Establishing A Link between Carbon Dioxide Levels and Forest Area

Nicholas Beaty

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Marshall University

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Introduction

Carbon dioxide levels and climate change have become very controversial issues in society, and many are beginning to fear the effects on the Earth from the high levels of CO_2 in the atmosphere and the greenhouse effect. While the greenhouse effect is a natural process of the Earth that is vital to survival, there has been an observed increasing intensity with the introduction of emissions of certain substances, a main one of which being carbon dioxide, which traps heat within the Earth's atmosphere. The emission of carbon dioxide has been discussed heavily, with countries around the world meeting to discuss and agreeing to cut their emissions of CO_2 due to the seemingly rising temperatures from the greenhouse effect. With the increasing intensity of the greenhouse effect, it opens a question to how badly carbon dioxide emissions can affect the Earth's temperatures; making this a topic of great importance to research.

Many people have begun to argue that deforestation has a devastatingly negative impact on climate change, as these trees lower carbon dioxide levels due to carbon mitigation. Throughout the process of deforestation, many decades of carbon storage can be released from the trees being unable to hold the carbon stored after death. It has also been estimated, by the Climate Institute, that twenty-five percent of the total greenhouse production comes from the processes and aftermath of deforestation (Bennett 2017). This shows how big of a factor deforestation can be within the climate change equation and raises the question on how the world's forests could be a very big variable to look at along with the carbon dioxide emissions.

I plan to study the area of the European Union, to prevent the bias that trends occur from a single data set can establish a causality and to get more of a trend for how the whole region can be affected from forests. The European Union has seen a growth in their forest area and the trend continues to grow throughout the years, making it a prime area to see if the growth of forests can possibly lead to a decline in the carbon dioxide emissions. This area is important to investigate, due to many countries having many areas that are under sea-level and can be directly influenced by the long-term impacts from climate change. If the trends of climate change continue, many famous European cities (such as Amsterdam, Venice, and Brussels) will be underwater and could eventually affect the European framework in general.

This project is guided throughout three main research questions: “Is there a relationship between forest area and carbon dioxide level depletion,” “To what extent does an increase in forest area lower carbon dioxide levels,” and “Is there a way to derive this relationship into the principle of climate change as a whole?” By using data representing the total forest area along with data carbon dioxide levels (both from 1990 to 2015) of select countries to try and establish a link between forest area within a country leading to lower carbon dioxide levels.

Literature Review

Research Questions & Topics

Most of the literature present asks the question about how forests are impacting the economy, such as “Does putting a price on the carbon dioxide levels being emitted through cap-and-trade programs effect carbon dioxide?” with less carbon being emitted (some of which through deforestation itself), possibly leading toward lower levels of carbon dioxide (Daniels 2010). Literature has also explored the effect between soil, forests, and the carbon dioxide levels and how they tend to fluctuate, such as when one variable starts to move significantly, what happens to the other variables that also depend on each other (Batavia 2018, Canadell 2008, Fang 2014, Longobardi 2016, US EPA 2005, & Waheed 2018). These research questions often begin to ask if forested areas and carbon dioxide levels can be connected.

Methods & Data Used

The first step into seeing the change is investigating how the forests have grown and shrunk throughout the years, gathering data for the forests and their properties (age, type of forest, and region covered) came from watching forest area and measuring it in percentage of land area and seeing how those figures grow or shrink (Fang 2014, Silva 2015 & Waheed 2018).

Biomass within the soils being measured also became an important aspect for seeing how soil impacted the carbon mitigation within trees, although it was found that the forest area itself was correlated with the biomass within soils of a forest (Fang 2014). Soils have also seen the locations of forests change, by tracking the growth of trees/forests throughout decades to find out their patterns of growth movement to investigate the carbon levels in differing areas where forests moved from and where they relocated (Perschel 2007).

Another big factor within the equation of forests and carbon dioxide levels are the levels of carbon dioxide around the areas within forested areas, by using forest stocks and the carbon within these carbon stocks to see the levels of carbon dioxide that trees can mitigate from the air around them (Perschel 2007). Through cap-and trade programs used to reduce these levels, within the United States, which saw a decrease by monitoring the carbon dioxide levels in areas with reduced carbon use, areas with forest cover, and areas with neither of the above stipulations to find if there were correlations between how these variables reacted together (Daniels 2010).

