Abstract

I discuss recent research joint with J. Assunção, L. P. Hansen and T. Munson that shows that reforestation in tropical forests has great potential for carbon capture. This research accounts for the dynamics of carbon accumulation in tropical forests and uses a rich data set from the Brazilian Amazon, which encompasses 60% of the largest tropical forest on earth. Specifically, we document that (a) in a business-as-usual scenario, the Brazilian Amazon would emit 17 Gigatons of CO2e in the next 30 years and (b) with transfers to Brazil of $25 per net ton of CO2e captured, optimal land use would imply substantial reforestation in areas currently used for low-productivity cattle ranching, yielding 15 Gigatons of CO2e capture in 30 years. Transfers of $25/ton compare very favorably with other CCS schemes or with prices in carbon trading-markets. The total change in trajectory, 32 Gigatons, is large relative to the carbon budget estimated to avoid 50% odds of exceeding 1.5°C warming. We discuss structures that would give incentives for Brazil not to abandon carbon capture in the future. We also briefly summarize work in Araujo et al. (2023) that shows that forest degradation in the Amazon generates substantial negative externalities to other portions of the forest.

*Non-technical background paper based on “Carbon prices and forest preservation over time and space in the Brazilian Amazon” joint with J. Assunção, L. P. Hansen ad T. Munson. Research partially supported by Columbia Climate School and by Princeton University.
1 Introduction

In this paper, I discuss recent research joint with J. Assunção, L. Hansen and T. Munson that uses data on the Brazilian Amazon Forest, which comprises 60% of the largest tropical rainforest in the world, to examine the potential benefits and costs of reforestation as part of the solution to avoid excessive global warming. Tropical rainforests are forest ecosystems located between the tropics and characterized by high levels of rainfall, an enclosed canopy and high carbon-density.  

Carbon stored in the Amazon, if released, would produce approximately 600 Gigatons\(^2\) of CO\(_2\), equivalent to more than 15 times the estimate by the International Energy Agency of global energy-related emissions during 2023.\(^3\) As other tropical forests, the Amazon plays a crucial role in regulating local and regional precipitation and temperature and are thought to have a large impact in global climate.\(^4\) The forest “recycles” rain and trade-winds carry moisture to areas southwest, affecting economic activities, including agricultural productivity in the crucial cerrado region.\(^5\) In addition, the Amazon is incredibly bio-diverse; it holds approximately 10% of the world’s vertebrate and plant species.\(^6\)

Unfortunately, the Brazilian Amazon has experienced deforestation that already reached 15% of its area in 2017. If we remain on this business-as-usual trajectory, deforestation would exceed 22%, creating a scenario that could yield as described in Flores et al. (2024) “unexpected eco-system transitions and potentially exacerbate regional climate change.” In addition, deforestation and degradation lower water recycling and causes loss of moisture in areas down-wind, creating a cascading effects that doubles the impact of the initial damage.\(^7\)

Deforestation has made the Brazilian Amazon a substantial outlier when placed on a plot of countries’ emissions per-capita vs. GDP per-capita. (see Figure 1.)

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\(^1\)The Congo forest, the second largest tropical rainforest, covers an area of approximately 290 million hectares mostly in DRC and the Republic of Congo. Other smaller major tropical rainforests include the Sundaland forest in Indonesia and Malasia and the Australasian forest in Indonesia and Papua New Guinea. In this paper, I will often refer to tropical rainforests as tropical forests, although this is not exact.

\(^2\)I use the term CO\(_2\) is used to refer to extended CO\(_2\), which accounts also for other greenhouse gases, such as methane.

\(^3\)Flores et al. (2024).

\(^4\)Araujo (2023).


\(^6\)Araujo et al. (2023)

\(^7\)Flores et al. (2024)
Figure 1: Each dot represents a country in 2018, except for the European Union and the Brazilian Amazon. Highlighted letters stand for (C)hina, (I)ndia, (E)uropean Union, and (U)nited States. Sources: World Bank Data, downloaded on March 2021; Fatos da Amazônia 2021 (www.amazonia2030.org).

