The impact of Amazon deforestation on Brazil's carbon footprint

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Introduction

The relevance of forests for reducing climate change is significant, as they act as carbon reservoirs and absorb CO_2 from the atmosphere. Tropical rainforests in particular, such as the Amazon, are highly effective and can absorb significantly more CO_2 than native forests. The Amazon is the largest tropical rainforest in the world and plays a central role in the global carbon cycle. Around 60 % of the Amazon region is located in Brazil, making the country a key player in the fight against climate change. At the same time, the Amazon is massively threatened by deforestation and degradation, which has a significant impact on the global carbon footprint.

The aim of this project is to analyse the impact of deforestation in the Amazon region on Brazilian CO_2 emissions. To this end, deforestation and emissions data from 2004 to 2019 will be analysed to determine the correlation between the destruction of rainforest areas and the increase in CO_2 emissions from land use change. The aim of this analysis is to illustrate the central importance of the Amazon region for global climate stability and to emphasise the relevance of its protection.

Used data

Description of the Data

The SQL datasets previously created using an automated ETL pipeline are used for the analysis. This extracted the data from the original datasets 'Brazilian Amazon Rainforest Degradation' from Kaggle [1] and 'CO_2 and Greenhouse Gas Emissions' from Our World in Data [2].

The deforestation dataset contains annual deforestation data from 2004 to 2019 for Brazilian states and for the entire Amazon region; the area data is given in square kilometres (km^2).

The CO_2 emissions dataset contains annual CO_2 emissions filtered through the pipeline to Brazil, divided into emissions with and without land use change. The term land use change refers to a change in the way land is used. This can include, for example, the conversion of forest or wetland areas into arable or building land. Such changes are often irreversible and can have a significant impact on the environment [3]. An important aspect in this context is deforestation, which describes large-scale deforestation and leads to a significant reduction in important habitats and a destabilisation of the ecological balance [4]. The values are given in megatonnes (Mt), where one megaton corresponds to one million tonnes. The period was limited by the pipeline to the years 2004-2019.

Structure of the Data

The deforestation dataset contains one column for the year of data collection, nine columns for deforestation per state and one column for total deforestation in the Amazon region (AMZ LEGAL). The states are Acre (AC), Amazonas (AM), Amapá (AP), Maranhao (MA), Mato Grosso (MT), Para (PA), Rondonia (RO), Roraima (RR) and Tocantins (TO). The rows are the years 2004-2019.

The CO_2 dataset table has eight columns containing the following information:

- **"Country"**: Geographic location.
- **"Year"**: Year of observation.
- **"co2"**: Annual total emissions of CO_2, excluding land-use change.
- **"co2_including_luc"**: Annual total emissions of CO_2, including land-use change.
- **"cumulative_co2"**: Total cumulative emissions of CO_2, excluding land-use change, since the first year of available data
- **"cumulative_co2_including_luc"**: Total cumulative emissions of CO_2, including land-use change, since the first year of available data.
- **"cumulative_luc_co2"**: Cumulative emissions of CO_2 from land-use change since the first year of available data
- **"land_use_change_co2"**: Annual emissions of CO_2 from land-use change

Total CO_2 emissions, including those from land use change (co2_including_luc), ranged from a maximum of 2560,971 Mt in 2004 to a minimum of 1443,259 Mt in 2010. Within the same period, CO_2 emissions

from land use change (land_use_change_co2) contributed the largest share, with values ranging from 2199,537 Mt (2004, maximum) to 1000,087 Mt (2011, minimum). The remaining columns were irrelevant for the further analysis and were removed by the pipeline. The rows correspond to the years, analogous to the deforestation dataset.

The data pipeline ensures that all columns mentioned are available and that the data sets do not contain any missing values.

Licensing Information

The dataset 'Brazilian Amazon Rainforest Degradation' [1] is licensed under the Creative Commons licence CC0, which means that the data can be used without restrictions and it would not be necessary to mention it here. For the dataset 'CO_2 and Greenhouse Gas Emissions [2]', which is licensed under the Creative Commons BY licence, the correct indication of the author and the licence is required. This requirement is met in this report by correctly indicating the licence in this section and the author's name and licence information in the sources.