Research Locations

Many studies look at a single country, such as Pakistan and China; however, more data is present to be picked out and could be studied even further (Fang 2014 & Waheed 2018). Studies have also been established in the United States to look for economic uses and the state of soils that are able to hold forested areas (Daniels 2010 & Perschel 2007). Japan has also been a location subject to study their forests and carbon dioxide levels (Fang 2014).

Results

These studies have shown that forests can absorb billions of tons of carbon dioxide and have even been able to establish themselves as a factor in the global carbon cycle (Canadell 2008). Literature has shown that forested areas have been able to absorb anywhere from eight to twenty-five percent of carbon levels (per hectare) within a twenty-five-year span (Fang 2014 & Daniels 2010). Some literature even found that with more deforestation, carbon dioxide emissions tend to be more pronounced within regions, establishing a possible link into how forests and the carbon dioxide levels begin to become interconnected (Waheed 2018). However, these forests (while growing) are shifting with location, with some soil holding the carbon in the absence of trees, making soil enter the equation (Perschel 2007 & Silva 2015). With all these variables into the equation, it has shown that there could be a distinct link between how the forest area and carbon dioxide levels have a positive correlation with each other and could open the door for more investigation on the matter.

Data & Research Methods

Data

The data I plan to use for this project has to do with the forest cover of the European Union and the carbon dioxide levels of the same area throughout time and study the how these levels have changed independently and to possibly see if forest cover increases a fair amount, if carbon dioxide levels will be affected by the presence of these trees.

The World Bank is a collection of five institutions that aim to bring knowledge about sustainable development, ending poverty, and increasing prosperity between people that are partnered with 189 countries to provide these statistics and pieces of information. This organization holds data of how much area of a country is covered in forest, dating back to 1990 throughout 2015. They gathered this data by defining forest as not only presence of trees, but the absence of other land uses as well where trees reach a minimum height of five meters. They are given this data from the Food and Agriculture Organization (FAO) and do not include inland water bodies (rivers and lakes) when they take the total area of the countries studied (World Bank 2018).

The World Bank also provides data for carbon dioxide emissions for countries in metric tons per capita. These figures consider manufacturing, the use of oil versus natural gas, and fossil fuel consumption into the figures for each country. However, they do exclude emissions from processes such as deforestation. They take all this information into account to get totals from 1960 to 2014 (World Bank 2018).

I plan to take these figures from European countries within the European Union and see if they can correlate to when the forest levels raise if the carbon dioxide emissions become collectively lower.

Research Methods

Mostly quantitative analysis for this project to be able to see if there is a change in the two variables of forest cover and carbon dioxide emissions and to see if there could be a link between the two variables throughout many countries. The use of scatter plots will be used to first find if there is a viable correlation between the two variables using the European Union average, the main goal from this portion quantitative analysis is to find a link (if there is one to be made).

After investigating the European Union averages, the next step would be to further investigate this correlation individually and scatter plot the data carbon dioxide emission levels, along with the percentage forest cover, from 1990 until 2014, for each of the twenty-eight countries admitted into the European Union and investigate linear regression analysis for each country. Afterwards, the countries will be split into quartiles based on r-squared values in order to see if there were any geographical correlation to these values as well.

I plan to use countries within the European regions and plan on choosing multiple to get the complete picture of if forests and carbon dioxide levels could be relevant together, and not form rationale from a single country's data, nor just using the overall European Union average. The biggest limitation on the data I have is that it does not completely consider to what the countries could also be doing to combat climate change and could produce exaggerated changes that may not be one hundred percent due to the forest cover within a country.

Analysis & Results

Analysis

For analysis, data was compiled for each European Union country, including the United Kingdom, from the World Bank. The data compiled consisted of the percentage of land within the nations covered by forest and carbon dioxide emissions, both of which taken yearly from 1990 through 2014. Graphical analysis was used for the two differing variables (carbon dioxide emissions and forest cover) to get a better idea for the trends. The next, and most crucial part was to use linear regression analysis in order to calculate the r-squared values and establish the dominating trend in forest cover and carbon dioxide within each individual country and the European Union using scatter plots.