More than 85% of deforested and not yet abandoned areas has been dedicated to beef cattle (Mapbiomas- www.mapbiomas.org), with very low productivity. The goal in this case is not to run a profitable cattle farm, what may be impossible, but mainly to establish property rights in public land, by establishing continuous possession, hoping to benefit from the next amnesty law. It is therefore not surprising that the strategy of replacing the forest with cattle failed to generate reasonable standard of living for the local populations. Median wage in agriculture in the Amazon region are below the already low Brazilian minimum wage and the overwhelming share of workers are informal. The Amazon has some of the lowest indicators of health, education, sanitation and communication in Brazil.

The substantial deforestation of the Amazon is truly an ecological and economic disaster but currently it offers an opportunity. In the Amazon, trees can store the equivalent of 500-550 tons of CO$_2$ on the average hectare. Because land productivity is low and typically declines over time, 20% of deforested areas are currently abandoned and experiencing large-scale reforestation, highlighting the opportunity for forest restoration.
2 Carbon prices and Amazon forest reforestation

In Assunção et al. (2023) we investigate the potential social gains of preservation and reforestation in the Brazilian Amazon through the lens of a dynamic and spatial model that considers the trade-off between cattle production and carbon capture. The model is dynamic and quantitative and uses detailed spatial information from multiple data sets. We account explicitly for the dynamics of carbon accumulation in the forest - a crucial ingredient to provide credible measures of the potential role of preservation and reforestation in the Amazon forest to moderate global warming at different horizons. The data document large cross-sectional variability in cattle farming productivity and in the potential absorption of carbon in the Brazilian Amazon. To account for this variability, the model considers a detailed division of the Brazilian Amazon into various sites.

Figure 2: Initial values for agricultural area and carbon stock

![Figure 2](image)

(a) Agricultural area  
(b) Carbon stock

Figure 2 shows the initial land allocated to agriculture and the initial stock of absorbed carbon across sites. Figure 3a shows how carbon sequestration capacity varies across the different sites, and Figure 3b does the same for the productivity of cattle-ranching. The correlation between these two productivity measures across sites is \( -0.35 \). Thus, while cattle-ranching productivity and carbon absorption capacity are negatively correlated, this relationship is imperfect.

\footnote{Since the last agricultural census was done in 2017, here and in what follows we set 2017 as the starting date.}
The paper also considers the impact of uncertainty concerning the future evolution of cattle prices and the fact that value of crucial parameters such as the productivity of cattle production and potential for carbon capture are known imprecisely - what is sometimes referred as “deep uncertainty”.

We first use the model to elicit an estimate of the “shadow price” of CO\(_2\) emissions revealed by the deforestation that actually occurred from 1995 to 2008. The year 1995 is the first date at which we have reliable price data on cattle prices\(^9\). In 2008, the Amazon Fund was established with financing mostly for the Norwegian and German governments. The funding was a pay-for-performance scheme based on an emissions price of $5 per ton of CO\(_2\).

We employed this estimated shadow price per ton of CO\(_2\) to make forecasts that capture “business-as-usual.” This shadow price is an implicit measure of the value for Brazilians of the “forest services” provided by preserved areas, including carbon accumulation. Other services would include the value of production that occurs without destroying the forest\(^{10}\). Although this shadow price depends on the particular version of the model we use, they coalesce around $7 per ton.

We then considered the effect on future preservation and reforestation of adding different amounts of $b$ dollars for every net ton of CO\(_2\) captured to the shadow price\(^{11}\). The variation in shadow prices across models, actually make predicted future trajectories less dependent on the model variation chosen. A model that is more aggressive on deforestation needs a higher shadow price than that of a less aggressive model to explain the same observed

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\(^9\) 1995 marks the establishment of the Real plan that finally ended a period of very high and volatile inflation, making recorded prices less trustworthy before.

\(^{10}\) i.e., forest products like natural rubber, nuts, and açaí, sustainable timber, tourist services.

\(^{11}\) Thus there is no reward for pure preservation.
deforestation. Thus for a fixed transfer level $b$ per ton of CO$_2$, a planer using the more aggressive model would be considering a higher total price for captured carbon, bringing the future trajectory closer to the trajectory that would obtain if the planer would use the less aggressive model.

Of course, Brazil would have to find it advantageous to sign an agreement to commit to receive (pay) $b$ dollars per unit of CO$_2$ captured (emitted). For instance, as Figure 4 below shows, in the business as usual scenario, Brazil would substantially increase the deforested area, specially in the next twenty years. A very small $b$ would lead to a small change in the optimal trajectory for Brazil, but if agreed to, it would imply on net payments by Brazil. Brazil would clearly be better off by declining to sign an agreement that specifies a small amount per ton of net CO$_2$ captured.