Analysis

Method

To answer the question of what influence deforestation in the Amazon has on Brazil's CO_2 emissions, two analysis steps are carried out.

In the first step, the correlation between deforestation and CO_2 emissions from land use changes is analysed. This involves examining whether there is a linear relationship between the total annual deforestation area (AMZ LEGAL) and CO_2 emissions from land use change (land_use_change_co2). For this purpose, the annual deforestation data for the period 2004-2019 are aggregated and compared with the corresponding CO_2 emission values for Brazil. The Pearson correlation was selected as the method of analysis as it is suitable for quantifying specific linear relationships between two metric variables. It measures the strength and direction of a linear correlation between two variables, with results ranging from -1 to +1, where +1 indicates a strong positive correlation and -1 a strong negative correlation. A value close to 0 indicates no correlation.

In addition, the p-value is calculated, which indicates whether the result is statistically significant, i.e. whether the observed data was generated by chance or indicates a genuine effect. a p-value of less than 0.05 is aimed for in order to confirm statistical significance.

In addition, a scatter plot with a regression line is created (see figure fig:correlation), which illustrates the relationship between deforestation and CO_2 emissions and supplements the Pearson correlation by, for example, making outliers recognisable.A steep regression line indicates a strong relationship, while a flat line implies a weaker relationship. Data points that lie close to the line indicate that the straight line represents a good fit to the data.

In the second step, the total emissions are compared with the emissions from land use changes. For this purpose, the percentage share of CO_2 emissions from land use changes (land_use_change_co2) in total CO_2 emissions (co2_including_luc) is calculated. The key figure calculated in this way illustrates the contribution of land use changes - especially deforestation - to Brazil's overall carbon footprint. The calculated percentage is then visualised in a bar chart (see figure fig:percentage).

Results

The Pearson correlation value of 0.92 shows a strong positive linear relationship between deforestation and CO_2 emissions from land use change. The p-value is 0.0000, which means that the result is statistically significant and the correlation is highly unlikely to be due to chance. The scatter plot (see Figure fig:correlation) shows that most of the data points are relatively close to the regression line, which indicates a good fit of the line to the data and further confirms the strength of the correlation.

The data also show that the share of CO_2 emissions from land use change in total CO_2 emissions in the period from 2004 to 2019 is 73.46 %. These values are represented in the bar chart by a red dashed line (see figure fig:percentage). It can be seen that the percentage is relatively constant over the years and fluctuates between 67.27 % and 85.89 %. The highest percentages occur at the beginning of the period under review, while the lowest percentages are recorded in 2011 and 2017.

Interpretation

The high correlation value of 0.92 and the regression line suggest that annual deforestation is a significant factor for CO_2 emissions from land use change.

The high average share of 73.46 % illustrates that land use change, which includes deforestation, has a significant impact on Brazil's carbon footprint. This emphasises the urgency of reducing deforestation rates in order to ensure a sustainable reduction in overall emissions. The slight decreases in the years 2004 to 2010 could be due to measures to curb deforestation or political interventions.