Using the overall European Union averages and a scatter plot, along with a regression analysis line to gather a possible connection between the two separate variables. (Figure 1). By gathering the slope of the regression line (-0.5257), it is suggested that a negative correlation exists between the carbon dioxide emissions and forest cover; such that, when one variable increases, the other will decrease.

Results

The R^2 value of 0.6441 makes the statement 'Approximately 64 percent of the variation in CO_2 levels can be accounted by the forest cover within a nation'. While this r^2 value was found by plotting the data points on a scatter plot graph through Microsoft Excel that also found the regression line along with the r-squared value, the value can be confirmed using the formula

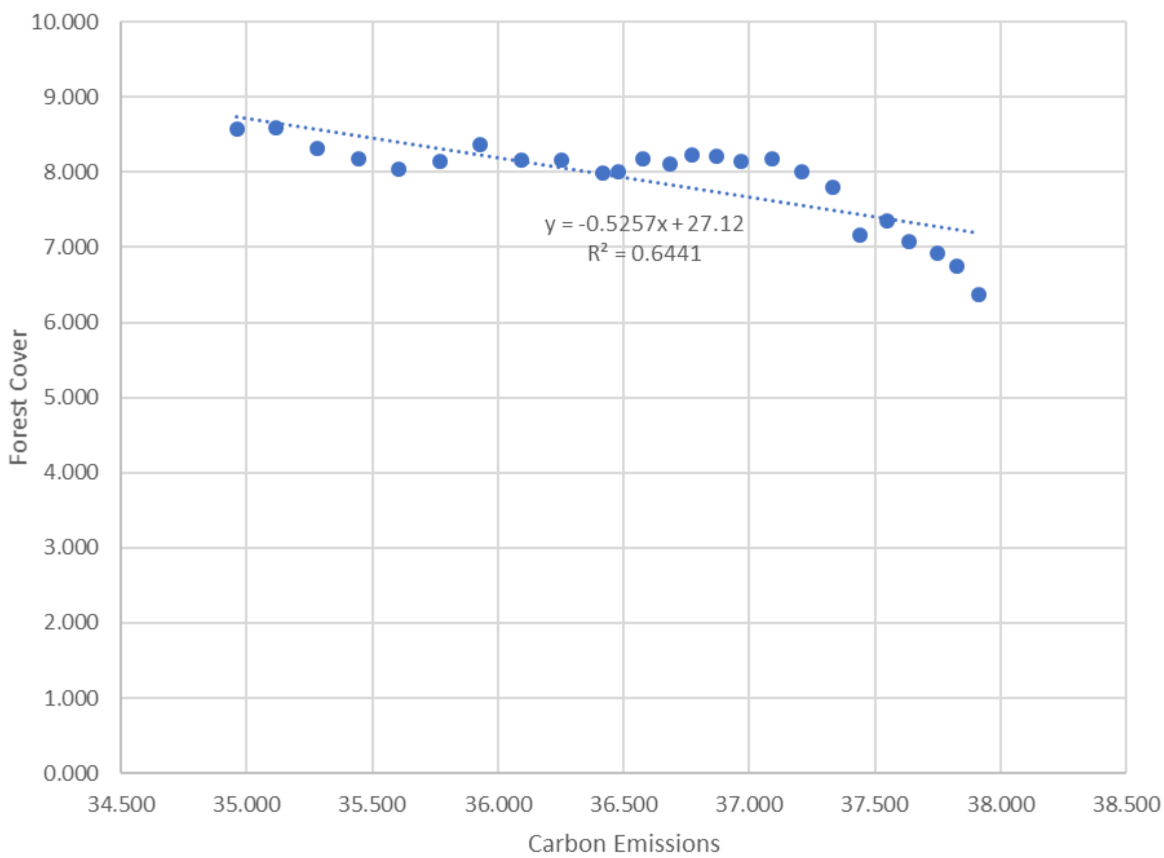


Figure 1. European Union Average: CO2 and Forest Cover with Linear Regression Line

for Pearson's Correlation Coefficient (which will give the r value) and squaring it, as shown below, with x representing forest cover and y representing the carbon dioxide emissions:

$$r^2 = \left(\frac{N \sum xy - (\sum x)(\sum y)}{\sqrt{[N \sum x^2 - (\sum x)^2][N \sum y^2 - (\sum y)^2]}} \right)^2$$

where N represents the number of pairs of scores, $\sum xy$ representing the summation of the products of forest cover and carbon dioxide emissions for each year, $\sum x$ representing the summation of all yearly forest cover values, $\sum y$ representing the summation of all yearly carbon dioxide emission totals, $\sum x^2$ representing the sum of all squared forest cover values and $\sum y^2$ representing summation of all squared carbon dioxide emission values.

