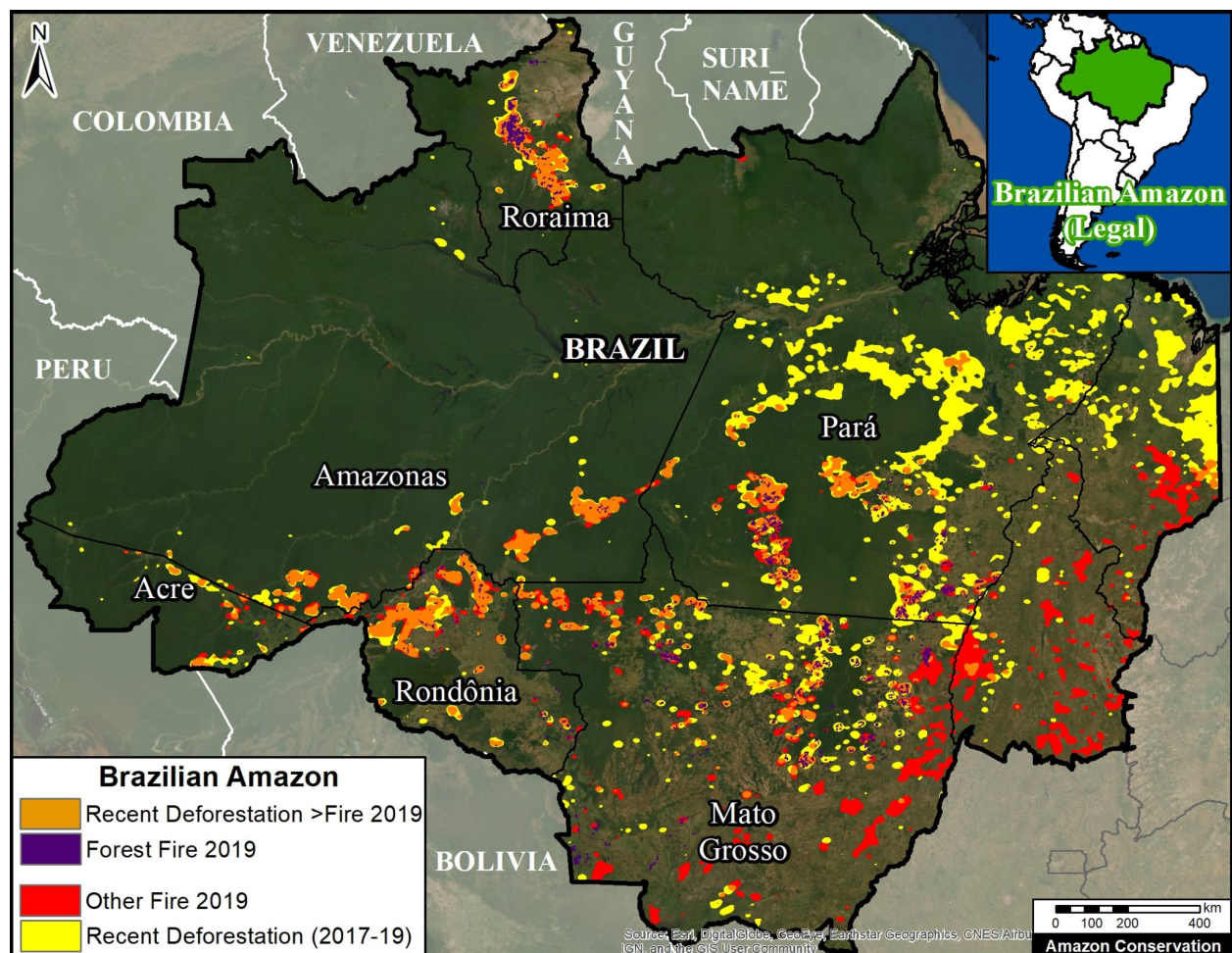


Modeling Amazon Rainforest Land Use Trends to Assess the Feasibility of Climate Goals



Finer, M., and N. Mamani. "MAAP: 113." *Monitoring of the Andean Amazon Project*, 13 Nov. 2019, maaproject.org/2019/brazil-amazon-fires/. Accessed 28 Jan. 2021. Map.

Introduction:

Conserving Earth's precious resources is an essential step towards establishing a greener future. In the past 400 years, the rapid pace of technological and medical advancement has allowed us to reaffirm our relationship with nature. I believe that our ability to use the environment to our advantage implies the responsibility to maintain its beauty. The balance between human development and coexistence with nature is currently in question in the Amazon Rainforest.

Over the past 50 years, the Brazilian government has prioritized economic growth at the expense of the tropical forest that is one of "the most biodiverse places on Earth" (Thomson). With the untouched Amazon Rainforest spanning across the country and government encouragement, there is no question as to why farmers have begun clearing land across this area. As a result of poorly regulated access to this land, the Brazilian agricultural industry has grown ("Land Use and Agriculture in the Amazon."). Of course, this has come at a cost: a staggering 17% - 18% of the forest has undergone deforestation in the past 40 years and this proportion will only continue to grow if actions are not taken (Butler). Deforestation has caused droughts and has been cited as a large cause of the wildfires that have sprouted across this area in the past few years (De Freitas Paes). As the unrestricted access to the Amazon Rainforest has resulted in detrimental effects on the resources it supplies, the situation is a prime example of the Tragedy of the Commons.

In 1968, Garret Hardin outlined this economic theory. He suggested that unregulated access to a shared resource will inevitably lead to individual parties acting in their own interest, at the expense of each parties' long term interests. He uses the example of a cattle pasture open to the public. Because the farmers using the land do not own it, there is no incentive to

sustainably use it. Additionally, nothing bars other farmers from abusing the land. Competition drives the individual farmers to graze more cattle than the land can support until eventually no cattle can be sustained at all (Hardin). Laws in Brazil preventing forest loss have been volatile, resulting in the illegal use of public lands, which harms the long term well-being of the ecosystem.

