# The Effects Deforestation Has on Climate Change

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This report aims to find the impact that deforestation has on our climate through carbon emissions. This was found by comparing forest levels between the years 2000 and 2020 to find the difference and then calculate the levels of carbon dioxide added or removed from the atmosphere that difference amounted to, using estimates for tree mass and density across different continents.
Deforestation was found to account for 8.3% of total yearly greenhouse gas emissions between 2000 and 2020, totalling to 122.25 Gt of $CO_2$ emissions over the 20-year period. The specific values calculated in this report have large uncertainties, but the datasets used do indicate that deforestation is having a negative impact on climate change.

## 1. Introduction

Trees and forests are one of the best natural carbon sinks in the world, on average taking in 10-40 kg of $CO_2$ from the atmosphere per year [1] and already cover almost a third of the Earth's land, amounting to 4.06 billion hectares (ha) [2]. Providing us with a way to counteract our carbon emissions, right now. However, we are losing tree coverage through deforestation and natural events such as wildfires, for example, in the years between 2010 and 2020, the net forest loss was 4.7 million hectares per year [2].

Deforestation occurs mainly due to agriculture; large areas of forest are cut down to make room for animals or other food production, like soya or palm oil. With tropical forests being affected the most by this [3]. When trees are cut down, they stop taking in carbon from the atmosphere, but when they are burned, the carbon they are storing is released in the form of carbon dioxide.

Deforestation creates unnecessary risks to our environment, through polluting the air and possibly being the cause of forest ecosystems crossing tipping point thresholds. This report aims to investigate the impact deforestation has on the climate by using datasets on forest areas over time to quantify the amount of carbon that is released back into the atmosphere when trees are cut down, and also try to find the causes and incentives that drive deforestation.

In section 2, the processes that trees and plants undergo are discussed to see how they collect and store carbon from the atmosphere. Section 3 shows plots and tables of the data collected from datasets and section 4 analyses them. Finally, section 5 explains what the results gained mean and provides examples of existing and potential solutions to the issue posed by deforestation.

## 2. Theory

Trees take in carbon from the atmosphere through the process of photosynthesis, which can be represented by the chemical equation,

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2 \qquad [4]$$

where carbon dioxide ($CO_2$) is taken from the atmosphere through the tree's leaves and reacted with water ($H_2O$), drawn in from the tree's roots. This chemical reaction requires energy from the sun and results in glucose ($C_6H_{12}O_6$), which is a sugar that plants use for energy and provides the materials needed to grow [5]. The process also produces oxygen ($O_2$) as a biproduct, which is then released back into the atmosphere.

A tree uses photosynthesis to grow, but how much carbon does the average tree store? Much like us, most of a tree's composition is made up of water, amounting to about 50% of a tree's total mass [1]. Ignoring this gives the dry mass of a tree and 47.5% of this dry mass is carbon [1]. So, a quarter of a tree's mass is made up of carbon and from this, an estimate can be made for the amount of carbon in a tree based off its mass; with a 1000 kg tree containing 237.5 kg of carbon. Taking the molar mass ratio of carbon dioxide (44 g/mol) and carbon (12 g/mol), a tree must take in 3.67 kg of carbon dioxide from the atmosphere to create 1kg of carbon for itself [1]. Meaning a single 1000 kg tree would have absorbed 871.63 kg of carbon dioxide from the atmosphere [1]. This value is an estimate and wildly depends on the type of tree in question.

The individual processes behind how a plant lives and grows are well understood, but on a macroscale, how much carbon a tree can take in depending on its age is still debated. For example, measuring the mass growth rate per year of individual trees, on a large scale, shows an increase in the rate a tree gains mass as it ages [6], so an increase in the amount of carbon it removes from the air through photosynthesis. However, using satellite observations, a separate study concluded that trees between the ages of 50 and 140 years absorbed the most carbon from the atmosphere [7]. This uncertainty hinders our ability to counteract the effects of deforestation, as it is unknown whether priority should be given to protecting older forests or planting new ones.

Satellite imaging can also give us helpful information on deforestation globally, such as the location and severity of tree loss.