The same process of linear regression and graphical analysis was replicated for each of the 28 member nations of the European Union separately to gain more insight on how the countries are behaving individually. After gathering the individual country r-squared values, they were separated into four quartiles (each with 7 countries) to study the geographical distribution. Table 1 lists the countries in their respective quantiles, along with their r-squared value with the first quantile having the highest r-squared values, and the fourth quantile having the lowest r-squared values.

1st Quantile	2nd Quantile	3rd Quantile	4th Quantile
Germany- 0.9084	Poland- 0.5561	Slovenia- 0.1803	Lithuania- 0.0277
Belgium- 0.8352	Denmark- 0.4898	Italy- 0.1648	Finland- 0.0106
Czech Republic- 0.7784	Estonia- 0.4332	Cyprus- 0.1603	Portugal- 0.0094
United Kingdom- 0.7509	Croatia- 0.3459	Latvia- 0.0969	Ireland- 0.0076
France- 0.6909	Romania- 0.2955	Austria- 0.0837	Greece- 0.0002
Hungary- 0.6711	Sweden- 0.2180	Bulgaria- 0.0743	Malta- 0.0000
Slovakia- 0.6655	Netherlands- 0.2138	Spain- 0.0521	Luxembourg- 0.0000

Table 1. Quantiles of EU countries with their R-Squared values.

