Data Visualization Report

Data Visualization
T520040101

Group 7

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Contents

List of Figures

1 Abstract

This project aimed to address the urgent need to understand and mitigate the impact of global warming on Earth's atmosphere, with a specific focus on the crucial role of forests. Trees, being central to this endeavor, possess a unique ability to absorb carbon dioxide (CO2) and release oxygen. The primary objective of the project was to evaluate the carbon storage capacity of global forests, with a focus on identifying efficient ones for preservation and enhancement. Two definitions of "efficiency" were applied: the amount of carbon stocks in forests and the amount of carbon stocks normalized by the forest area. Through these definitions, an effort was made to gain an overview of the worldwide state of green, analyzing it from both a geopolitical and temporal perspective. The findings indicated a decline in global carbon stocks attributed to human activities such as deforestation and wildfires. High-carbon stock countries were identified, and the normalized data highlighted Guyana as the most efficient country in terms of carbon stocks per forest area.

Here is the link to see the dashboard:
`https://mf2r1h-andrea0munari.shinyapps.io/data_visualisation/`

2 Introduction

Trees have an amazing property: they are breathing carbon dioxide (CO2) while releasing O2 (oxygen). In other words, the exact opposite of humans and animals. Therefore, forest ecosystems are extremely important to keep stability in the atmosphere of planet Earth. Not to mention the current global warming due to human activity these last decades, it is becoming urgent to preserve forests in order to build a sustainable world for tomorrow. More than global warming, we can talk about climate disruption, leading to more natural disasters than there were in the past. Among them, a noticeable example is the repeated wildfires happening everywhere in the world, but mostly in the biggest well-known forest, such as Canada, Brazil, Australia, Russia. But wildfires are also happening in smaller countries everywhere in the world, like in Greece or Spain.

All of this has led to a feedback loop. While CO2 is increasing due to human activity, the new drier conditions are creating more fragile forests that are fire-prone. The fire season is becoming longer, releasing all the more CO2 and so maintaining global warming (J. MacCarthy, 2023).

One of the many challenges this century is facing is to control this increase of temperature to not jeopardize life on earth. To do so, there are a lot of actions to take. Regarding the role of forests in the world, the issue to maintain the balance between O2 and CO2 is to protect forests and to plant new trees.

In this project, the aim is to study the capacity of forests from all over the world to stock CO2. We want to find the most ‘efficient’ forests to protect them or even try to use their properties (climate, leaves etc) to create new ones and protect other ones which can have similar properties.

3 Background and Motivation

The last few years are well-known for their recurrent wildfires. According to abcNEWS, "Canada wildfire emissions represent 27% of the total global wildfire carbon emission for 2023, the report states" (Julia Jacobo and Dan Peck, 2023). Face to issues regarding environment, global warming and greenhouse emissions, forests are playing a major role in nature by regulating the climate. Indeed, forest are stocking CO2 and releasing O2 in the atmosphere through the photosynthesis (Joanna Mounce Stancil, 2015). In other words, forest's leaves are taking the CO2 emitted by humans, animals and their activity and are cleaning the air by releasing O2. Different types of forests can have more precise properties. Tropical rainforests have an ecosystem able to fix an important quantity of carbon in the biomass. Thereby, the Amazon forest is widely called the "lungs of the earth".

This project was a great opportunity to work on a dataset related to the environment. The challenges of this century for the planet are wide, from greenhouse emissions to plastic pollution and biodiversity evolution etc. The aim goal is to better understand one of them. The dataset is intended to be useful and make a sense for all of us in a society where over-consumption and material desires are omnipresent and far away from the new reality humanity is facing. The final dataset chosen is linked to the greenhouse emissions by giving the quantity of carbon stocks in forest, as well as other relevant indicators.

4 Project Objectives

The goal of this study is to identify the crucial forests that should be preserved in the fight against climate change. To this end, efficiency was chosen as the indicator of forest value, with efficiency being defined as "the ability to retain carbon dioxide." Accordingly, the main research question of this study was designated as: **"What are the most efficient forests in the world?"**

In order to answer this question, sub-questions were identified. The goal was to obtain an overview of the state of green in the world through a historical and geographical analysis of forests.

The sub-questions were as follows:

1. Did the world's carbon stocks increase or decrease in 28 years globally?
2. What is the current state of carbon stocks in the world?
3. How have carbon stocks evolved on each continent?
4. What proportion of the world's carbon stocks do the best countries account for?
5. Is there a correlation between carbon stocks and forest area?

5 Data

5.1 Description

The data set chosen is coming from the Food and Agriculture Organization of the United Nations (FAO), 2022: `https://climatedata.imf.org/datasets/66dad9817da847b385d3b2323ce1be57_0/about`.
The data consists of 6 different indicators, and each of them presents values for every country in the world and for every year from 1992 to 2020. The indicators are numerical and continuous data types.

In addition, the data also contains the means for each indicator both for each individual continent (Oceania, Europe, Africa, Asia, and America but not Antarctica) and an average for the world as a whole. The mean among the world does not include the small countries values. Besides, as some countries were formed during the period of interest, the values from the year of formation has been used to compute the previous values using the ones from the original country.

This data also contains the ISO2 (Aplha-2) and ISO3 (Alpha-3) codes of each country, as well as their numerical number defined by the United Nations Organization (UNO). These are widely used codes (categorical data types) consisting of 2 or 3 letters to talk about countries as acronyms in a simple and international way.

The 6 indicators are depicted here:

- Forest area: It is the area of the forest in each country or continent measured in 1000HA.
- Land area: It is the area of the total land measured in 1000HA. For many countries, this variable is not expected to change over time as the borders of most of the countries didn't change from 1992.

- Carbon stocks in forests: It shows the quantity of carbon stocks in living biomass in forests measured by million of tonnes of carbon.
- Share of forest area: This indicator is a part of the 15th SDG (Sustainable Development Goal) ”Life on land” given by the United Nations. This indicator is exactly the sub-goal 15.1.1 which is ”Forest area as a proportion of total land area” and is measured in a percentage.
- Index of forest extent: This indicator shows the magnitude of the forest area of a given year with reference to the base year 1992, that is depicted as 100. It is measured as an index.
- Index of carbon stocks in forests: The indicator shows the magnitude of the carbon stocks in living biomass in forests of a given year with reference to the base year 1992, that is depicted as 100. It is measured as an index.