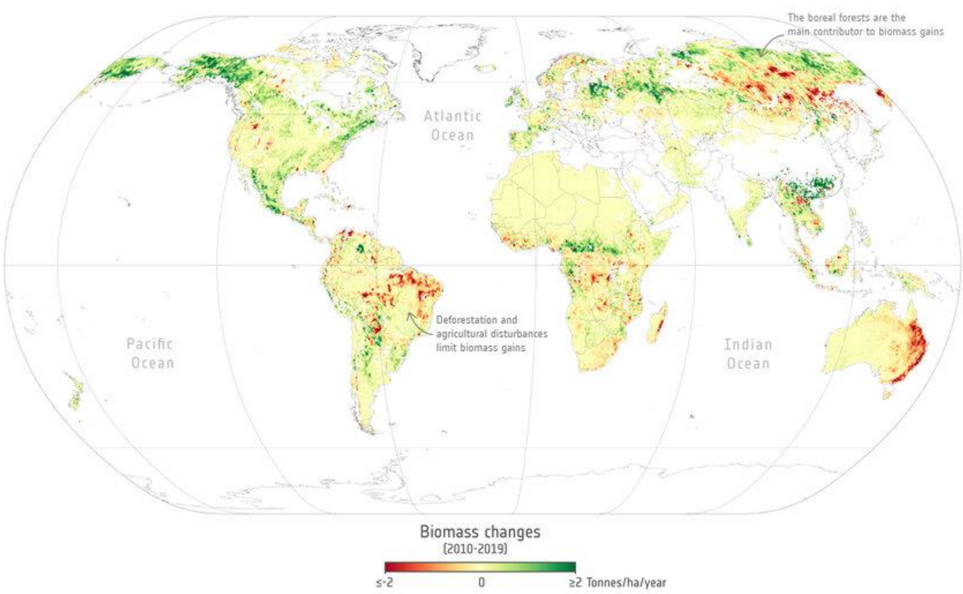


**Figure 1:** Global biomass changes over the decade of 2010-2019 shown using a colour gradient to represent changes. Credit: ESA [7]

Figure 1 shows that deforestation is occurring mainly in tropical forests [7], stopping carbon from being stored and even causing carbon dioxide to be released back into the atmosphere through the burning of trees to make room for agriculture [3].

The continued deforestation of ecosystems like the Amazon could potentially lead to triggering tipping points in the forest's system. Tipping points are thresholds in a system that, when passed, leads to spiralling feedback loops that can greatly change the system itself. Deforestation in the Amazon rainforest leaves large areas of dry grass land where trees used to stand. Without these trees, as deforestation continues, a positive feedback loop is created. Where less trees leads to less evapotranspiration, which is the process of water evaporating from the ground to the atmosphere. With less moisture in the atmosphere, there is less rainfall, which can lead to droughts which cause further dieback to the forest [8], strengthening the effects of the feedback loop.