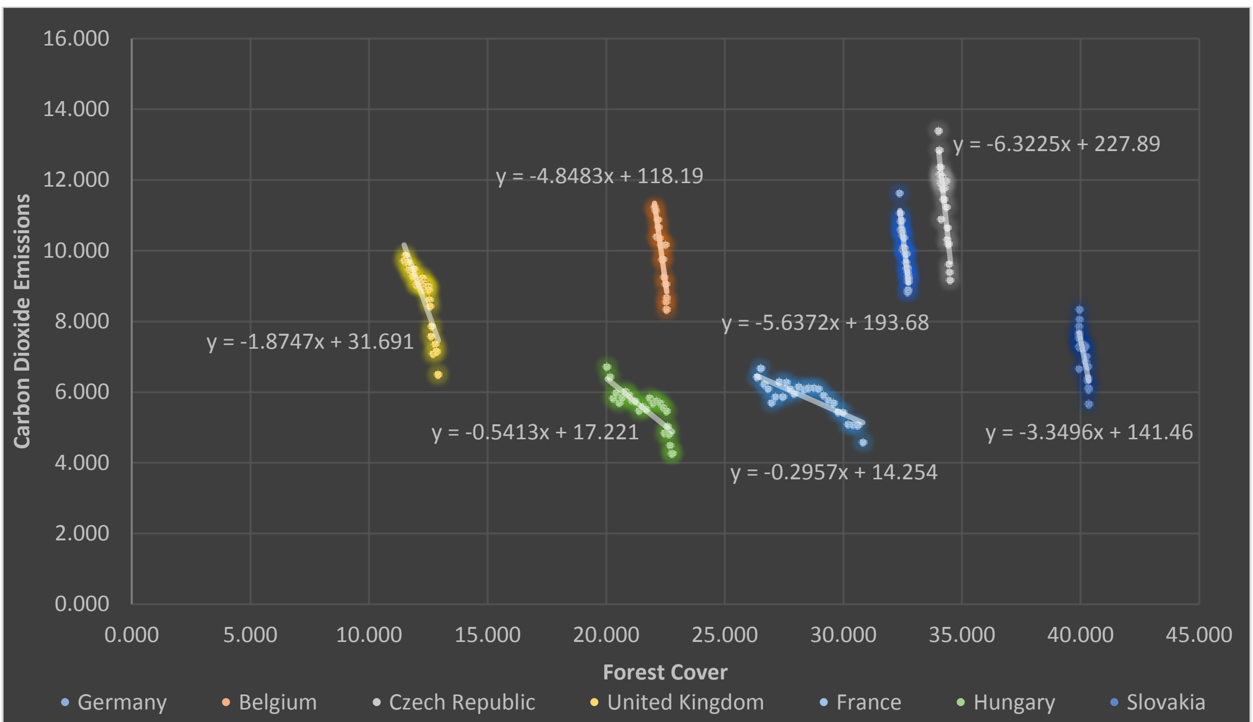


Figure 2. First quantile combined scatter plot with best-fit regression lines.