5.2 Pre processing

To ensure the proper treatment of this data set, a cleaning and reorganization process was undertaken. Initially, the data frame presented a structure in which each year was represented by a separate column. Subsequently, each indicator was arranged in separate rows for each country (see Figure ?). To optimize the arrangement, it was necessary to swap variables and years, thus achieving a single column for all years and separate columns for each indicator. In order to further simplify the data, superfluous information has been excluded, such as the source of the values, and some blank columns labeled 'CTS_Code', 'CTS_Name', 'CTS_Full_Description'. In addition, the years were renamed, as they were all preceded by the letter 'F'.
Data visualization on a map utilizes information from the ggplot library, encompassing details such as longitude, latitude, and country names. However, certain country names in the analyzed data had to be modified to align with the country names provided by ggplot in association with geographic coordinates. Additionally, the ISO3 code obtained through latitude and longitude was introduced as a new column to facilitate the identification of corresponding countries in our dataset. The final step involved filtering the data exclusively for the year 2020.

6 Vizualisation/Dashboard

6.1 Design

Regarding the design of data visualization, the decision was made to create an interactive dashboard for navigation. The aim was to enable users to explore various charts based on their areas of interest. The dashboard pages were arranged according to the points outlined in the objectives part. It was opted to include a brief caption for each graph to enhance user comprehension. The following sections outlines, for each point of the objectives, which type of graphs and how many of them were chosen to be used. Then the results will be described and analyzed.

6.1.1 Carbon stocks trend in the world through the years

This section addresses the initial question: "Did the world's carbon stocks increase or decrease over 28 years?".A **line chart** was selected, depicting the years (1992 to 2020) on the x-axis and carbon stocks in million tonnes on the y-axis (Figure 1). This chart prints the mean (already in the data) value of carbon stocks in the world, year by year. After plotting the graph, annotations were inserted under it in the dashboard to clarify what happened at breaking points that altered the overall trend.

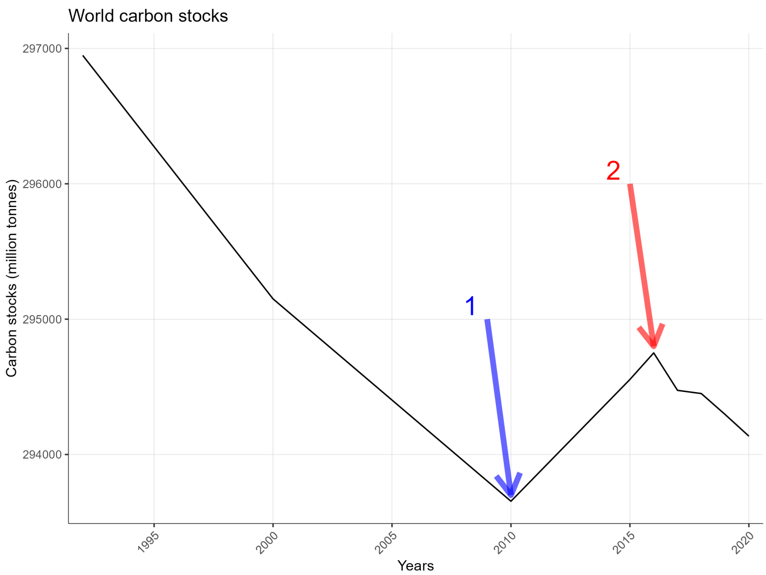

Figure 1 – Global line plot - world carbon stocks through the years

6.1.2 Current state of the carbon stocks in the world

This part is answering the second question: "What is the current state of carbon stocks in the world?". To depict the current global status of carbon stocks, it has been decided to create a **World map** showing the amount of carbon stocks for each country in the world in the year 2020 (i.e., the last year of the database). The idea was to have a relatively simple and immediate general overview of the current situation, allowing the user to quickly grasp which countries have the most carbon stocks. The choice of colors was important to facilitate this: it was chosen to use a gradient scale of multiple shades of green, with gray indicates countries for which data were unavailable.

Two distinct versions were delineated: one to display the global carbon stock levels (on a logarithmic scale) and another to showcase normalized amount of carbon stocks relative to the forest area (figure 2). The dashboard allows the user to switch between map types using a drop-down list. Both maps features are interactive: hovering the cursor over a specific country provides the value of the indicator relative to that region.