In recent years, subsidized land development and a rollback of forestry policies has made developing the Amazon Rainforest less punished (Thomson). As a result, farmers have flocked to the opportunity for capital gain, often without regard for their environmental impact. If left unchecked, overdevelopment of this land has undeniable negative externalities. In a time when carbon emissions are high, as a carbon sink, the Amazon rainforest has been a large contributor to its removal from the atmosphere. In the long run, high carbon levels lead to climate change. Rainforests are also the most biodiverse ecosystems on Earth. As they are torn down, they are replaced with monocultures. Areas that may have once housed thousands of species may be reduced to a single crop. Rainforest soil is notoriously unfertile, resulting in the wide-scale use of fertilizers that cause eutrophication in local waterways. Most commonly, deforested land has been used for cattle grazing and soybean growth. These two practices are often used in conjunction. As cattle grazing overextends the land's capabilities, farmers will often push farther into the forest and replace existing land with soybean production ("The Impact of Industrial Agriculture in Rainforests.").

This topic resonates with me personally for several reasons. I have always had a special appreciation for the environment. This past spring, I led a fundraiser for Conservation International and paired it with an effort to educate kids about ways they could practice earth-friendly habits. During this pandemic, I have come to appreciate nature even more. I began

taking on a larger responsibility for yard work around my house just to enjoy the outdoors. My dad and I have planted several trees throughout our yard during this time. The Tragedy of the Commons came to interest me because it immediately struck me as an economic reason why the world has been slow to respond to climate change. I am currently taking Environmental Science and have become more aware of the carbon cycle and deforestation. I am interested in the field of mathematical economics and saw this as an opportunity to explore the intersection of these two subjects.

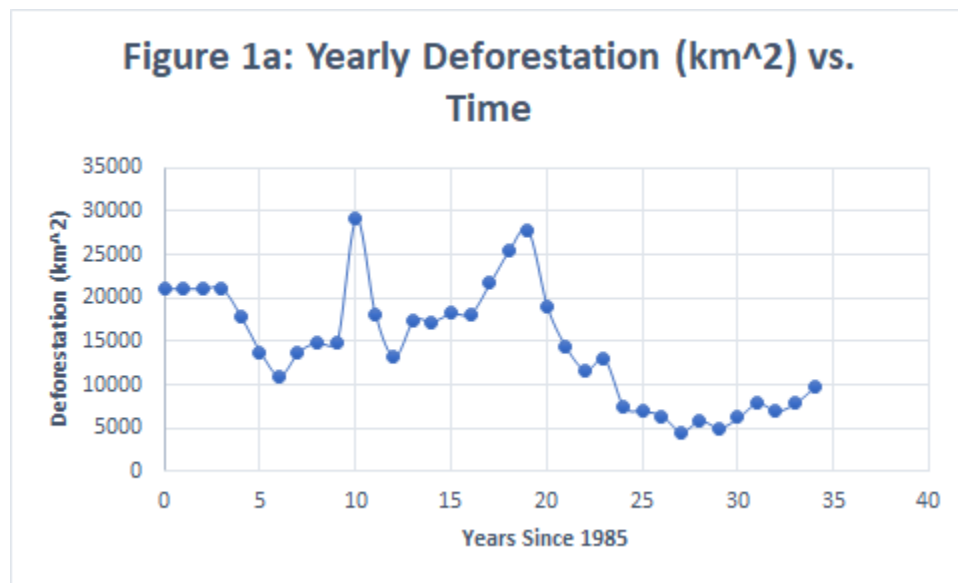
Aim and Approach:

Using satellite data from Brazil's National Institute of Space Research (INPE), this exploration will attempt to model land use trends in the Brazilian Amazon. Since 1985, deforestation has been tracked across this area. I will determine the best regression model that accurately displays past trends and can be used to extrapolate future deforestation. In 2015, Brazil signed the Paris Climate Agreement, an international treaty pledging action to prevent climate change. They pledged action to meet the following goals by 2030: zero illegal deforestation in the Brazilian Amazon, restoring and reforesting 12 million hectares of land, and improving sustainable forest management practices ("Brazil." *Climate Action Tracker*). I will model these reforestation efforts assuming a constant rate of reforestation to meet the 2030 goal. Using integration, I will determine the net amount of forest that has been added or removed in the Amazon Rainforest. I will analyze the results to determine whether the Paris Agreement goals can be achieved. If they are not feasible, I will propose a model that can be implemented to achieve the desired results. I will also provide a cost analysis of agricultural activities that are common in the Amazon to determine a subsidy that could be implemented to reduce forest expansion.

Data:

Table 1: Yearly and Cumulative Areas of Deforestation (km ²)					
Year	Yearly Deforestation	Cumulative Since 1985	Year	Yearly Deforestation	Cumulative Since 1985
1985	21,050	21,050	2003	25,396	348,835
1986	21,050	42,100	2004	27,772	376,607
1987	21,050	63,150	2005	19,014	395,621
1988	21,050	84,200	2006	14,285	409,906
1989	17,770	101,970	2007	11,651	421,557
1990	13,730	115,700	2008	12,911	434,468
1991	11,030	126,730	2009	7,464	441,932
1992	13,786	140,516	2010	7,000	448,932
1993	14,896	155,412	2011	6,418	455,350
1994	14,896	170,308	2012	4,571	459,921
1995	29,059	199,367	2013	5,891	465,812
1996	18,161	217,528	2014	5,012	470,824
1997	13,227	230,755	2015	6,207	477,031
1998	17,383	248,138	2016	7,893	484,924
1999	17,259	265,397	2017	6,947	491,871
2000	18,226	283,623	2018	7,900	499,771
2001	18,165	301,788	2019	9,762	509,533
2002	21,651	323,439			

Table 1 shows the amount of land that has been deforested each year since 1985 (Butler). In the third and sixth columns, I have calculated the cumulative amount of land by adding the amount of land deforested between 1985 and the given year. It should be noted that the INPE yearly data is measured from August 1- July 31. For simplicity, all of the subsequent analysis will adopt this definition of a year.