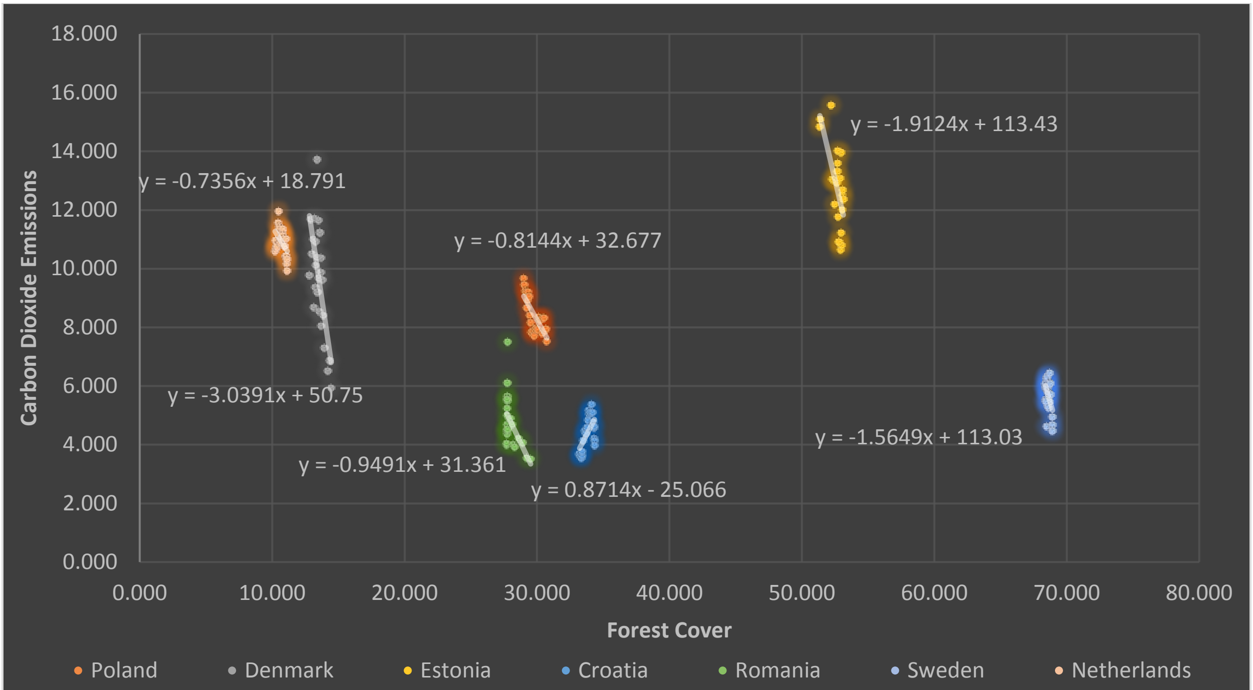


Figure 3. Second quartile combined scatter plot with best-fit regression lines

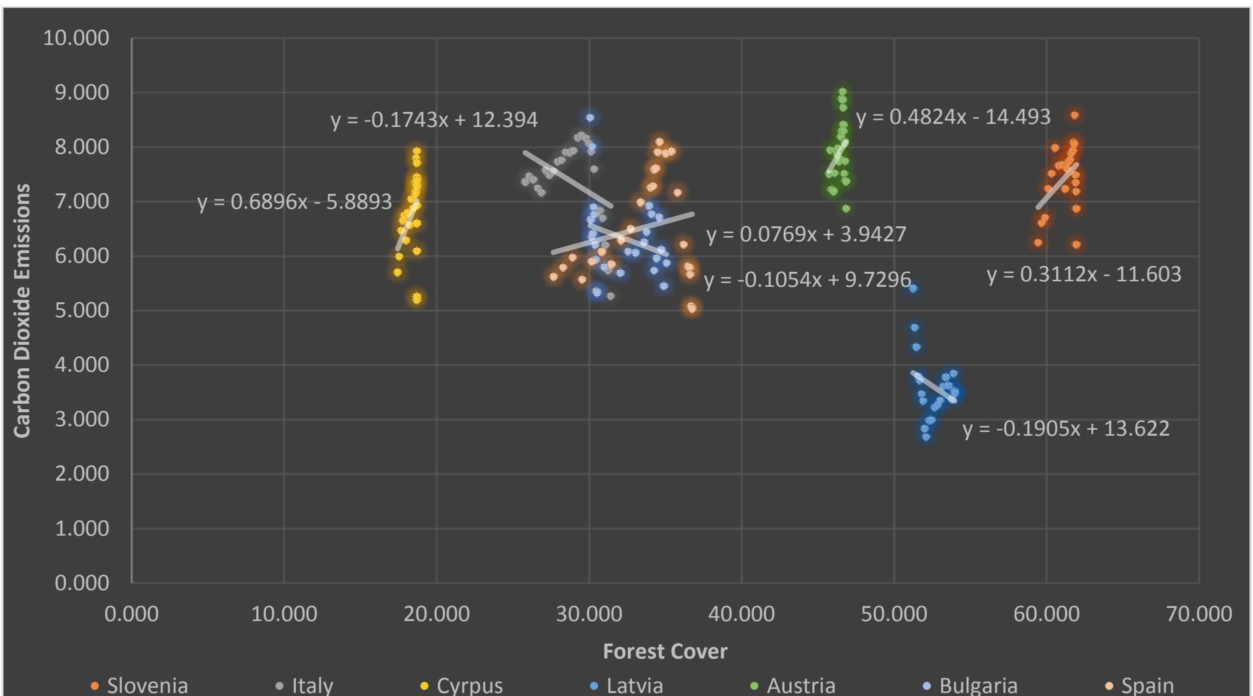


Figure 4. Third quartile combined scatter plot with best-fit regression lines.