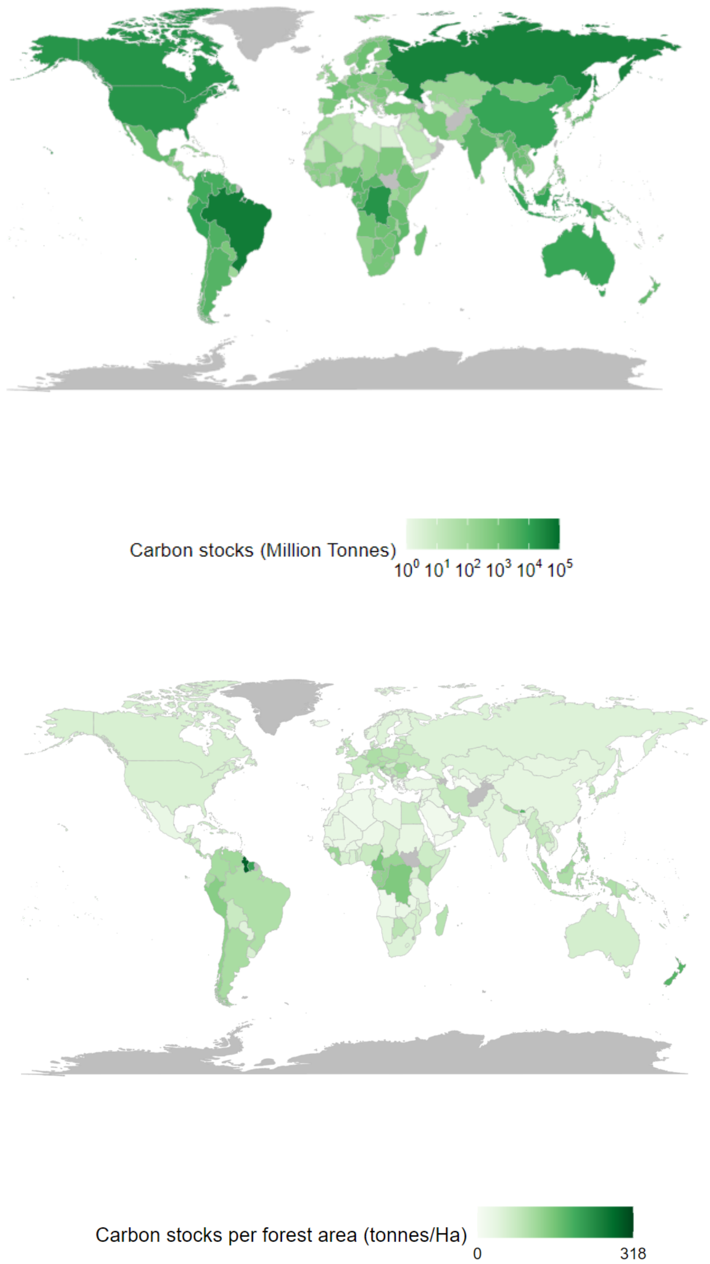

Figure 2 – World Maps

6.1.3 Evolution of carbon stocks on each continent

The previous maps provided an overview of the current worldwide carbon stocks situation. However, capturing the current state in a snapshot proved inadequate to address the research question effectively. As a result, it was deemed necessary to illustrate the continent-wise progression of carbon stocks over the years using **line graphs**. This part is answering the question: "How have carbon socks evolved on each continent?". Two variations of these graphs were generated: one depicting the evolution of carbon stock quantities in million of tonnes, and the other is representing the same trend but with normalized data with the forest area.

As a result, 10 new charts (two for each continent, excluding Antarctica for which there is no data) were included in the dashboard (appendix 1). The x-axis displays years (1992 to 2020), and the y-axis shows carbon stocks (in millions of tonnes or tonnes per Ha for normalized data). Each line on the graph represents a country.

Since most countries on a continent are not relevant to the study (small amount of carbon reserves), it was decided to assign a color to countries that had carbon reserves exceeding 8000 million tonnes for the non normalized data, and 140 tonnes/Ha for the normalized one. The threshold is highlighted with a dotted line and countries below this threshold are grayed out as not relevant to the study. The exclusion of non-relevant countries allows, first, to show the large gap with those that are actually important and second, not to hide information to the user.

To get a general overview of the status of carbon stocks for all continents, it was decided to summarize all average data in a single line graph. The summary graph helps to understand which continents may have the greatest impact faced to global warming. The graph on figure 3 shows five lines, one per continent in order to compare the carbon stock of all continents, year by year. The colors in this graph are not random, but each continent is represented by the same color used in the next bubble graph and taken from the gapminder website (`https://www.gapminder.org/tools/#$chart-type=bubbles&url=v1`).

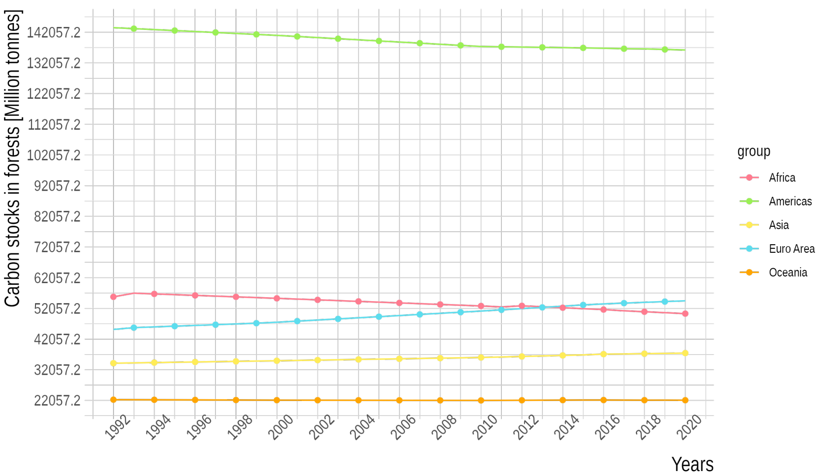

Figure 3 – Line Chart - All continents

6.1.4 Proportion of the world's carbon stock represented by the best countries

Pie Chart

As only a select few countries emerged as significant contributors to large carbon stocks, it became intriguing to examine the actual ratio between the carbon stocked by these nations and those held by the rest of the world collectively. The objective was to assess the impact of the top countries on the total carbon stock of all the world's forests. This part is answering the question: "What proportion of the world's carbon stocks do the best countries account for?".

The decision was made to compute the average carbon stocks over the years for the major contributors and to aggregate the average reserves of all other "non-significant" countries. Given the limited variation in values across the years visible on line charts (appendix 1), employing the average value was deemed appropriate. The outcomes are visually presented through a pie chart. The colors were used to accentuate a comparison between the sum of all average values of carbon reserves related to non-significant states (in gray) and all values of significant countries (in color). In addition, the specific colors were chosen in agreement and for continuity with the previous line charts. Each country is represented by the same color as it is in the line chart.

A second version of the pie chart was then added regarding the countries with higher densities of carbon stock normalized by forest area. It illustrates the minor impact of those countries on the world's total carbon stocks. The 2 pie charts are given in figure 4.

