process emissions and solid wastes) constrained by this remaining $CO_2$ budget. This was done in an IAM called BLUES, which simulates the evolution of the Brazilian energy, industrial, land-use and waste sectors, as well as their GHG emissions through 2050. The BLUES model is a perfect-foresight, least-cost optimization model for Brazil, which was built on the MESSAGE (Model for Energy Supply Strategy Alternatives and Their General Environmental Impacts) platform. In simple terms, the model is designed to simulate the competition between technologies and energy sources to meet the demand for food and

energy services (exogenous to the model, including lighting, heating/cooling requirements, mechanical energy and mobility, among others), with the objective of minimizing the total cost of the system. The platform is designed to develop and evaluate alternative strategies for energy supply, in line with restrictions such as limits for investments, fuel availability and prices, environmental regulations, market-penetration rates for new technologies, and so on.

BLUES comprises six native regions, where one is a main overarching region into which five sub-regions (following the geopolitical division of Brazil) are nested. BLUES optimizes the energy system between 2010 and 2050 in five-year intervals. Each representative year is divided into 12 representative days (one for each month) made up of 24 representative hours. In other words, there are 12 load curves of 24 hours each, leading to a total of 288 time slices per year. Power generation must balance supply for every time slice. Intermittent sources are restricted to 25% of total power generation capacity, beyond which a fully dispatchable technology (for example open-cycle gas turbines) must be jointly deployed as a capacity reserve.

The energy system is represented in detail across energy transformation, transport and consumption sectors, with over 1,500 technologies customized for each of its six native regions. The industrial sector is broken up into 11 detailed sub-sectors: cement, ceramics, chemicals, food and beverages, iron and steel, metallurgy, mining, alloys, pulp and paper, textiles, and an aggregate of other industries.

The transportation sector is divided into passenger and freight transportation. Passenger transportation takes the exogenous demand for transportation services (passenger km, pkm) and allocates it to different transportation technologies based on costs and on modal splits from the literature and auxiliary models. Passenger private transportation modes include light-duty vehicles (LDVs) and motorcycles, while passenger public transportation includes buses, micro-buses, subways (metro), rail, aeroplanes and boats. LDVs can be powered by gasoline, ethanol or flex (ethanol and gasoline), or can be hybrid, plug-in hybrid or battery electric vehicles. Motorcycles can be fueled by gasoline, flex or electricity. Buses can be powered by diesel, ethanol, biodiesel or electricity. Boats can be powered by heavy fuel oil (bunker) or diesel.

The buildings sector is made up of residential, commercial and public sectors. The end uses considered are lighting, air conditioning, refrigeration, cooking, water heating and appliances. End-use technologies can use electricity, natural gas, liquefied petroleum gas (LPG), fuel oil, diesel, biomass or charcoal, depending on the end use. A portfolio of technological alternatives for energy-use efficiency and demand reduction is available, which includes, for example, light-emitting diode light bulbs, efficient appliances and distributed generation (rooftop photovoltaic and solar heaters).

For the 2010–2030 period, the results from land use were provided by a detailed analysis of OTIMIZAGRO, and simulated in the BLUES model, which optimized the energy system. Then, to be able to cope with the carbon budget through 2050, BLUES was free to model land-use transitions from 2031 to 2050. These land-use transitions were calibrated according to the OTIMIZAGRO results.

In summary, BLUES has almost 28,000 technological nodes, of which roughly 8,000 are specific for representation of the energy system; the remaining 20,000 were developed for representation of the land system. Optimization is carried out using the CPLEX solver, for almost 9,000 user-specified restrictions. Overall, the model has over one million decision variables and represents a linear programming problem with over 500,000 rows and 400,000 columns.

For further details on the methodological procedure and methods applied in the study, see Supplementary Information.

**Data availability.** The main data included in the energy system model applied in this study are listed in Supplementary Table 5. The data follow the format and template of the international climate and energy system modelling within CD-Links (www.cdlinks.org) and are consistent with the data for all other models of the CD-Links project. Two IAMs are included in the CD-Links project, and other IAMs have been developed by other research centres. One is a global optimization model of the energy and land-use systems based on the MESSAGE platform, and is called COFFEE (Computable Framework for Energy and the Environment). This model is mentioned in the Supplementary Information as one of the tools used by the research community to determine the Brazilian total $CO_2$ budget. The other tool is the BLUES model, as already described.

The authors declare that most of the other data supporting the findings of this study are available within the Letter and its Supplementary Information. Nevertheless, given the very detailed nature of both land-use and energy system models (time and spatial resolutions), specific regional and technological data can be made available from the corresponding author upon request.