As Figure 4 shows, with “business-as-usual” (zero transfers), the optimal choice involves an increase in the agricultural area from 15% to more than 20% of the biome. This increase may actually cause sufficient deforestation for the hydrological cycle of the Amazon to degrade to the point of being unable to support rain forest ecosystems in certain areas of the current biome. (Flores et al. (2024)). The predicted trajectories are much different with additional payments per ton of $10, $15, $20 or $25. Figure 5 reports the trajectories over time of the transfer payments for $b = 15$ and $b = 25$. The peak payments occur after about 12 years for both values of $b$. As expected, transfer payments for $b = 25$ are much larger that the corresponding payments for $b = 10$.  

Figure 4: Agricultural area and carbon stock evolution.
The transfer payments result in a substantial decrease in agricultural area and a corresponding increase in forested area. Table 1 gives the discounted value to the planner of a commitment to receive $b$ of net transfers for each ton captured of CO$_2$. It also gives a decomposition of this present value. “Forest services” are measured at the calculated Brazilian shadow price for zero-transfers. Net transfers to Brazil are reported separately. Even transfers of $10 per ton are enough to compensate the losses of agricultural output, but the largest contributor to the gains is the increase in forest services. The larger transfer of $25 per ton of net captured CO$_2$ almost doubles the value for the planner - a net gain of $226 billion. This net gain is composed of a loss of $354 billion in the value of cattle output, which is more than compensated by $353 billion in transfers and $246 billion in forest services. Adjustment costs, the costs of changing land-use, are a small part of the story.

Table 1: Present-value decomposition

<table>
<thead>
<tr>
<th>$b$ ($$)</th>
<th>Agricultural Output Value ($$ billion)</th>
<th>Net Transfers ($$ billion)</th>
<th>Forest Services ($$ billion)</th>
<th>Adjustment Costs ($$ billion)</th>
<th>Planner Value ($$ billion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>372.86</td>
<td>0.00</td>
<td>-139.75</td>
<td>7.69</td>
<td>225.42</td>
</tr>
<tr>
<td>5</td>
<td>133.26</td>
<td>30.43</td>
<td>46.26</td>
<td>5.64</td>
<td>204.31</td>
</tr>
<tr>
<td>10</td>
<td>57.72</td>
<td>116.05</td>
<td>88.20</td>
<td>11.73</td>
<td>250.24</td>
</tr>
<tr>
<td>15</td>
<td>33.29</td>
<td>197.21</td>
<td>99.92</td>
<td>17.63</td>
<td>312.78</td>
</tr>
<tr>
<td>20</td>
<td>23.60</td>
<td>274.68</td>
<td>104.38</td>
<td>22.49</td>
<td>380.16</td>
</tr>
<tr>
<td>25</td>
<td>18.69</td>
<td>350.92</td>
<td>106.68</td>
<td>26.63</td>
<td>449.67</td>
</tr>
</tbody>
</table>

\[^{12}\]We use a measure of full output as value added. Thus, we have exaggerated the loss of agricultural output.
Table 2 displays the total effect of transfers per ton of net CO\textsubscript{2} captured in the first 30 years. For the zero-transfer case, the planner chooses deforestation that induces carbon emissions of 18 billion tons per year in the first 30 years. The table uses this baseline in featuring the “effective cost.” We calculated this as the ratio of discounted net transfers to the difference between the net carbon captured and the corresponding baseline value when $b = 0$. With transfers of $15/ton, optimal management induces capture of 7.2 billion tons by year 30. The effective costs per ton is $4.9, one-third of the amount paid per net-ton captured. With transfers of $25/ton, there are modest increases in captured carbon, generating effective costs that almost 80\% higher, but again with an effective price close to one third of the transfer payments per net-ton captured. The results in Table 2 illustrate the large gains from trade from instituting a contract that pays Brazil per net ton of CO\textsubscript{2} captured.