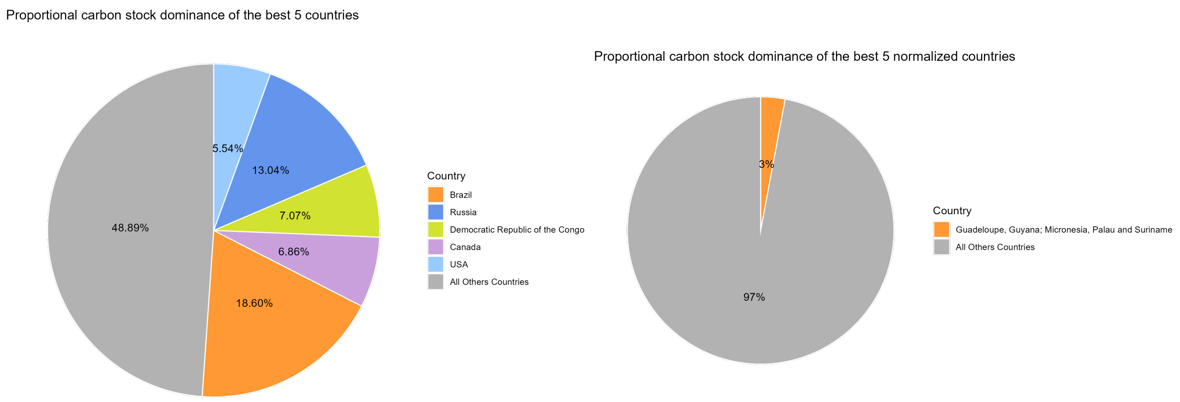

Figure 4 – Pie Chart - Proportion of best countries carbon stocks

Bar-Chart

The graph on figure 4 showed the most efficient forests over the years, using average values. However, another interesting point is to analyze which of these forests have improved in carbon storage capacity. Therefore, it was chosen to show with a bar-chart the changes of carbon stocks of the 5 largest contributors. The bar chart is comparing the amounts stored in 1992 and 2020. The use of color was also helpful for this chart to make the results easier to read: countries with satisfactory results, i.e., having higher amounts of carbon in 2020 than in 1992, were colored with shades of green. In red, on the other hand, were the countries with less bright results. The result is shown on figure 5.

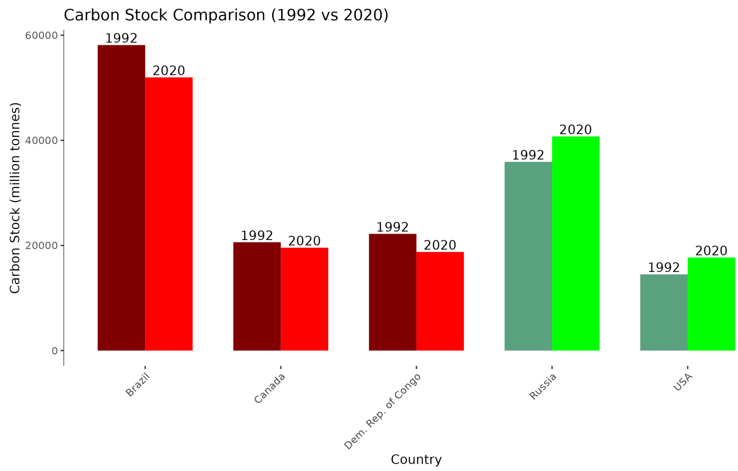

Figure 5 – Bar Chart of the best 5 countries in 1992 and 2020

The same way as before, a second version of the bar chart has been added regarding the most efficient countries in terms of normalized carbon stocks per forest area. The left of figure 6 is showing the carbon stocks per forest area for those countries. On the right, it shows only the carbon stocks not normalized for those same countries, but with the same scale as the bar chart on figure 5 for the previous countries. The idea is to highlight the minor impact of the countries defined as more efficient in terms of normalized carbon stocks compare to the amount of carbon stocked by the other ones.

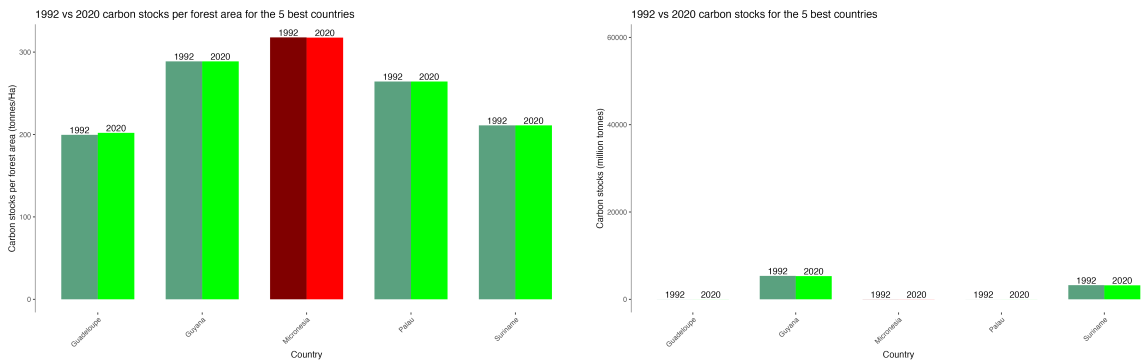

Figure 6 – Bar Chart of the best 5 countries from normalized data in 1992 and 2020

6.1.5 Correlation between carbon stocks and forest area

This part is answering the last question: "Is there a correlation between carbon stocks and forest area?". To visualize this correlation over the years, a **Bubble graph** was chosen as the most suitable representation. Forest area is plotted on the x-axis, carbon stocks on the y-axis, and each bubble corresponds to a country. The size of the bubbles conveys the share of forest area (which is the proportion of forest in the land area, in %).
The colors are used to distinguish the continents, as explained in the legend and are chosen from the website Gapminder (`https://www.gapminder.org/tools/#$chart-type=bubbles&url=v1`. The graph is also interactive: hovering over a bubble reveals the corresponding country, as well as the values of the indicators.

To have a better understanding, it was decided to animate the graph, offering a dynamic representation of the evolution of the situation over the years. By activating the play button, users can watch both positions and sizes of the bubbles changing, providing a temporal dimension to the data. The user can zoom as wanted to see more details about the bubbles very close to each other. The user also have the choice to change the axis and the indicator of the bubble sizes with drop-down lists. Even if we want to highlight a precise graph for the story telling, we decided to let the choice to the user to play with all the indicators.

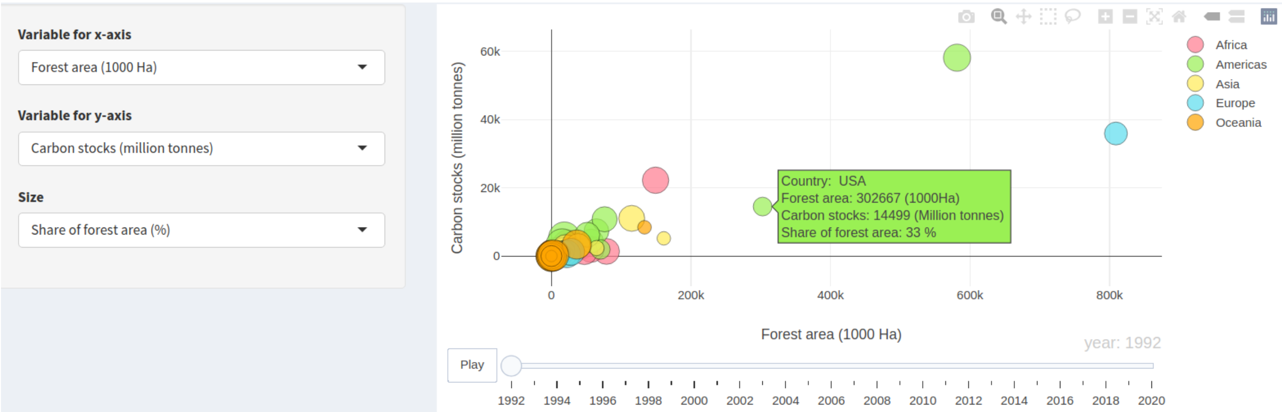

Figure 7 – Bubble Chart of carbon stocks among forest area (animated)