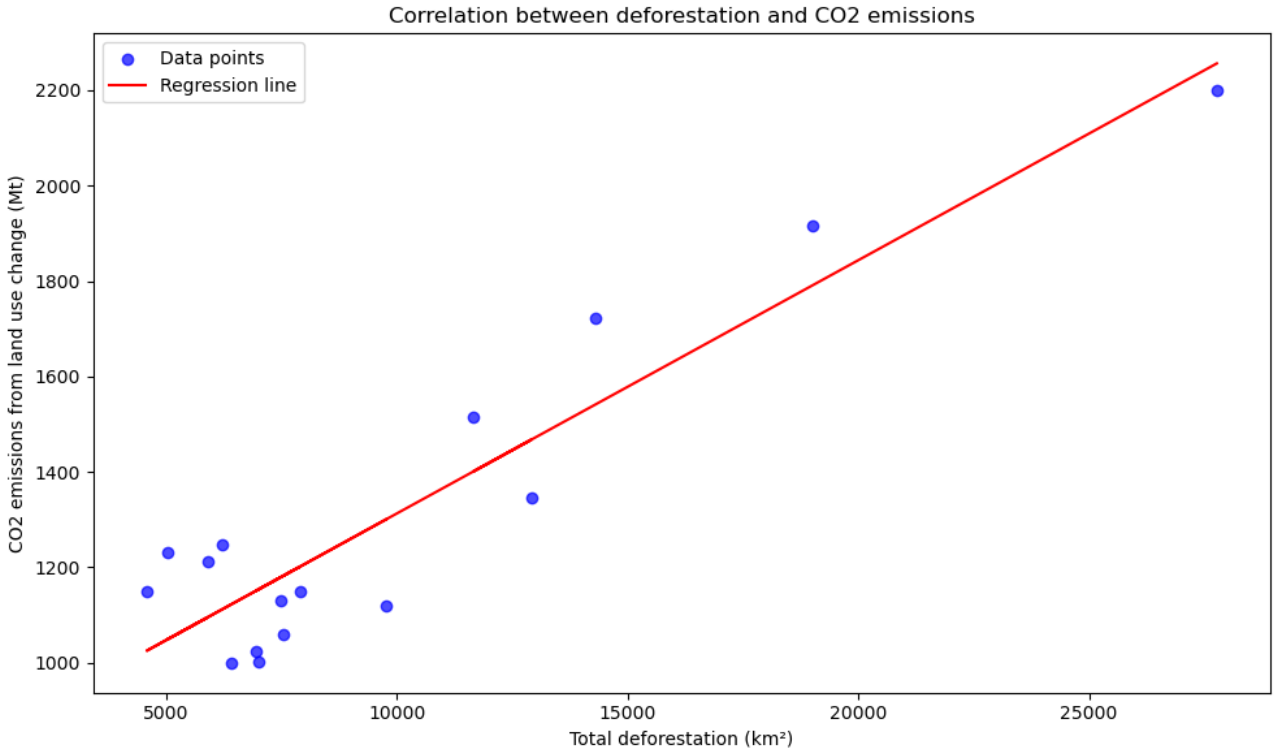

Figure 1: *Correlation between deforestation and CO_2 emissions*

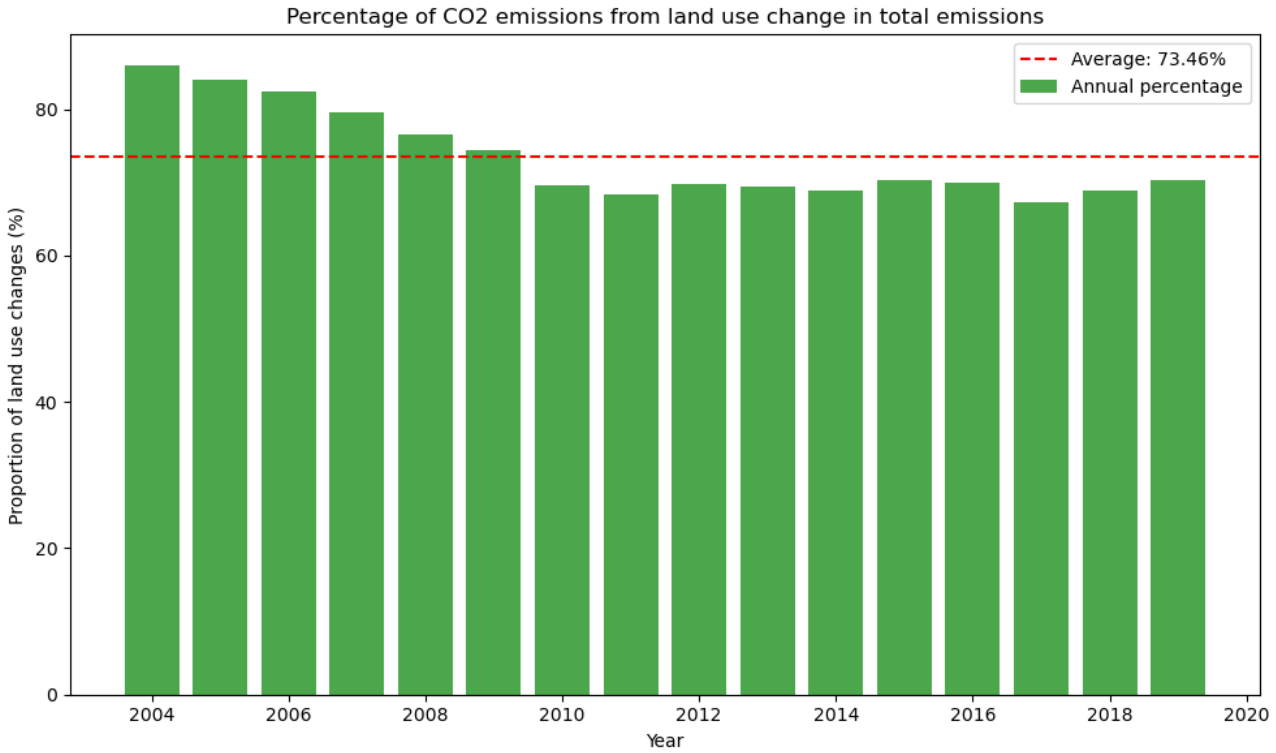

Figure 2: *Percentage of CO_2 emissions from land use change in total emissions*

Conclusions

The analysis shows that deforestation in the Amazon region has a significant impact on Brazilian CO_2 emissions, as it accounts for over 70 % of annual emissions from land use change. The high correlation value of 0.92 confirms this relationship.

However, it should be noted that correlation does not prove causality. It is possible that external factors, such as climatic conditions, economic developments or changes in land use policy, also play a role.

In addition, the analysis is based on a simple linear approach. No multivariate analyses were carried out to take into account other potential influencing factors such as fires or agricultural activities. In future studies, more complex models, such as multiple regressions or non-linear analyses, could provide deeper insights and reveal possible interactions between the variables.

It should be noted that the data only covers the period from 2004 to 2019 and does not take into account potentially relevant developments after 2019 that could have been caused by policy measures or external influences.the accuracy of the CO_2 data depends on the reliability of the underlying estimation methods. In addition, the CO_2 data could only use values for land use change that include deforestation; pure CO_2 data from deforestation alone was not available, which could potentially affect the accuracy of the analysis.