# 3. Observations and Data

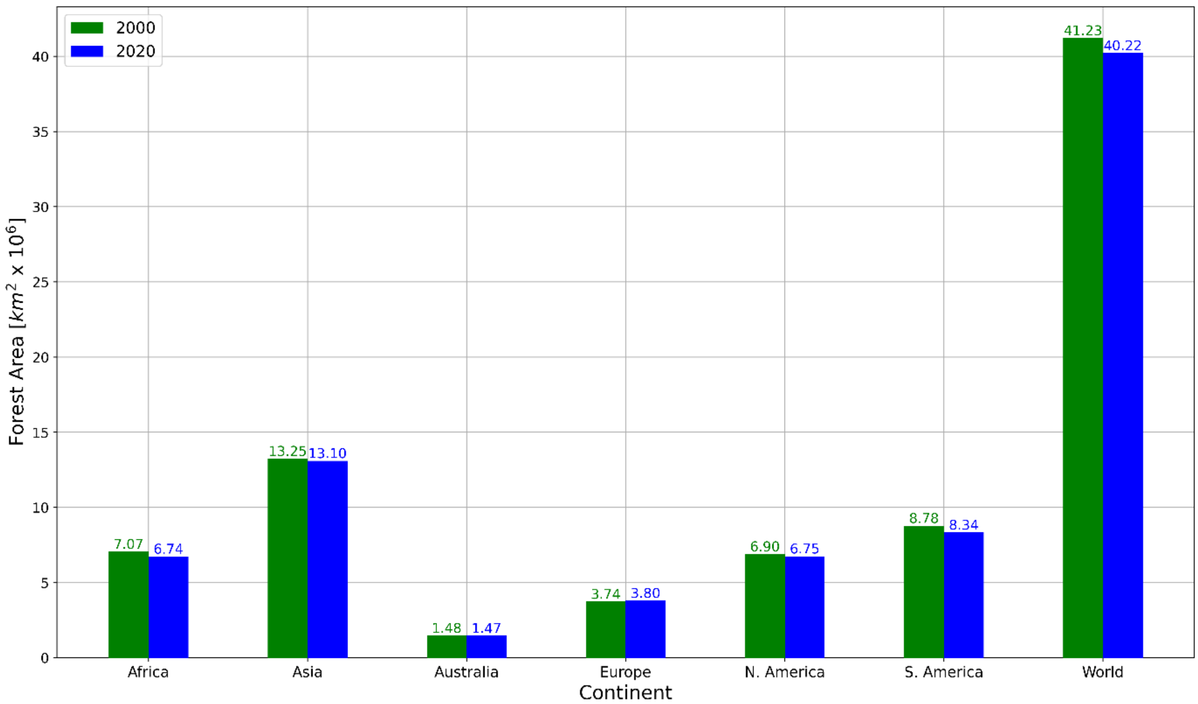


**Figure 2:** Comparison of forest area in every continent between 2000 and 2020. Plotted with data from 'The Global 2000-2020 Land Cover and Land Use Change Dataset Derived from the Landsat Archive: First Results' [9]

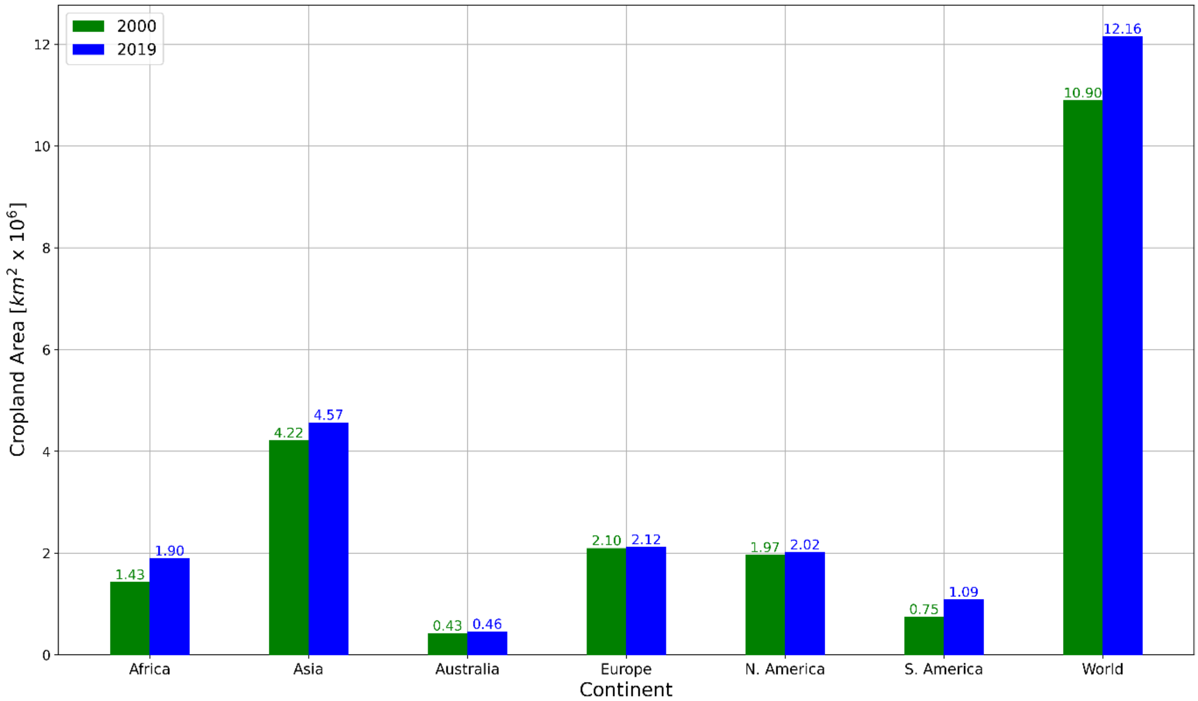


**Figure 3:** Comparison of cropland area in every continent between 2000 and 2019. Plotted with data from 'The Global 2000-2020 Land Cover and Land Use Change Dataset Derived from the Landsat Archive: First Results' [9]