6.2 Must-Have and Optional features

Given the minimal requirements stipulated for this project, the ensuing list outlines the manner in which these requirements were fulfilled:

- "At least three types of graphs": the graphs used were line charts, bar charts, pie chart, bubble chart and an interactive world map.
- "At least one animated graph": the bubble chart was animated to add a time dimension as well.
- "In total at least 8 graphs": The project has a total of 20 charts

In addition, although not necessary, it was chosen to make the map and the bubble chart interactive and also provide a different visualization of line chart outcomes through a pie chart.

7 Story/Results

The goal of the study is to find the most efficient forests, and as explained before, 'efficient' was defined as the ability to retain carbon dioxide. To find an answer, it was decided to look into two relevant indicators:

- Carbon stocks in forests
- Carbon stocks normalized by the forest area

The conviction is that through the analysis of these, a comprehensive answer can be provided, even if it may not be definitive. Given the complexity of the problem at hand, it is believed that each visualization and thus each answer will contribute to reach a final conclusion.

7.1 Efficiency as the amount of carbon stocked by forest

The first question is a general one to understand the global trending: **"Did the world carbon stocks increase or decrease in 28 years?"**. The expectation was a decline in carbon stocks given the large amount of wildfires in recent years. Despite the numerous initiatives to plant new trees, the largest initiatives were undertaken without proper consideration of the types of trees being planted and their appropriate locations, like China's Great Green Wall (Jane Trac, 2007). This oversight inevitably led to less efficient forests and a high mortality rate among planted trees due to an unsuitable habitat.

To have a definite answer to this question, the line chart in figure 1 was plotted to show the trend of carbon stocks in the world's forests. As noticeable from the plot, carbon stocks decreased since 1992, but the trend fluctuates several times. The most interesting trough is the one in 2010 and the biggest peak is the one in 2016. Therefore, some research was conducted to better understand what happened in these two years to reverse the previous years' trend. The research data gathered from various news articles about the world's forests is not comprehensive enough to provide a complete overview of the global situation for the year. The articles were selected based on their alignment with the observed global trends, but they should not be viewed as individual events that directly influenced the global carbon stock trend.

- **Brazil** had the lowest forest loss in 2010, but the worst drought on record was also registered (Rhett A. Butler, 2010). In 2016, it saw a big surge in deforestation, the highest since 2008.
- **Indonesia** signed a billion dollar agreement with Norway in 2010 to protect its forests and reduce greenhouse gas emissions. The agreement is effective by January 2011.
- Regarding **Malaysia**, Nestle partnered with the Forest Trust in 2010 to eliminate palm oil linked to rain forest destruction from its supply chain (Jeremy Hance, 2007).
- **Peru** faced severe drought and fires in 2016, leading to a state of emergency declaration (Alexa Eunoé Vélez Zuazo, 2016).
- **The Republic of Congo** experienced a massive fire in 2016 that swept through logged forests (Morgan Erickson-Davis, 2016). The situation was worsened thanks to the government awarding new logging concessions (John Cannon, 2016).

The initial expectation was confirmed by the graph, and thanks to the research the main causes of the highest peak and lowest trough were clearer.

The natural next step was to visualize the most up to date carbon stock levels globally through a world map to have a general overview of the current situation. As noticeable from figure 2, the first map (not normalized) shows that the most carbon stocks are stored in Brazil and in Russia, with Canada and the USA trailing behind with other countries that host portions of the Amazon forest. This was the expected result as it is quite evident that territorial extension is directly proportional to the quantity of reserved carbon, thus the biggest countries are necessary also the ones with the most carbon stocks. By the same reasoning, China was expected to hold much more carbon stocks given the size of the country. However, it was not because the amount of carbon stocks also depends on the suitable climate of the country.

To see the situation clearly, it was necessary to focus on one continent at a time, plotted as line charts in appendix 1. In this case it was expected to see the most carbon stocks in countries that have the largest land area and that are most renowned for their trees and forests, like Brazil for the Americas, China for Asia, Russia for Europe, etc.. For all the visualizations, a threshold has been set in order to highlight the biggest contributors for each continent. The threshold was set arbitrarily with the purpose keeping only around 10 countries on total.

In America, it is noticeable that Brazil is by far the largest contributor even with an almost linear decrease in carbon stocks over the years. It is followed by Canada, United States and Peru. Notice that among the largest contributors, the United States is the only country that managed to consistently increase its carbon stocks between 1992 and 2020. The graph is close to our expectations, even if we could have thought that Canada would be closer to Brazil.

In Africa, only Democratic Republic of Congo distinguishes itself from the others, despite the fact that we did not expect to see any important carbon stocks in Africa because if the dry climate.

In Asia it was expected to see China dominate the carbon stocks. However, it is Indonesia, despite a descending trend. China, although starting and finishing second, had a constant increase over the years, almost matching Indonesia in 2020 and surpassing the threshold in 2016.

Given that Oceania is the smallest continent by land area, it's unsurprising that its carbon stocks are less than those of the other continents. As expected, Australia is the largest country in this region and so holds the majority of carbon stocks, albeit with a slight downward trend.

Taking into account Russia within the European continent, it becomes evident that it holds the most carbon stocks by a significant margin, leaving all other European countries far behind.