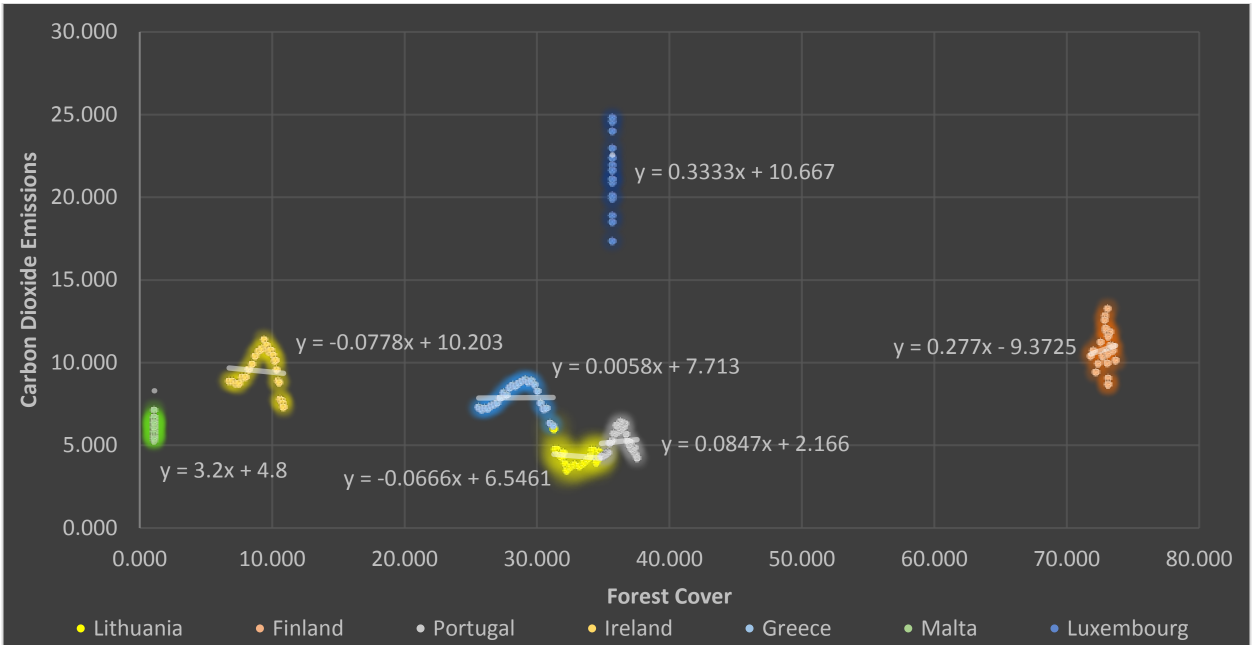
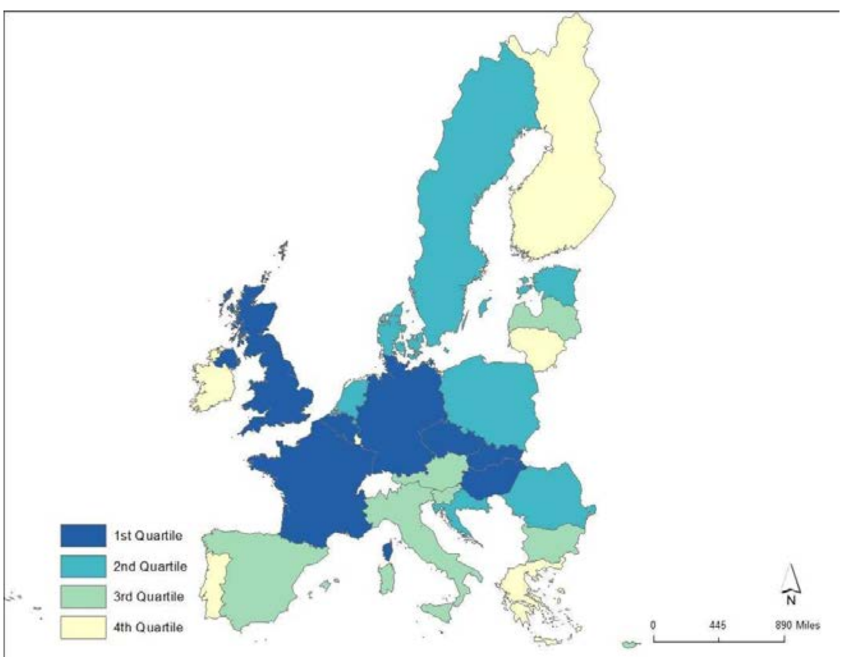


Figure 5. Fourth quartile combined scatter plot with best-fit regression lines.

The final aspect of the project was to map the r-squared values in order to study the geographical distribution of these values, which can be found in Map 1. Many of the more developed countries within the European Union are present within the first quartile, however; a notable exception is present within Slovakia and Hungary. This exception could be due to the



Map 1. A quartile map of European Union countries based on r-squared values.

climates of these countries, as some of the more developed countries have less favorable climate for forest growth (such as Portugal) that could possibly affect their ability to grow forests that can mitigate the carbon dioxide emissions. Also, the presence of the Carpathian Mountains, which have their highest peaks known as the Tatras within Slovakia and Poland (who falls in the second quartile) that stretches along the Danube River as well. The combination of the Carpathian Mountains and the Danube River make these areas have higher level of vegetation (including forests) that can mitigate the carbon dioxide even more than some of the developed countries.

The second quartile has Poland, Croatia and Romania, who both experience the presence of the Carpathian Mountains and higher forest levels which could explain why they are in the second highest quartile. Some developed countries also fall within this quartile, such as Denmark, Sweden, and the Netherlands. The lone country that is geographically and economically different from the countries within this quartile is Estonia, who has a large amount of forest for their small size country, at almost 50 percent of the land being covered with forest. This could explain why their r-squared value is higher compared to the other countries within this quartile, despite not having many similarities with the other countries.