As seen by Figure 1a, there was a major spike in deforestation in the early 2000s. However, in the following years, large areas of land were placed under federal control to prevent deforestation. Since then, several factors have contributed to the rising deforestation beginning in 2012. There is a correlation between the development of infrastructure in the Amazon and deforestation (Ferrante and Fearnside). Increased access to roads allows farmers to expand farther into the rainforest because they can transport their crops easier. Additionally, an increase in population and investment have contributed to rising deforestation. Perhaps the most influential factor is the current Brazilian president, Jair Bolsonaro, who was elected in 2018. President Bolsonaro has taken purposeful steps to dismantle Brazil's environmental policies.

Along with his administration, Bolsonaro has not been enforcing illegal deforestation fines and has even publicly supported illegal soybean farms (Mendonça).

Considering the length of time that Figure 1a models, I did not expect there to be a regression model that could accurately depict the trend. The highest r^2 was 0.5077 which was found through the use of an exponential regression. This inaccuracy confirmed my expectation. In response, I have decided to graph the cumulative deforestation. This results in a positive correlation between time and deforested land that can be better modeled. I will determine the second derivative function to analyze inflection points. Using the second derivative test, I will be able to determine the years in which deforestation has gone from falling to rising, or vice versa.

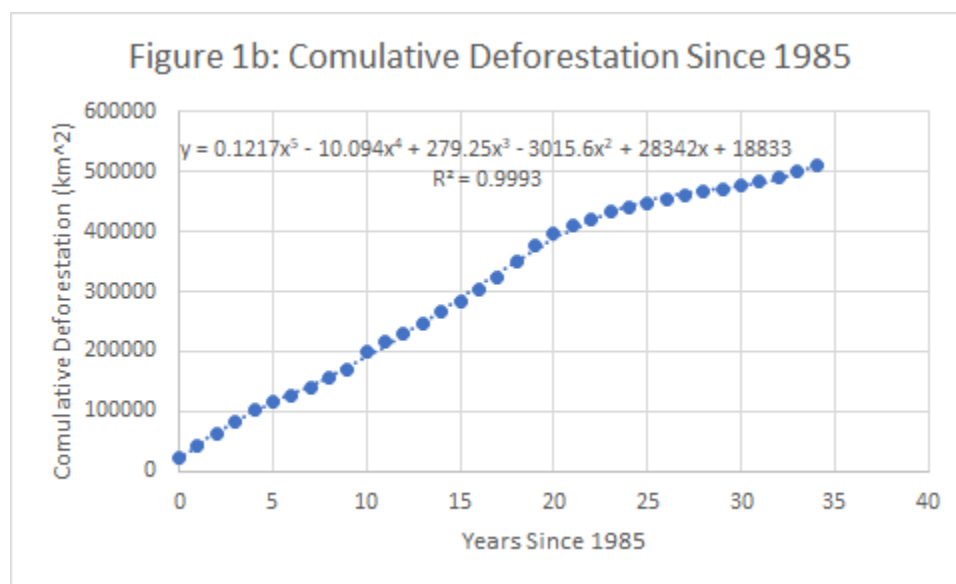


Figure 1b: the cumulative deforestation occurring since 1985. Each data is a summation of the previous year's deforestation in addition to the current year's deforestation. The trendline function y is in terms of x , the years since 1985.

This degree 5 polynomial accurately depicts the trend, but inflection points are difficult to discern. I will use the second derivative test to confirm the increasing rate of deforestation seen after 2012 in Figure 1a.

$$y = 0.1217x^5 - 10.094x^4 + 279.25x^3 - 3,015.6x^2 + 28,342x + 18,833$$

$$\frac{dy}{dx} = 0.6085x^4 - 40.376x^3 + 837.75x^2 - 6,031.2x + 28,342$$

$$\frac{d^2y}{dx^2} = 2.434x^3 - 121.128x^2 + 1,675.5x - 6,031.2$$

$$0 = 2.434x^3 - 121.128x^2 + 1,675.5x - 6,031.2$$

$x = 5.635, 15.196, 28.933$ are inflection points.

Second Derivative Test for $x = 28.933$:

$$2.434(28)^3 - 121.128(28)^2 + 1,675.5(28) - 6,031.2 = -650.384$$

$$2.434(29)^3 - 121.128(29)^2 + 1,675.5(29) - 6,031.2 = 52.478$$

Based on the above calculations and Figure 1a, the data follows the socio-political trends occurring in Brazil that are catalyzing deforestation. Through the second derivative test, it can be seen that the year 2014 is an inflection point, specifically indicating a shift from a downwards concavity to an upwards concavity as the second derivative goes from negative to positive. Although this suggests that in the year 2014 deforestation began to rise, it can be seen that 2012 actually held the minimum deforestation. For this reason, and to allow for more data points, I am choosing to narrow my focus starting from 2012 rather than 2014. This will grant a better picture of the current situation and will allow for more accurate assumptions for extrapolation.