From all these charts it is possible to see the major contributors to carbon stocks in the world divided by continent. But are these levels of carbon stocks enough to compensate for the CO2 produced by humans and animals? According to Hannah Ritchie et al, 2020, the world's greenhouse gas emissions in 2020 have been 54.82 billion tonnes, while globally the carbon stocks amounted to 294 136 billion tonnes. In 1992, more carbon was stocked in forests (297 million tonnes) and the world emitted way less greenhouse gases (37.66 billion tonnes). As global greenhouse gas emissions continue to rise, the amount stored in forests is decreasing: this contributes to an intensification of the greenhouse effects.

From the preceding line charts, it was possible to understand that only a few selected countries—namely Brazil, Canada, Russia, USA and Congo—significantly contribute to enriching global carbon stocks. Therefore, it was interesting to assess the impact of these countries on the total carbon stock of all the world's forests. The chart on figure 4 reveals that these five countries alone contribute to more than half of the world's carbon reserves. It is intriguing to observe that Brazil has the same carbon reserves as Russia and the USA combined. Unexpectedly, Congo stocks a substantial amount of carbon, ranking ahead of the United States. The results from this data suggest that it is essential to safeguard and value the forests in these five countries, as without them more than half of the world's carbon reserves would be lost. This may be true, however it is good to first normalize these quantities relative to the forest area to understand, on an equal area basis, which countries have larger carbon stocks. This will be done at a later stage.

The pie chart contains average values, obtained through an arithmetic mean of the different quantities of carbon reserves each year. It is important to understand whether their capacity to retain carbon has decreased or increased over the years. This detail is providing information about the impact of climate change, due to human activity, and therefore wildfires. The bar chart on figure 5 clearly shows how the amounts of carbon reserves in Brazil, Canada and Congo decreased, while an increase was observed in Russia and the USA. However, the changes have not been so significant.

Small changes, in fact, may be normal. The global rise in temperatures resulting from increased emissions produces two different effects: on the one hand, it fuels the rapid growth of trees, but on the other hand, it shortens their average lifespan (Büntgen A. et al., 2019). These fast-growing trees retain CO2 for a much shorter period. Therefore, old-growth forests can be a large storage of carbon (Besnard S. et al, 2018), but the climate change might have played a significant role in the decline of carbon stock quantities within these regions.

Furthermore, as mentioned earlier, the deforestation that occurred in Brazil in 2010 significantly contributed to the decrease in carbon reserves in this country. Regarding Congo, data concerning the share of forest area highlight a decrease in the latter, which could be the cause of the decline in carbon reserves.

Finally, the correlation between carbon stocks and forest area was expected to be positive: as the forest area increases, the carbon stock also increases. On the figure 7, it is mostly the case. However, there are a few exceptions. It remains possible to identify the 5 largest contributors worldwide from the previous paragraphs. Globally, the correlation of carbon stock with forest area is linear. However, Congo has twice the amount of carbon stocks by China, but it with a much smaller forest area. It is because Congo is mostly composed from rain forests (Xu et al. 2017). These forests are exceptionally rich in plant diversity, and the trees there can grow up to 50 meters. Such a state of affairs guarantees enormous carbon stock values. This forest stores vast amounts of carbon in biomass. China, on the other hand, has no longer primary forests. In the 1990s, China adopted a policy to rebuild forest cover in the country and implemented many programs aimed at improving forest conditions ('How China Brought Its Forests Back to Life in a Decade'). This explains a significant increase in forest area, while carbon stock does not increase dramatically because these are young forests that do not store as much carbon as primary forests.

7.2 Efficiency as a sense of carbon stocks per forest area

The idea of this part is to be able to compare countries between them by normalizing the carbon stocks. Each value of carbon stocks in a country is divided by the area of the forest in the country. Now the biggest forests are not expected to have the most efficiency, even if they could. There were no specific expectations about the results. However, it was considered that the density of the forest might influence the carbon stocks per forest area.

The world map of the normalized carbon stocks in figure ? was surprising on many points. First, almost all the world has a similar efficiency in terms of normalized carbon stocks (not a lot of contrast on the map). It means that the previous best countries are quiet similar as any forest in term of carbon stock per area, except larger. Second, Guyana is the only country noticeable far from the others with a value of 289 tonnes/Ha (in very dark green on figure ?).

This impressive result from Guyana is reached thanks to "a purposeful government initiative, spanning multiple administrations to keep the country's deforestation rates among the lowest in the world" (OilNOW', 11 May 2022). To be more precise, the government managed to use 'carbon credits' (UNFCCC) to monetize their forest without turning the soil occupied by it into oil farms and mining facilities. Since Guyana manages to extract more carbon dioxide from the atmosphere than they emit, they obtain carbon credits to sell to other countries or companies that are still emitting more than they absorb. So forest became a real asset for this country, hence why the government pushed projects to take care and improve them like the Forest Carbon Partnership Facility project (FCPF). "The objective of this operation is to assist the Government of Guyana in its efforts to establish an enabling framework and build the capacity for Reducing Emissions from Deforestation and Forest Degradation (REDD+) as well as conservation, sustainable management of forests and enhancement of forest carbon stocks by providing financial and technical assistance" (Guyana - Ministry of Natural Resources, 2021).

Looking more precisely at the evolution of the normalized carbon stocks continent by continent over the years, the best countries are located in central America and Oceania. These are Guadeloupe, Guyana, Micronesia, Palau and Suriname. They all have a common point, they are tropical rainforests (forests located between precise latitudes very close to the Equator). Indeed, rainforests are producing way more biomass (up to 3 times for the old-growth forests of the Pacific Northwest) (Heather J. Johnson, 2023). It means that they are able to stock more CO_2. They represent 40% of the global carbon stocks on lands (Maria B. Mills, 2022).

Now we know that these 5 countries are more efficient per area. However, they are very small countries. It means that they are representing only a few part of the all carbon stocks. The pie chart on figure ? is supporting this. These 5 countries are representing only 3% of the whole carbon stocks in the world per year, while the 5 best countries of non normalized carbon stocks were more than a half. The efficiency per area is relevant, but the global impact on planet Earth might be more important at the end.

In order to have a better view of how small these 5 countries are in term of global carbon stocks in the world, the bar chart given on figure ? is showing the amount of carbon stocks with the same scale as the one from the previous non normalized carbon stocks countries (figure ?). One can see that the quantity of carbon stocks are not even visible because it is too small. Besides, looking at the carbon stocks per forest area (figure ?) is showing that they almost is no difference between 1992 and 2020. For some countries, there is no difference at all, because the scale of unit is too big to actually see the difference (tonnes/Ha is a lot, especially for a small country). The difference might be visible with a smaller scale like kg/m$\hat{2}$ for example. As mentioned before, these forests are certainly efficient per area, but they are very small in a world scale.