Table 2: Transfer costs – 30 years

<table>
<thead>
<tr>
<th>b</th>
<th>Net captured emissions (billion tons of CO\textsubscript{2}e)</th>
<th>Discounted net transfers ($ billion)</th>
<th>Discounted effective cost ($ per ton of CO\textsubscript{2}e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-17.75</td>
<td>0.00</td>
<td>–</td>
</tr>
<tr>
<td>5</td>
<td>5.95</td>
<td>21.53</td>
<td>0.91</td>
</tr>
<tr>
<td>10</td>
<td>11.59</td>
<td>85.52</td>
<td>2.91</td>
</tr>
<tr>
<td>15</td>
<td>13.77</td>
<td>154.38</td>
<td>4.90</td>
</tr>
<tr>
<td>20</td>
<td>14.53</td>
<td>219.90</td>
<td>6.81</td>
</tr>
<tr>
<td>25</td>
<td>14.92</td>
<td>284.48</td>
<td>8.71</td>
</tr>
</tbody>
</table>

As already hinted by Figure 5, Table 3 below shows that almost 2/3 of the 30 year gains-from-trade effect occurs in 15 years. In particular, the difference between the net carbon captured when $b = 25$ and the corresponding baseline value when $b = 0$ for the first 15 years exceed 20 billion tons of CO\textsubscript{2}, at an almost identical effective cost.

Table 3: Transfer costs – 15 years

<table>
<thead>
<tr>
<th>b</th>
<th>Net captured emissions (billion tons of CO\textsubscript{2}e)</th>
<th>Discounted net transfers ($ billion)</th>
<th>Discounted effective cost ($ per ton of CO\textsubscript{2}e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-12.09</td>
<td>0.00</td>
<td>–</td>
</tr>
<tr>
<td>5</td>
<td>2.39</td>
<td>9.91</td>
<td>0.68</td>
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<tr>
<td>10</td>
<td>5.18</td>
<td>43.50</td>
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</tr>
<tr>
<td>15</td>
<td>6.64</td>
<td>83.96</td>
<td>4.48</td>
</tr>
<tr>
<td>20</td>
<td>7.55</td>
<td>127.72</td>
<td>6.50</td>
</tr>
<tr>
<td>25</td>
<td>8.13</td>
<td>172.50</td>
<td>8.53</td>
</tr>
</tbody>
</table>

Figure 6 exhibits the initial occupation and the distribution of land allocation over 30
years for transfers per ton = $0, $10, and $25. Figure 6 shows that for the case of transfers that exceed $10 per ton of net emissions, the area of the biome that is occupied by cattle farming after 30 years would be substantially reduced in comparison to the 2017 allocation. This is in sharp contrast to what transpires in the $b = 0$ business-as-usual specification in which agricultural production becomes quite intense in the lower right sites.

![Figure 6: Agricultural area changes after 30 years.](image)

## 3 Implementation

Deforestation often uses heavy machinery and if you enforce preservation in an area, owners of equipment may simply move them elsewhere. Enforcement of preservation and limiting agricultural activity exhibits very strong economies of scale. This is well exemplified by the creation of the DETER plan in Brazil in the early 2000’s that used satellite information to find violations, and often used this information to apprehend and destruct violators’ machinery. Assunção et al. (2022) estimates that DETER reduced deforestation rates by 85% saving 10 billion tons of emissions in a decade, at a cost of less than $1/ton.

Due to the intense humidity, fires do not occur naturally in tropical rainforests, in contrast to temperate forests. However, repeated fires started to renew pasture frequently spread and cause forest degradation, and eventually lead to large forest fires. A larger contiguous protected area would have proportionally less contact with unregulated areas at the border and thus be more immune to accidental fires.

All these considerations as well as the necessary enforcement capabilities point out to assigning responsibility at the largest feasible jurisdiction. In the case of the Brazilian Amazon, the model in Assunção et al. (2023) assumes that Brazil is the jurisdiction.

13 “In the extensive beef-cattle production, annual or biennial fires are commonly applied to stimulate grass regrowth in the dry season when forage is in short supply. Most cattle ranchers do not make firebreaks and the fire spreads to large areas” Pivello (2011)
### 3.1 Incentives to defect

Table 1 shows that the planner would agree to sign an agreement to receive (pay) \( b = 25 \) dollars for each ton of CO\(_2\) captured (emitted) in the Brazilian Amazon. However, as see in Figure 5, the flow of payments falls after a peak and tends towards zero. This is natural, since mature forests reach an equilibrium. Figure 7 compares at each point in time up to 50 years, the value of continuing with the optimal path given transfers of \( b \) per ton with the value of defecting and facing \( b = 0 \). For \( t = 0 \) we know that Brazil would not defect but defecting becomes advantageous after 44 years. However the maximum present value of the difference, \( M \), equals \$8.2 billion. If transfers are \$30 per net captured ton, then \( M = 4.9 \) billion.