The third quartile contains some developed countries, who could suffer from some climatological issues with growing a large forest, with Spain and Italy having mostly warmer climate patterns that could dry out the land and make forests struggle to grow. Italy and Austria also struggle with sometimes the mountain peaks making trees struggle to grow within the area. Slovenia also gets some influence from the Carpathian Mountains, but little to no river presence can lower how plentiful their land is and makes forests struggle more when growing. Cyprus also struggles with very warm temperatures within their Mediterranean climate and many trees that do grow do not grow into a lot of forest cover. Bulgaria is influenced by the Balkan Mountains, and the higher slopes make tree growth in these areas very difficult at times, so once trees are cut down or knocked over, the trees that replace these may struggle to grow, if they grow at all. The final country in this quartile is Latvia, who struggles with forest growth at times due to their marshy lands that come from ice covering the land for a higher part of the year before their continentality warms up the land and permafrost melts, which could stunt the growth of these forests.

The final quartile contains two of the smallest countries within the European Union, Malta and Luxembourg, that struggle with increasing forest growth due to the highly urban area within the country. Two of the countries within this quartile also have Mediterranean climate, Portugal, and Greece, that could make forest growth harder to be fulfilled within these countries and could explain why they are in the lowest quartile in the r-squared value. Finland and Lithuania could suffer with their forest growth due to the climate changes from summer and winter, however, it cannot be completely confirmed, due to Finland having very high forest values. Ireland could suffer from the mountainous country-sides and has more urban area compared to Finland and Lithuania throughout the country, which could explain their lower forest values and why they are in the lowest quartile of the project.

Discussion & Conclusion

Discussion

The European Union's carbon dioxide emissions had an inverse relationship with the forest cover that covers the region, however; there were a couple countries where the relationship was only slightly inverse, or even some with direct relationships, despite most of the member countries having a stronger inverse relationship. By looking at these results from a geographical standpoint, it seems that most of the Western European countries (except for some noticeable outliers such as Spain, Ireland, and Portugal) tended to have higher inverse relationships when it came to their carbon dioxide emissions and forest cover within the countries. This is significant due to Western Europe developing sooner and would not be expected as these nations were very industrial in the past, despite some of these countries turning towards lowering their carbon dioxide emissions. Another point from a geographical standpoint is that the two smallest countries within the European Union, Luxembourg and Malta, had the lowest r-squared values. This would come from them having such small areas and their forest cover not changing very much throughout the time period, as Malta has very low forest cover due to it being a very urban, Mediterranean island that focuses on tourism and Luxembourg having some forest that doesn't increase or decrease from year-to-year.

The findings are like previous results, due to it establishing that carbon dioxide mitigation from forested areas can have some influence on the overall carbon dioxide emissions within a certain area and should be investigated further. This reinforces that planting more forest area could be a possible solution for lowering emission levels within countries that possess very high carbon dioxide emission levels. However, the findings are limited as it does not take in other processes that effect the carbon dioxide emission levels within the countries that could have lowered the levels or made them spike even more to make the relationships less prevalent. Overall, the results were as expected, with some countries showing stronger relationships than others and the European Union, overall, showing an inverse relationship between the carbon dioxide emission levels when forest area (as a percentage) of a country increased.

Conclusion

The main question I sought out to answer was "Does forest cover within a country effect the carbon dioxide emissions that country produces?" when using the EU, and the member countries, that there is an inverse relationship between the carbon dioxide emissions and forest cover. Partly due to carbon dioxide mitigation that previous studies have highlighted as a reason for carbon dioxide emissions lowering around forested areas. This research covers an area that has seen increased forest growth overall and carbon dioxide emissions tended to lower when the forest area increased.

However; there were some limitation to this study, this study did not account for outside influences that could have affected carbon dioxide emissions. There have been other proposals that combat carbon dioxide emission levels that were not accounted for within this project, such as a country that may have simply lowered their emission levels, and the forest area may have had minimal effect. This outside influence could have affected the project heavily and could be accounted for with more investigation. Future studies could also investigate what would occur if these carbon dioxide emission levels stayed constant throughout the duration, along with investigating if forest area is the main influence in the dropping carbon dioxide emission levels.

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