To conclude about the efficiency of carbon stocks per forest area, Guyana is from far the best country. In general, the tropical rainforests are better to stock the carbon. However, Guyana is a very small country with a small forest area. Worldwide, these countries are not heavy enough to balance with the increasing carbon emission due to human activity.

8 Conclusion

The main goal of this report was to visualize and analyze the carbon stocks data from the FAO Global Forest Resources Assessment 2020. Various types of charts were used, such as line charts, bar charts, pie charts, bubble charts, and maps, to show the trends, distribution, and correlation of carbon stocks across the world and different continents. In order to finalize the data analysis, non-normalized and normalized by forest area carbon stocks were compared. This was done to measure the efficiency of the world's forests independently of the forest area and land area.

The main findings of this report are:

- The global carbon stocks have decreased from 1992 to 2020, mainly due to human activities such as deforestation, and wildfires.
- The top five countries with the highest carbon stocks are Brazil, Canada, Congo, Russia, and the USA. They account for more than half of the global carbon stocks.
- The carbon stocks vary significantly across different continents, with the Americas having the highest (by far) carbon stocks through the examined years, and Oceania having the lowest.
- The normalized carbon stocks show that Guyana is the most efficient country in terms of carbon stock per forest area, thanks to its low deforestation rate and its smart use of carbon credits. The other relevant countries of this study are Guadeloupe, Suriname, Micronesia and Palau.

Some limitations and challenges faced during the project were the lack of data for some countries, the difficulty of comparing different scales and units, managing the trade-off between simplicity and complexity of the charts, especially regarding the world map and the animated bubble chart. Another challenge was finding sources to understand what caused big changes in the world carbon stocks since it is impossible to pinpoint specific events that explain the global trend.

Improving the work can be done by exploring the causal factors and impacts of carbon stocks. Besides, it is possible to go deeper within the analysis by using all the indicators furnished by this data. We decided to focus only on some of them for our study and question points.

In conclusion, the carbon stocks data provide valuable insights into the state and evolution of the forests and their role in mitigating climate change. The report proved how data visualization can help to communicate and interpret the data in an effective and engaging way. The most relevant takeaway from this project is the importance of preserving and enhancing the forests as a natural resource and a global asset.

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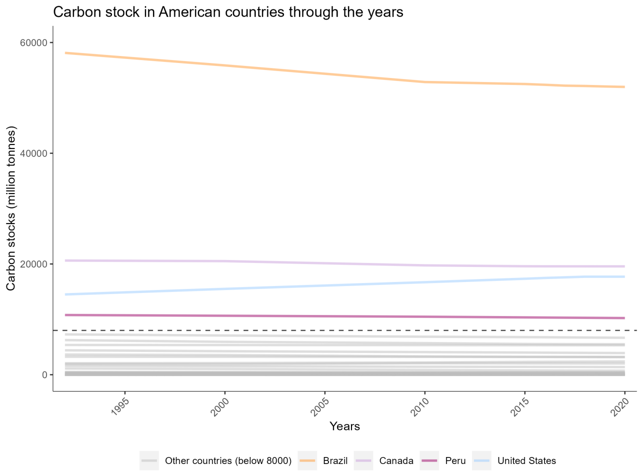
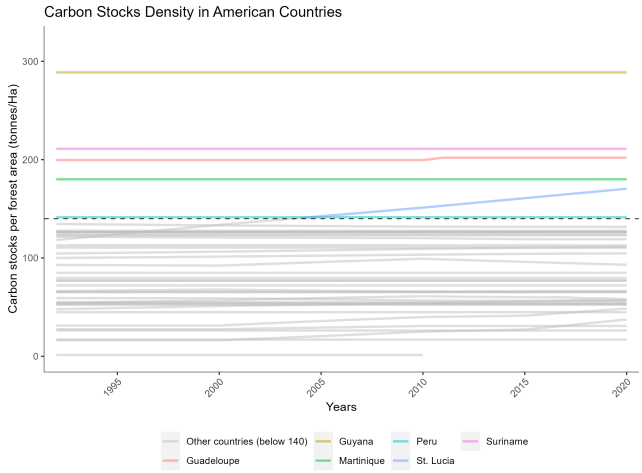
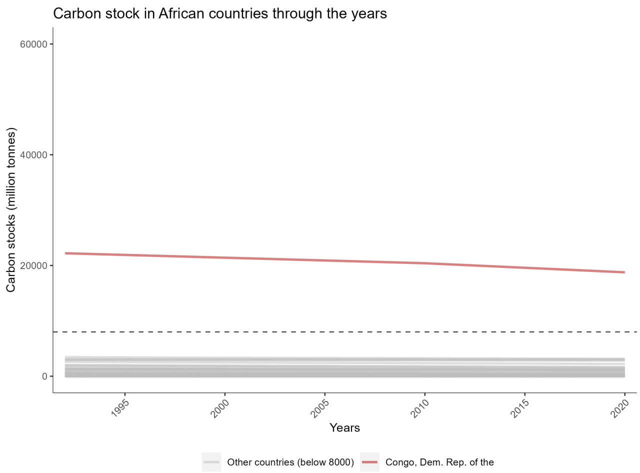
10 Appendix 1 - Continent line graphs