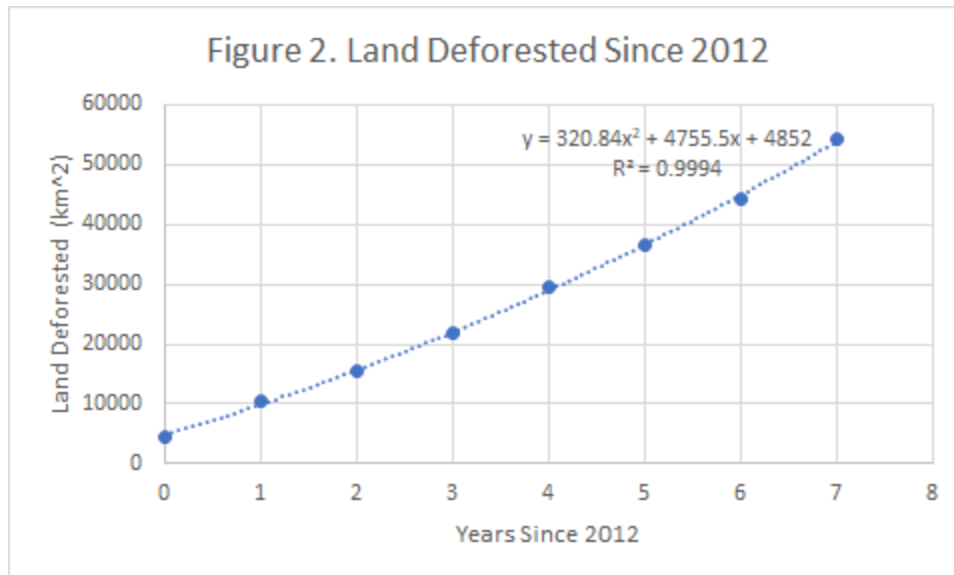


Figure 2 illustrates the cumulative amount of land that has been deforested between 2012 and 2019 and the quadratic regression used to model the trend.

I had initially expected to find that a higher degree polynomial would provide a more accurate regression. At first glance, it seemed as though this prediction was supported: the quadratic regression had an R^2 of 0.9994 while the fourth degree polynomial had an R^2 of 0.9995. However, there was a significant difference between their p-values: the quadratic regression had a p-value of .000376 while the fourth degree polynomial had a p-value of 0.844. Because the 0.844 p-value is much greater than the 0.05 threshold needed to reject the null hypothesis that the additional coefficients have no effect on the predicted values, I can conclude that the additional degrees do not enhance the regression. The same was true for the third degree polynomial. The quadratic regression has a p-value much less than 0.05, showing that the second degree variable coefficients add value to the predicted values. Therefore, the quadratic regression provide a concise and accurate model for the data

Next, I will find the first derivative of the cumulative deforestation function to determine a function for the rate of deforestation.

$$d(x) = 320.84x^2 + 4,755.5x + 4,852$$

$$d'(x) = 641.68x + 4,755.5$$

The above function gives the approximate rate of deforestation in km² per year. I will use it to extrapolate to 2030. In the 2015 Paris Agreement, Brazil pledged to reforest 12 million hectares, or 120,000 km², of land. Because I do not have data revealing the progress on this reforestation, I will make the assumption that there was 0 reforested land in 2015 and that it will increase at a constant rate of 8,000 km² per year until 2030, when the goal is reached. This assumption yields the following function and first derivative. The translation (x-3) has been added rather than x to show that reforestation started in the year 2015:

$$r(x) = 8,000(x - 3)$$

$$r'(x) = 8,000$$

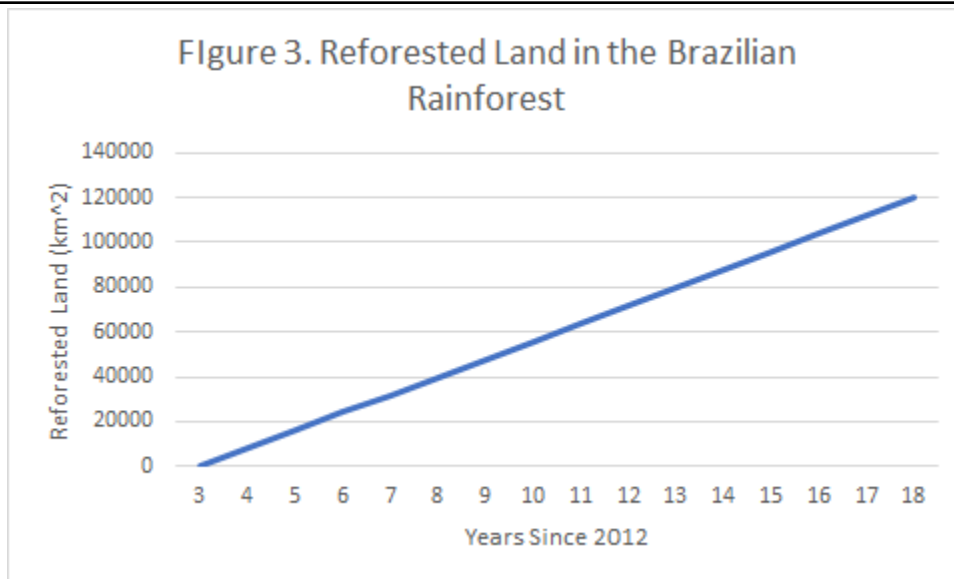


Figure 3 illustrates the reforestation function $r(x)$ from 2012 to 2030.

Table 4: Rates of deforestation and reforestation in the Brazilian Amazon based on the functions I have derived.

x	d'(x)	r'(x)
0	4755.5	8000
1	5397.18	8000
2	6038.86	8000
3	6680.54	8000
4	7322.22	8000
5	7963.9	8000
6	8605.58	8000
7	9247.26	8000
8	9888.94	8000
9	10530.62	8000
10	11172.3	8000
11	11813.98	8000
12	12455.66	8000
13	13097.34	8000
14	13739.02	8000
15	14380.7	8000
16	15022.38	8000
17	15664.06	8000
18	16305.74	8000

To determine the net change in forested land, I will graph both the deforestation rate and the reforestation rate on the same plot and integrate the difference between them. Because the deforestation function had such a high R^2 value, and the current political factors at play, I believe that it is safe to assume that deforestation will continue at this rate through 2030. However, extrapolation has its drawbacks. Less is known about the factors that could contribute to forestation in the distant future. As a result of the increasing variability, the accuracy of the extrapolation decreases as time increases.

