Is a trillion trees enough?

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Abstract. Global warming is a major environmental concern of our times. \cite{1}. It has been suggested that the planting of trees could constitute a way of mitigating the adverse effects of the increasing anthropogenic carbon emissions. We propose a quadratic model to predict the global average temperature in diverse scenarios. We remain under 1 degree of anomaly when combining planting trees and zero-carbon energy production by 2050. When we find that to remain under the 1.5 degree of anomaly set by the Paris agreement, the fossil-fuel energy production needs to decrease to at least 39\% combined with planting a trillion trees.

1 Introduction

Global warming represent an important environmental issue. The gas emissions due to the increased industrialization and the increase of the population have invariably led to a rise of the global average temperature and correspondingly to a rise in ocean temperatures and the sea level. It has been suggested by many scientific panels that this increase in the global average temperature may be the cause for the extinction of various species as well as other natural catastrophes \cite{15}. For example, recently it has been shown that the largest king-penguin colony has experienced a drastic reduction in its population (see \cite{16}), reducing from 2 million individuals to 90,000. Another alarming fact is the change in the ocean microbiotic life. \cite{8} have shown that bacteria are becoming smaller and there are more of them as a result of global warming. What would be the effect of this for ocean life in general? One way to stop the increase of the global temperature would be to reduce gas emissions \cite{13} with the goal of having the temperature rise not more than 1.5 degrees Celsius, as recommended by the Paris agreement \cite{14}.

It has been suggested that planting of new trees could offer a way of capturing back the newly created CO2 emissions, thus neutralizing the effects of increased industrialization. Currently, there are approximately 3 trillion trees on the planet, with 6 trillion at the dawn of humanity \cite{2}. Another 1.2 trillion would be necessary to absorb the excess of CO2 in the atmosphere according to \cite{5}. Identifying major industries and activities which contribute to gas emissions and convincing people to find alternatives is essential as well as reforestation efforts and planting trees in arid areas.
In this paper we are examining scenarios whether planting a trillion trees could constitute a solution to neutralizing the increasing CO2 emissions. We understand this is a controversial topic as it should not be given as a proper ‘solution’ but simply as a way to sequester carbon dioxide from the atmosphere. We decided to set as a potential amount of absorbed carbon dioxide by planting trees 42 gigatons as calculated by [11], it is much lower than the 205 gigatons envisioned by [2] but our findings show that even with this lower target the results are significant. This paper showcases some preliminary evaluations in understanding the situation and trying to predict the effect of diverse scenarios on the global average temperature. We find that combining planting trees and bringing energy production to zero carbon would keep the global average temperature anomaly below 1 degrees Celsius. We discuss limitations and assumptions of our approach, which understandably only considers a limited number of factors in the overall complex environmental ecosystem.

2 Proposal

Our approach is data-driven, enabled by modern machine learning techniques and considering multiple variables for predicting the outcome of various ‘what if’ scenarios.

We use multivariate polynomial ridge regression [6] of degree 2 to train our model based on the global average temperature and the amount of CO2 in the atmosphere. We use this model to make predictions under various scenarios by changing the values of the CO2 for the upcoming 30 years. We use the amount of CO2 sequestrated (absorbed) by trees as a proxy for inferring the reduction in the CO2 levels. Ridge regression is similar to linear regression except in the way to resolve the coefficients, instead of using the least square method, we use as an estimator:

\[
\hat{\beta}(\lambda) = \arg\min_{\beta} \|y - X\beta\|_2^2 + \lambda \|\beta\|_2^2
\]  

(1)

In equation [1] \( y \) represents the observed global average temperatures, \( X \) is a matrix of CO2 levels and years, \( \beta \) is the estimated vector of coefficients for the regression, the goal being to minimize the \( L_2 \) norm (euclidean distance) between the observations and the predicted values. \( \lambda \) is a hyper-parameter used by ridge regression to avoid overfitting, it is chosen as to minimise the mean squared error.
2.1 Datasets:

To predict the trend in future CO2 levels and temperatures we use historical data offered by the National Oceanic and Atmospheric Administration (NOAA) as well as NASA.

3 Scenarios

We analyse various scenarios of possible evolutions in CO2 and temperature levels from 2020 to 2050. The code to produce our predictions and scenarios is available on Google Colab.

We consider three main scenarios, spanning from no reduction of gas emissions, to a small but realistic reduction, to zero-carbon. For each scenario we examine what would transpire if we a) did not plant any new trees (and assume the current amount of trees remains constant), b) plant a trillion trees. We call the later case, scenario "prime".

3.1 Scenario 1: A continuous increase of gas emissions by 2050 with/without no trees planted

First, we consider the scenario in which no action is taken and the CO2 levels in the atmosphere continue to rise. We use a quadratic regression to predict the rise of CO2 and use this prediction as input to predict the rise of the temperature in our multivariate model. In this case our model predicts the temperature will rise to 2.17 degrees anomaly above the pre-industrial levels, as shown in Figure 1a.