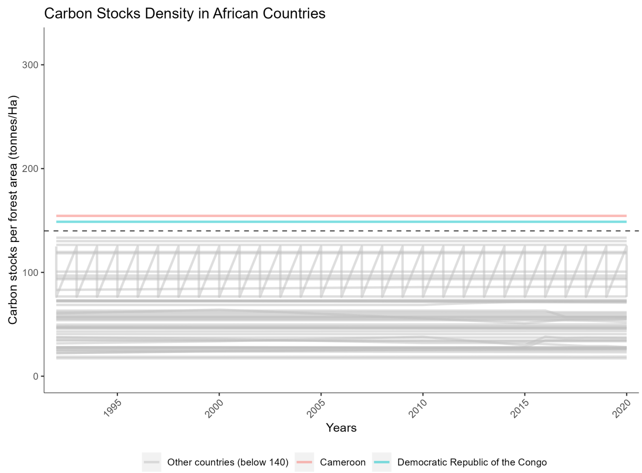
Line Chart - America



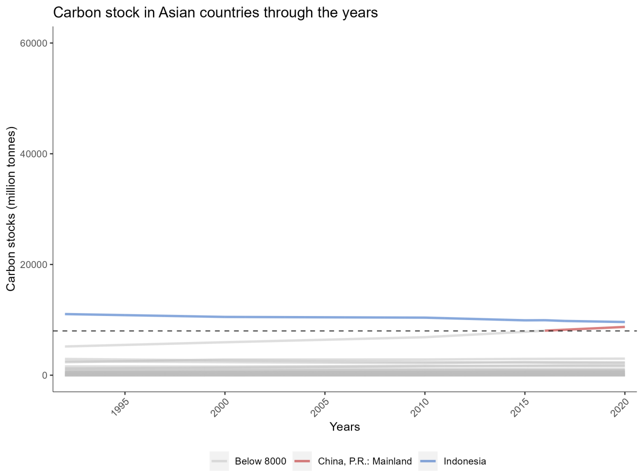
Line Chart - America Normalized



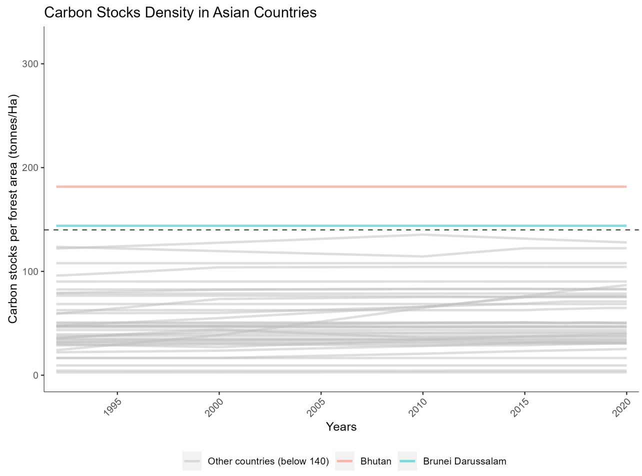
Line Chart - Africa



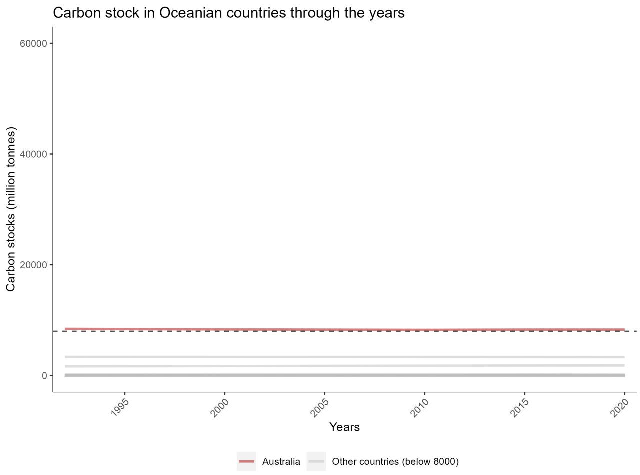
Line Chart - Africa Normalized



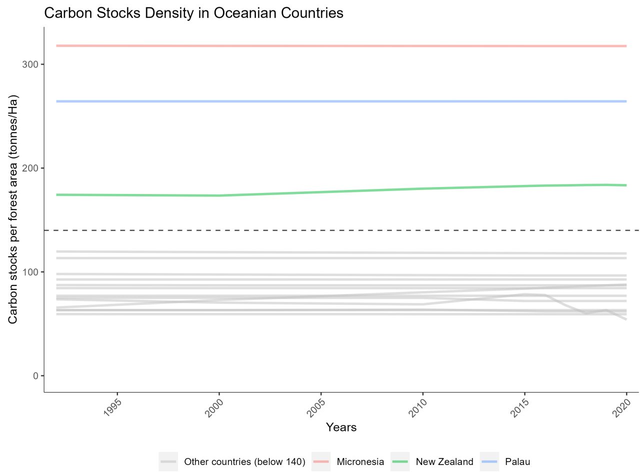
Line Chart - Asia



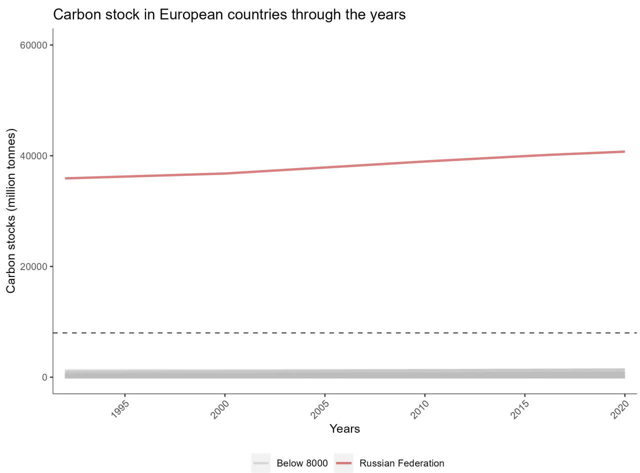
Line Chart - Asia Normalized



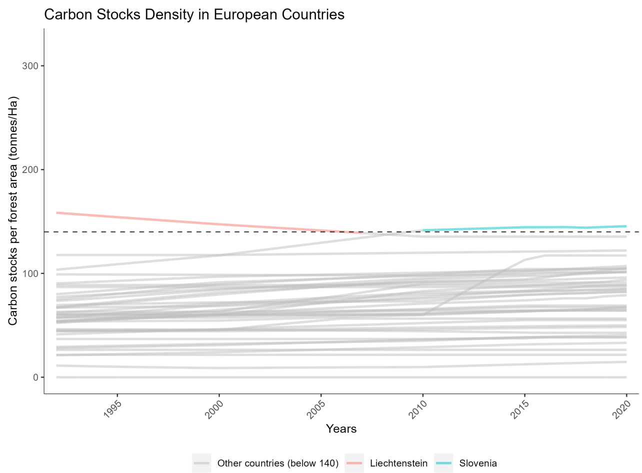
Line Chart - Oceania



Line Chart - Oceania Normalized



Line Chart - Europe



Line Chart - Europe Normalized