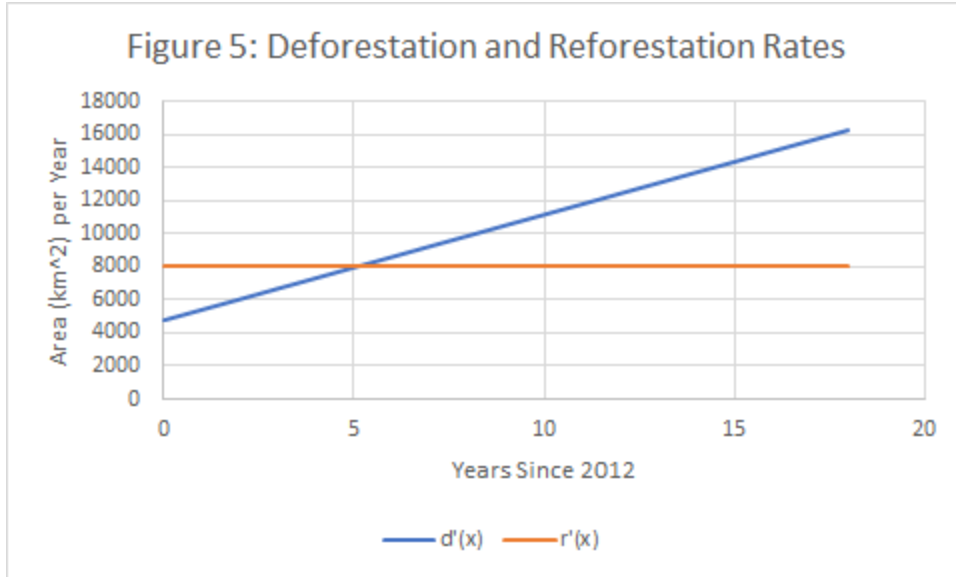


Table 5: The first derivatives of the cumulative deforestation and reforestation functions. The reforestation rate is greater than the deforestation rate until $x=5.06$ years or approximately 2017.

The projected net forestation, in km^2 , between 2015 and 2030 can be determined by evaluating the following definite integral:

$$\begin{aligned}
 & \int_3^{18} r'(x) - d'(x) \, dx \\
 & \int_3^{18} 8,000 - (641.68x + 4,755.5) \, dx \\
 & \int_3^{18} -641.68x + 3,244.5 \, dx \\
 & = (-320.84(18)^2 + 3,244.5(18)) - (-320.84(3)^2 + 3,244.5(3)) = -52,397.1 \text{ km}^2
 \end{aligned}$$

In spite of the current reforestation efforts, my projections indicate that there will be a net loss of forested land of $52,397.1 \text{ km}^2$ between 2015 and 2030.

Analysis:

Several assumptions have been made to reach this conclusion. For one, the deforestation function has been extrapolated considering the current socio-political conditions. Cattle farming

“offers numerous perceived social advantages, including a quiet lifestyle, safety and social status” in Brazil, making the transition to sustainable agriculture difficult (Garret and Ferreira). I believe that this fact, in addition to the current political regime that has no regard for the environment, makes this a fair assumption. However, President Bolsonaro will be up for re-election in 2022. An incumbent open to environmental advocacy may alter the rate of deforestation for the better.

Reforestation may help Brazil meet emissions targets, but it is far from the solution to deforestation. When forests are developed, there is a tremendous loss of biodiversity. Oftentimes, reforestation replants trees of a single or a few species, doing very little to replenish the forest’s original state. However, “for the landscape to truly regain its native identity takes a lot longer – up to 4000 years” (Brahic). An interesting extension could be to account for the rate of natural reforestation. This could lead to valuable findings as farmers could potentially rotate back to overgrazed plots of land when fertility has been restored instead of expanding into the forest. Additionally, the actual progress of reforestation is unknown. It is highly plausible that under the current administration, reforestation has not occurred at all, in which there would be a much larger loss in forested land. I assumed a constant rate of reforestation, which may not be the case. Both the reforestation and deforestation functions are extrapolated, which causes the results farther into the future to decrease in accuracy.

To make the most impact on reducing deforestation, there must be an economic incentive to sustain the natural state of the land. More sustainable and lucrative agriculture, such as fruit, has not been as popular in Brazil due to the high entry cost and lack of infrastructure needed to transport materials and yields. On the other hand, increased infrastructure has resulted in increased deforestation. Analyzing the per hectare profit procured through Brazil’s most common

Amazon agricultural products, cattle ranching and soybean production, and the deforested land that exceeds the sustainable capacity, I will attempt to determine a government subsidy that could be paid to landowners who do not develop forested land.

Between 2015 and 2030, there will be a net loss of 52,397.1 km² (5,239,710 ha) of forest. Approximately 80% of deforested land in the Amazon is used for cattle ranching ("Cattle Ranching in the Amazon Region."). For simplicity, I will assume that the remaining 20% is used for Soybean production. The average beef cow weighs 1200 lbs or about 545 kg. It yields approximately 490 lbs or 222 kg of boneless trimmed beef ("How Much Meat Can You Expect from a Fed Steer?"). On average, it costs Amazon ranchers a very low \$0.15 to produce a kilogram of beef (Veiga). Therefore, (222 kg / cow)*(\$0.15 / kg)= \$33.3 to produce a cow. Typically there is only one cow per hectare (Arantes). Ranchers then receive an average revenue of \$250 per hectare (Garret and Ferreira). The profit, revenue minus cost, therefore equals \$216.7 per hectare. Soy farmers make an average profit of approximately \$229 per hectare (Langemeier).