We consider the previous prediction for the rise of CO2 levels and deduce from it a logarithmically spaced vector of 0 to 42 gigatons of carbon dioxide (transformed in ppm) over the next 30 years. We then use this constructed CO2 levels in order to predict the global average temperature. Giving the scenario shown in Figure 1b. We observe a decrease in the global average temperature which would remain under the 2 degree boundary of the Paris agreement at 1.59 degrees Celsius.

3.2 Scenario 2: A realistic decrease of gas emissions by 2050 with/without a trillion trees planted

The oil and gas companies predict an increase of 25% of non-fossil energy as a part of the total energy production in the next 30 years. Emissions would
keep on rising but at a decreased rate of 100% to 69% over the next 30 years. We apply this rate in equation (2) to compute the CO2 levels of this scenario and deduce the potential absorption for each year in the case of the prime scenario. The CO2 level for a certain year is defined by the CO2 level of the previous year \(CO_{2, year-1}\) to which we add the predicted increase times the reduction rate for that year.

This scenario is more realistic than the following one of aiming for zero-carbon emissions by 2050. If no carbon sequestration is put in place the temperature would reach a 1.69 degree anomaly, in Figure 1c. With the absorption thanks to trees, the temperature would remain below 1.19 degrees, in Figure 1d.

\[ CO_{2, year} = CO_{2, year-1} + (CO_{2, pred[year]} - CO_{2, pred[year-1]}) \times rate[year] - absorption[year] \]  
\[ (2) \]

3.3 Scenario 3: Zero-carbon by 2050 with/without a trillion trees planted

The scenario of reaching zero carbon by 2050 is implemented by applying a linear reduction rate from 100% to 0% over the next 30 years to the CO2 increase predicted originally, we use this rate in equation (2). In this case, the temperature remains below 1.5 degrees anomaly (Figure 1e) at 1.28 and decreases to 0.85 degrees when combined with planting trees, in Figure 1f.

3.4 Scenario 4: How much do we have to decrease gas emissions to remain under 1.5 degrees

We develop a simple algorithm to find the minimum decrease of gas emissions required such that the global average temperature remains under 1.5 degrees when combined with planting trees to absorb 42 gigatons of carbon dioxide.

We find that the least decrease of gas emissions required is 39% by 2050. in 2020 renewable energy represents 19% of the energy production, and fossil-fuel 71%; a simple cross product results in the opposite situation, renewable must be 69% (100-81*39/100) of energy production by 2050 and respectively fossil-fuel energy must represent 31% of all energy production(81*39/100).

4 Discussion and assumptions

Our analysis assumes a connection between CO2 levels and the global average temperature. We know that a correlation exists but this does not imply a direct causal relationship between the two variables. There is still debate whether a reduction of the CO2 in the atmosphere would result directly in a decrease of the temperature as our models show, in [9] Pietrafesa et al. use Granger causality to highlight the relation between carbon emissions and global average
temperature; in [12] Sippel et al. analyse the relation between various factors and temperature and conclude the increase is due to human factors. We are interested in using Granger causality models to compare with our predictions. Moreover there are many other factors involved when planting trees; the albedo caused by the change of surface, i.e. when the trees are grown the land surface becomes darker compared to having ice or sand which reflects sunlight, dark surface absorbs light and heat; the species of trees being planted, different varieties will absorb CO2 at different rates, mangrove, oaks and chestnut seem to be good candidates although species to be planted depend on the local climate [10]. Reforestation and afforestation efforts as well as the development of a climate economy [3] to protect existing forests are essential to solve the climate crisis.

In our study, we assumed that the capacity of the Earth’s oceans to absorb CO2 will remain constant. However, there have been raising concerns that the increase in the average ocean temperatures and acidity may affect the capacity of the ocean’s algae to continue absorbing CO2 at the same rate [4].
Table 1: Table of prediction plots for each scenario. The columns represent whether we plant trees or not; the rows represent the three scenarios on the change in gas emissions. The light blue area shows the 95% confidence interval as two times the root mean squared error (0.114).
5 Incidence on energy production

As we have seen with Scenario 4 prime, the part of fossil-fuel energy must decrease from 81% to 31% of the global energy production as illustrated in Figure 1 and renewable energy from 19% to 69%.

![Graph showing energy production evolution](image)

Fig. 1: Projected required evolution of the global energy production to remain under 1.5 degrees of anomaly with 42 gigatons of CO2 sequestrated by trees by 2050.

6 Conclusions

Our data-driven modeling showed that scenarios involving planting trees appear viable and will not lead to an increase of more than 1.59 degrees in the global average temperature within the next 30 years. Among the scenarios without an increase in forest coverage, only the zero-carbon scenario restrains the temperature increase below 1.5 degrees. We believe there is a high risk of not reaching zero-carbon emissions by 2050 and without carbon sequestration actions taken urgently the global average temperature would rise above 1.5 degrees. The combined scenario of planting large quantities of trees and reducing gas emissions closer to zero would bring the global average temperature back below 1 degree of anomaly. We find that to remain under the 1.5 degree of anomaly set by the Paris agreement, the fossil-fuel energy production needs to decrease to 39% combined with planting a trillion trees and respectively the part of renewable energy to grow to 69% of the global energy production by 2050. In our opinion both efforts of reforestation and energy transformation are necessary to solve climate change.
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