However, recent studies, such as that by Lapola et al. (2023) [5] support the assumption that deforestation is a major driver of CO_2 emissions from land-use change, especially in tropical regions such as the Amazon. The study shows that deforestation and degradation in the Amazon region emit up to 0.2 petagrams of carbon per year; a petagram (Pg) is a unit of measurement for weight and corresponds to one trillion kilograms (1 Pg = 1,000,000,000,000,000 kg). This corresponds to a large proportion of the total CO_2 emissions in the region.

The analysis provides a clear and easily understandable basis that shows the extent to which deforestation contributes to the carbon footprint. Despite its weaknesses, it could be the starting point for further analyses that could not be carried out due to a lack of time. For example, the regional differences in deforestation rates in the federal states and their specific influence on CO_2 emissions could be analysed.

References

[1] Mariana Boger Netto. *Brazilian Amazon Rainforest Degradation*. https://www.kaggle.com/datasets/mbogernetto/brazilian-amazon-rainforest-degradation. Accessed: 2024-12-23. 2019.

[2] Pablo Rosado Hannah Ritchie and Max Roser. *CO2 and Greenhouse Gas Emissions*. https://ourworldindata.org/co2-and-greenhouse-gas-emissions. Accessed: 2024-12-23. 2024.

[3] *Landnutzungsänderung*. https://nachhaltigkeit-wirtschaft.de/glossar/landnutzungsaenderung/. Accessed: 2025-01-12. 2025.

[4] *Entwaldung*. https://www.studysmarter.de/studium/umweltwissenschaft/umwelt-nachhaltigkeit/entwaldung/. Accessed: 2025-01-12. 2025.

[5] David M Lapola et al. "The drivers and impacts of Amazon forest degradation". In: *Science* 379.6630 (2023), eabp8622.