The most effective way to stop deforestation would be for the government to provide farmers a per area subsidy equal to the profit farmers would receive if they were to develop this land. The following calculations show the total cost of such a subsidy:

$$0.80 * 5,239,710 \text{ ha} = 4,191,768 \text{ ha used for cattle ranching}$$

$$0.20 * 5,239,710 \text{ ha} = 1,047,942 \text{ ha used for soybean farming}$$

$$\text{Total Cost of Subsidy} = (4,191,768 \text{ ha} * \$216.7 \text{ per ha}) + (1,047,942 \text{ ha} * \$229 \text{ per ha}) =$$

$$\$1,148,334,844$$

$$\text{Average subsidy per hectare of potentially deforested land} = \$1,148,334,844 / 5,375,266 \text{ ha}$$

$$= \$213.6 \text{ per ha}$$

This initially struck me as a largely unfeasible method due to costing such a significant amount of money. However, I was surprised when I compared the total cost of this subsidy to the over 373 billion USD that the Brazilian government spent in 2019 ("Brazil: Government Spending, in Dollars."). Relative to this amount of spending, this subsidy may be much more feasible than I anticipated.

A subsidy like this one could be distributed following the time scale of the deforestation function as a preventative measure. However, it only accounts for one production cycle and may have to be repeatedly paid to be effective. This clearly has some drawbacks as the government must incur an opportunity cost that cannot be spent elsewhere. In addition, the government finances this payment through the money it receives from taxes. It can be argued that Brazilian citizens ultimately will not benefit from this as they are paying the taxes that funds the subsidies. Also, increased oversight would be needed to ensure that subsidized land is not being developed for unsustainable use.

Ideally, deforestation would follow a logistic model which allows for growth up until a maximum level.

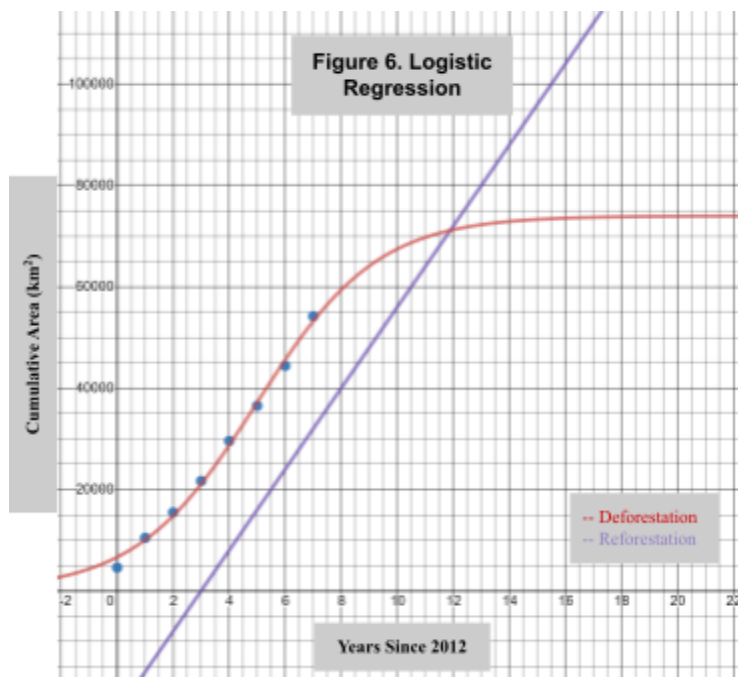


Figure 6 displays the same data points as Figure 2, the cumulative area of land that has been deforested since 2012. It differs, however, by utilizing a logistic regression model rather than the original quadratic model I had used. It also shows the reforestation function I have derived.

The logistic function, found using my graphing calculator's regression features, was:

$$e(x) = \frac{74,083.384}{1 + 10.127 * e^{-0.465 * x}}$$

This shows that in spite of current deforestation trends, a carrying capacity of 74,083.384 km² may still be feasible.

When set equal to the reforestation function, we get the following:

$$r(x) = e(x)$$

$$8,000(x - 3) = \frac{74,083.384}{1 + 10.127 * e^{-0.465 * x}}$$

Using a graphing calculator, it can be determined that the functions intersect at:

$$x = 11.905 \text{ years since 2012}$$

According to Figure 6, up until about 2024, there will be a greater quantity of deforestation than reforestation. However, because it is logistic, it has a carrying capacity of 74,083 km² and begins to level out as the reforestation surpasses it.

Conclusion

Deforestation in the Brazilian Amazon is a complex situation that is constantly changing. Current trends indicate that it will continue to rise unless significant action is taken. I believe my exploration has been successful in modeling land use trends in the context of Brazil's culture, economy, and society. Through my analysis, it is fair to say that it is unlikely that Brazil meets its Paris Agreement targets. To meet my logistic carrying capacity, a number of strategies could be implemented. Because the Amazon Rainforest consists of mostly public land, nothing prevents individuals from traversing farther into it. In the eyes of farmers, the land is limitless, and if their

neighbor is going to continue to overgraze and deforest more land, they would be at a disadvantage if they did not too. However, replacing rainforest with cattle pastures takes an area of land that was previously a carbon sink, to one that emits large quantities of carbon dioxide. For now, no one suffers directly from this, but in the long term, this can lead to climate change, which could significantly change the conditions for agriculture. To combat deforestation, land in the Amazon needs to be privatized or held more firmly by the government. Paired with the subsidy I discussed, farmers would have a direct incentive to preserve the land that they own (perhaps through more sustainable agriculture), rather than pushing further into the forest. Alternatively, a permit system could be implemented. Permits auctioned by the government could allow for a certain amount of land to be deforested. This creates a market in which permits can be traded amongst farmers, thus internalizing the cost of negative externalities. Gradually, the number of permits available could be decreased, which increases their price and decreases demand. The goal would be to decrease the deforestation permits overtime to eventually allow for the maximum 74,083 km² area I derived through the logistic regression. Lastly, more severe punishments could be put in place for illegal deforestation. For example, fines that exceed the profits of cattle grazing or criminally charging individuals who repeatedly disregard deforestation regulations. Of course, any of these proposed actions require the Brazilian government to take on a larger role enforcing their laws and do not guarantee decreased deforestation.