![Figure 7: Value under \( b = \$25 \) transfer scheme vs value of defecting.](image)

There are at least two ways to avoid defection. One, a carrot, would involve buyers establishing a fund with a value of \( M \) (8.2 billion for the case of \$25/ton transfers) at time 0. The fund would be payable to Brazil if planned deforestation did not deviate substantially from the target up to \( t = 50 \).\(^{14}\) Given the estimates in Table 2, this would amount to adding 25 cents to the effective cost per ton. Alternatively, one could consider a stick: Brazil would be required to issue a bond with an initial value of \( M \) that would accumulate at the fixed real interest rate, which becomes due if, and only if, a substantial deviation in planned reforested area is observed at some time up to 50 years. The carrot or stick could be complemented by a boycott of agricultural goods produced in the Amazon, if Brazil defects.

\(^{14}\) Conditioning on area would avoid Brazil’s exposure to shocks in carbon absorption capacity that may result from global warming.
4 Spatial amplification of forest degradation

In tropical forests trees recycle humidity back to the atmosphere\textsuperscript{15}. Thus rainfall generates tree transpiration which recharges atmospheric humidity. Trade-winds move humidity causing rain in downwind direction and generating “flying rivers” that are responsible for between 30 and 40% of the total rainfall in the Amazon. Thus in addition to its local-impact, human induced forest-degradation in the Amazon is likely to cascade in the south-western direction of the trade-winds in the region. In Araujo et al. (2023) we use panel data technique and high resolution data-sets on the state of the forest\textsuperscript{16} and on wind speed and direction to estimate the causal effect of degradation in the Amazon forest. We estimate that, on average, the presence of cascading effects mediated by winds in the Amazon doubles the impact of an initial damage. However, we find heterogeneity in this impact. While damage in some regions does not propagate, in others amplification can reach 250\%\textsuperscript{17}. Regions with high propagation multipliers demand special attention from policy-makers. We also identify regions that are particularly sensitive to degradation in other area of the Amazon biome. Since wind patterns do not respect borders, these effects can be transnational. For instance, degradation of the forest on the Brazilian state of Rondonia, a region that has suffered some of the highest rates of deforestation in the recent past, results in degradation of portions of the Bolivian Amazon.

The presence of these externalities makes deforestation more costly and reforestation more beneficial than the values obtained in Assunção et al. (2023). This makes the difference between the “business as usual” outcome and the results when sufficient transfers of per net ton of CO\textsubscript{2} are arranged, even more dramatic.

5 Additional remarks.

5.1 Reforestation versus other carbon capture and storage schemes.

Carbon capture and sequestration schemes (CCS) in the US, as well as other countries, involve predominantly capture for use to enhance the yield from old oil/gas reserves (EOR). The US is the largest deployer of CCS projects. The Congressional Budget Office reported in 9/2023 that the fifteen CCS facilities then operating in the United States had the capacity to capture only 0.4 percent of the nation’s total annual CO\textsubscript{2} emissions. 95\% of the capacity

\textsuperscript{15}Salati et al. (1979).
\textsuperscript{16}The degradation state of any forest-site is measured by its Leaf Area Index (LAI), the ratio of the total (one-sided) area of leaves in a site to the site’s area.
\textsuperscript{17}Since Araujo et al. (2023) only account or spillovers mediated by winds, the multiplier of 2 should be seen as a lower bound.
provided by these fifteen facilities was used for EOR. An additional 121 CCS facilities were under construction or in development at that date. If these facilities are completed, US carbon capture and sequestration annual capacity would amount to 165 million tons or 3 percent of current annual CO₂ emissions.

Once we consider the extra CO₂ emitted by the additional production of carbon based fuel, it is not clear how much net capture of CO₂ each of these facilities yields, but Occidental Petroleum, currently developing large carbon removal facilities projects in Texas, uses EOR to sell "net-zero oil [sic]". A joint report on the 2010 symposium on the Role of Enhanced Oil Recovery (EOR) in Accelerating the Deployment of Carbon Capture and Sequestration (CCS), co-hosted by the MIT Energy Initiative (MITEI) and the Bureau of Economic Geology at the University of Texas (UT-BEG) states that “The motivation ... lies with the convergence of two national energy priorities: enhancement of domestic oil production through increased tertiary recovery; establishment of large-scale CCS as an enabler for continued coal use in a future carbon-constrained world. These security and environmental goals can both be advanced by utilizing the carbon dioxide (CO2) captured from coal (and natural gas) combustion for EOR.”¹⁸ Under IRA, U.S. 45Q credit for EOR CCS is $60/ton for facilities that start construction before 2033, and pay prevailing wages for the first 12 years of operations.

CCS projects have long-term risks that private companies cannot or are not willing to hold. In fact, limited liability implies that indemnification for loss is only possible up to the value of the firm’s assets (Gollier (2005). This explains why long term liability for leaks in CCS are often transferred to governments ex-ante, even for projects undertaken by well-funded firms.¹⁹

5.2 Emissions price-dispersion

Figure 8 below shows April 2023 prices reported by the World Bank for direct carbon pricing instruments and carbon markets around the world, which exceed of at least $25 - the amount we estimate would produce notable carbon capture via reforestation in the Brazilian Amazon. Notice that some of the largest programs, such as the EU ETS, display prices that are multiples of $25.

¹⁸Initiative (2010).
¹⁹For instance, the Australian Commonwealth and Western Australia state agreed to take over liability of Gorgon CCS project from Chevron and partners that include Shell and ExxonMobil after closing of project.
Since a ton of additional CO$_2$ emitted (captured) anywhere has the same effect on climate change, basic economics indicates that the implicit carbon tax (subsidy) should also be invariant to location.$^{20}$ In fact, this is the rationale behind tradable-emissions schemes such as the EU ETS. Nonetheless the politics of fighting climate change has resulted in programs with very different carbon prices.

6 Conclusions

Simulations reported in Table 2 suggest that international carbon payments of $25 USD/ton can reduce emissions by 32 billion tons of CO$_2$ equivalent emissions in the next 30 years. Fifteen billion tons represent carbon capture by natural regeneration, for which Brazil will receive payments, and the rest represents avoided emissions from deforestation that would happen in the “business-as-usual” scenario. As shown in Figure 7, carbon capture in this $25/ton scenario is front loaded but the average CO$_2$ capture over the 30-year period would amount to 500 million tons. Griscom et al. (2017) estimates that nature-based solutions such as forest restoration, avoided land conversion, forest management and other practices have the potential of capturing about 11.3 billion tons of CO$_2$ per year globally, with costs no greater than $100 USD/ton. Our simulations of transfer costs (Table 2) suggests that optimal management of the Brazilian Amazon could make a substantial contributions at a

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$^{20}$ Additional subsidies should be given to developers of technologies that though inefficient today may show promise for the future, but there is no obvious reason why the subsidy should be proportional to current output.
much lower effective cost. Of course, given the alternative costs of current CO$_2$ capture or emission savings schemes there is plenty of space for bargaining over transfers per ton of CO$_2$ captured by reforestation of natural forests.

Simulations in Assunção et al. (2023) ignore the loss of biodiversity or resiliency, including the possibility that Amazon deforestation triggers broad based consequences (Steffen et al. (2018) and Flores et al. (2024)). These simulations do not account for the cascading effects discussed in Section 4. In addition, the calculations in Assunção et al. (2023) ignore the negative effect in agriculture productivity in regions outside the Amazon in Brazil, a country that is currently the fourth largest agricultural producer and third largest exporter in the world, which are likely to result from business as usual. Thus a change in trajectory from deforestation to reforestation should produce even larger gains.

Tropical rainforests are present in many other developing countries that are likely to benefit from transfer payments for reforestation. In return we would obtain more breathing time to wait for the technological solutions that would help us reach net-zero emissions.

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21 See Araujo (2023).
References


Juliano Assunção, Lars Peter Hansen, Todd Munson, and José A Scheinkman. Carbon prices and forest preservation over space and time in the brazilian amazon. *Available at SSRN 4414217*, 2023.


An MIT Energy Initiative. Role of enhanced oil recovery in accelerating the deployment of carbon capture and sequestration. 2010.


Will Steffen, Johan Rockström, Katherine Richardson, Timothy M Lenton, Carl Folke, Diana Liverman, Colin P Summerhayes, Anthony D Barnosky, Sarah E Cornell, Michel Crucifix,