I thoroughly enjoyed this exploration as it allowed me to use calculus to provide meaningful insight on an environmental issue. It opened my eyes to how mathematics can be used as a lens to clarify complex systems.

Works Cited

- Arantes, Arielle Elias, et al. "Livestock Intensification Potential in Brazil Based on Agricultural Census and Satellite Data Analysis." *SciELO Brazil*, Sept. 2018,
[www.scielo.br/scielo.php?script=sci_arttext&pid=S0100-204X2018000901053#:~:text=The%20estimated%20Brazilian%20cattle%20stocking,et%20al.%20\(2014\)](http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0100-204X2018000901053#:~:text=The%20estimated%20Brazilian%20cattle%20stocking,et%20al.%20(2014).). Accessed 18 Jan. 2021.
- Brahic, Catherine. "How Long Does It Take for a Rainforest to Regenerate?" *New Scientist*, 11 June 2008,
www.newscientist.com/article/dn14112-how-long-does-it-take-a-rainforest-to-regenerate/. Accessed 18 Jan. 2021.
- "Brazil." *Climate Action Tracker*, 22 Sept. 2020,
climateactiontracker.org/countries/brazil/pledges-and-targets/. Accessed 18 Jan. 2021.
- "Brazil: Government Spending, in Dollars." *The Global Economy*, 2020,
www.theglobaleconomy.com/Brazil/government_spending_dollars/#:~:text=Brazil%3A%20Government%20spending%2C%20billion%20USD&text=The%20latest%20value%20from%202019,is%2056.59%20billion%20U.S.%20dollars. Accessed 26 Jan. 2021.
- Butler, Rhett A. "Calculating Deforestation Figures for the Amazon." *Mongabay*, 4 Jan. 2020,
rainforests.mongabay.com/amazon/deforestation_calculations.html. Accessed 18 Jan. 2021.
- "Cattle Ranching in the Amazon Region." *Global Forest Atlas*, Yale University, 2021,
globalforestatlas.yale.edu/amazon/land-use/cattle-ranching. Accessed 18 Jan. 2021.

De Freitas Paes, Caio. "Amazon Fires May Be Worse in 2020 as Deforestation and Land Grabbing Spikes." Translated by Maya Johnson. *Mongabay*, 18 May 2020, news.mongabay.com/2020/05/amazon-fires-may-be-worse-in-2020-as-deforestation-and-land-grabbing-spikes/#:~:text=Amazon%20fires%20may%20be%20worse%20in%2020%20as%20deforestation%20and%20land%20grabbing%20spikes,-by%20Caio%20de&text=Nearly%20800%20square%20kilometers%20of,the%20same%20period%20in%202019. Accessed 18 Jan. 2021.

Ferrante, Lucas, and Philip Martin Fearnside. "The Amazon's Road to Deforestation." *Science*, American Association for the Advancement of Science, 7 Aug. 2020, [science.sciencemag.org/content/369/6504/634.1#:~:text=Paving%20highways%20in%20the%20Amazonian,deforestation%20\(9%E2%80%9311\)](https://science.sciencemag.org/content/369/6504/634.1#:~:text=Paving%20highways%20in%20the%20Amazonian,deforestation%20(9%E2%80%9311)). Accessed 18 Jan. 2021.

Finer, M., and N. Mamani. "MAAP: 113." *Monitoring of the Andean Amazon Project*, 13 Nov. 2019, maaproject.org/2019/brazil-amazon-fires/. Accessed 28 Jan. 2021. Map.

Garret, Rachel, and Joice Ferreira. "For Cattle Farmers in the Brazilian Amazon, Money Can't Buy Happiness." *The Conversation*, 24 Oct. 2017, theconversation.com/for-cattle-farmers-in-the-brazilian-amazon-money-cant-buy-happiness-85349. Accessed 18 Jan. 2021.

Hardin, Garrett. "The Tragedy of the Commons." *Science*, American Association for the Advancement of Science, 13 Dec. 1968, science.sciencemag.org/content/162/3859/1243. Accessed 18 Jan. 2021.

"How Much Meat Can You Expect from a Fed Steer?" *SDSU Extension*, South Dakota Board of Regents, 6 Aug. 2020, extension.sdstate.edu/how-much-meat-can-you-expect-fed-steer#:~:text=So%2C%20to%20

20summarize%3A%20A%201200,490%20pounds%20boneless%20trimmed%20beef.

Accessed 18 Jan. 2021.

"The Impact of Industrial Agriculture in Rainforests." *Mongabay*, 28 July 2012,

rainforests.mongabay.com/0811.htm. Accessed 18 Jan. 2021.

"Land Use and Agriculture in the Amazon." *Global Forest Atlas*, Yale University, 2021,

globalforestatlas.yale.edu/amazon/land-use. Accessed 18 Jan. 2021.

Langemeier, M. "International Benchmarks for Soybean Production." *farmdoc daily* (6):171,

Department of Agricultural and Consumer Economics, University of Illinois at

Urbana-Champaign, September 9, 2016.

Mendonça, Elisângela. "Bolsonaro's Brazil Unlikely to Achieve Paris Agreement Goals:

Experts." *Mongabay*, 2019,

news.mongabay.com/2019/09/bolsonaros-brazil-unlikely-to-achieve-paris-agreement-goals-experts/.

Accessed 18 Jan. 2021.

Thomson, Ashley. "Biodiversity and the Amazon Rainforest." *Greenpeace*, 22 May 2020,

www.greenpeace.org/usa/biodiversity-and-the-amazon-rainforest/#:~:text=The%20Amazon%20Rainforest%20and%20Biodiversity&text=the%20Amazon%20rainforest.-,As%20an%20ecosystem%2C%20the%20Amazon%20is%20one%20of%20the%20most,and%20sustain%20this%20vibrant%20ecosystem.

Accessed 18 Jan. 2021.

Veiga, J. B., et al. "Cattle Ranching in the Amazon Rainforest." *Food and Agriculture Organization of the United Nations*, 2003, www.fao.org/3/xii/0568-b1.htm#P10_167.

Accessed 18 Jan. 2021.

IB Math HL Internal Assessment - Self Evaluation

Author of Paper: **Noor Mostafa**

Title of Paper: **Modeling Amazon Rainforest Land Use Trends to Assess the Feasibility of Climate Goals**

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A: COMMUNICATION		Marks Earned
0	The exploration does not reach the standard described by the descriptors.	3
1	The exploration has some coherence.	
2	The exploration has some coherence and shows some organization.	
3	The exploration is coherent and well organized.	
4	The exploration is coherent, well organized, concise, and complete.	
Comments:		
The whole IA itself is very well written. Eloquently stated aims, details, and mathematics along with personal insight and implications of politics. The only thing that could be in issue is being <i>concise</i>. Your intro was almost 2.5 pages long, and it was another 1.5 pages until you started doing real math. I understand that you were laying the ground works and everything, which I, as your teacher and the reader, do appreciate and enjoy. Some of your explanations in the middle of the paper were a little long winded as well. And some portions about the correlation values were repetitive.		

B: MATHEMATICAL PRESENTATION		Marks Earned
0	The exploration does not reach the standard described by the descriptors.	3
1	There is some appropriate mathematical presentation.	
2	The mathematical presentation is mostly appropriate.	
3	The mathematical presentation is appropriate throughout.	
Comments:		
No complaints here. Work is clearly shown. Graphs look very nice. Everything is labeled, has units, and titled.		
C: PERSONAL ENGAGEMENT		Marks Earned
0	The exploration does not reach the standard described by the descriptors.	4
1	There is evidence of limited or superficial engagement.	
2	There is evidence of some personal engagement.	
3	There is evidence of significant personal engagement.	
4	There is abundant evidence of outstanding personal engagement.	
Comments:		
You tied in your own personal interest with the mathematics, as well as using a lot of relevant political information as well to provide context to your calculations and predictions. Clearly, a lot of research and heart was put into creating your paper and models, so I would give this a 4 for sure.		
D: REFLECTION		Marks Earned
0	The exploration does not reach the standard described by the descriptors.	2
1	There is evidence of limited or superficial reflection.	
2	There is evidence of meaningful reflection.	
3	There is substantial evidence of critical reflection.	
Comments:		
Your reflection throughout the paper is pretty thorough and meaningful. You are also commenting on whether or not your models will be reliable for the time frame you are trying to speak about with both the socio-political and mathematical aspects. Your findings, along with their reliability, were a big focus of yours, which is good, but also you tried to use your data to plan for the future. Model what is to come and try to provide guidance on how to		

manage the issue of deforestation in brazil. I think your reflection is good.

Your final, actual reflection paragraph is rather short and lacking, but you did provide a lot of what you were probably going to say in the body of your paper. This is fine, in my opinion, but I think one good paragraph to bring it all home. Unfortunately I cannot assign a score of 2.5, or else I would. I am going to err on the side of caution with IB's strict grading and say this got you a 2.

E: USE OF MATHEMATICS (HL)		Marks Earned
0	The exploration does not reach the standard described by the descriptors.	4
1	Some relevant mathematics is used.	
2	Some relevant mathematics is used. Limited understanding demonstrated.	
3	Relevant mathematics commensurate with the level of the course is used. Limited understanding is demonstrated.	
4	Relevant mathematics commensurate with the level of the course is used. The mathematics explored is partially correct. Some knowledge and understanding is demonstrated.	
5	Relevant mathematics commensurate with the level of the course is used. Mathematics explored is mostly correct. Good knowledge and understanding are demonstrated.	
6	Relevant mathematics commensurate with the level of the course is used. Mathematics is <i>precise</i> and correct. Good knowledge and understanding are demonstrated.	
Comments:		
This one is hard. While I do think that you used many different aspects of math (integral and derivative calculus, statistics, etc), it is hard to measure how that ranks amongst the scoring. It does not go above and beyond the scope of the course (as in something new that you would not have learned in school), but what you do have written is very well done, everything is correct, and you explain it all very well. It puts me in a bit of a pickle. I think a good score to get here would be a 4. It is like finding a unicorn to get higher than that and since no teacher has really seen a 5 or 6, I will once again err on the side of caution that your paper belongs in that bracket. I can imagine them giving this a 4 or 3 due to the use of the statistics in your paper. The hypothesis testing was put in there, which I think was good, and you correctly stated the implications of the results, but they might take off slightly for not including the calculations or how you conducted that test. Just a guess, but I am not sure. I'll give you a 4. Well done nonetheless!		

Use this space for any other additional comments you may have (optional):

You should be *very* proud of this paper. I think that you did a fantastic job and argued everything very very well. Show it off, polish it up any more if you see fit, and send it to colleges. I think that what you

have is worth showing off, at the very least to friends and family :)