Figures 2 and 3 compare the difference in forest and cropland area across the continents over 20 years. From this comparison, land use has not changed much in Australia, Europe, and North America. But in Africa, Asia and South America, forest area decreased over the 20-year comparison, and cropland area increased in all three of these continents by roughly as much as the forest area decreased, or more. With the largest loss of forests happening in South America; losing (0.44 x $10^6$ $km^2$) or 5.0% of the year 2000 forest levels. And the largest gain of cropland is in Africa, gaining (0.47 x $10^6$ $km^2$) or 33.0% of the year 2000 cropland levels.

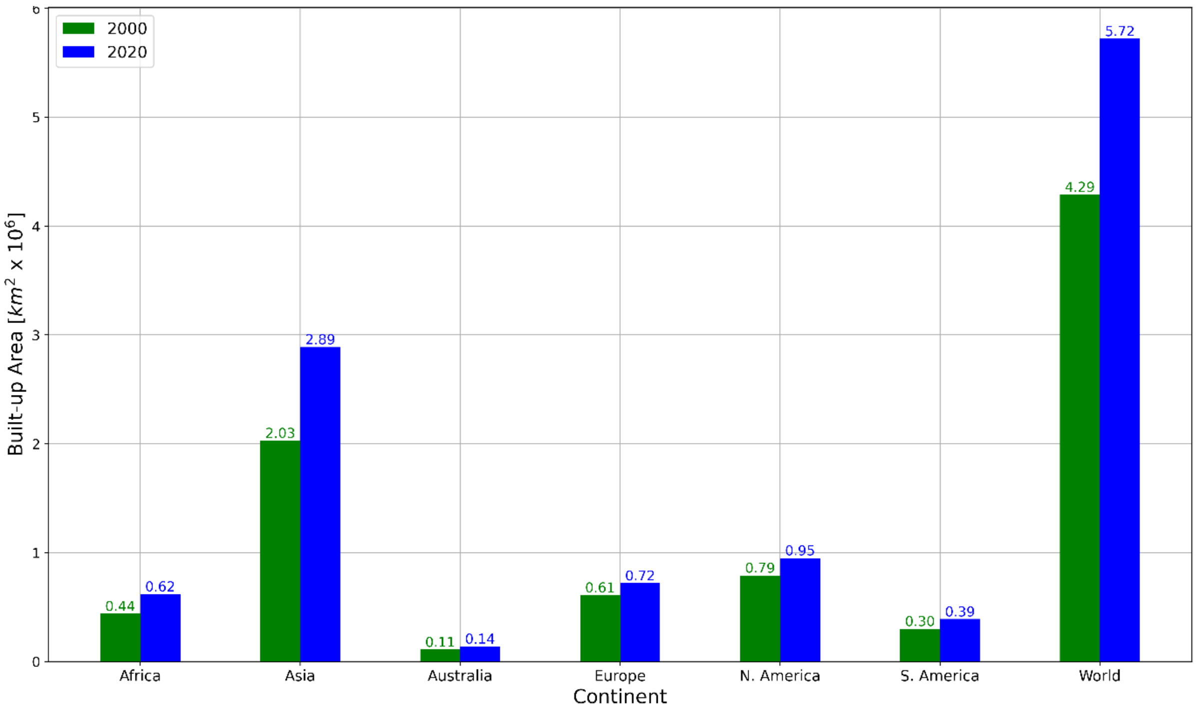


**Figure 4:** Comparison of built-up area in every continent between 2000 and 2020. Plotted with data from 'The Global 2000-2020 Land Cover and Land Use Change Dataset Derived from the Landsat Archive: First Results' [9]

Figure 4 shows the difference in built-up land between 2000 and 2020, which is defined as man-made land surfaces associated with infrastructure, commercial and residential land uses. The comparison shows that the infrastructure in every continent has increased over time, with Asia having the most built-up lands and expanded its infrastructure the most, likely due to the size of the continent when compared to the others.

By averaging the number of trees per square kilometre for every country in each continent, the average number of trees per square kilometre per continent was found to be,

**Table 1:** Average number of trees per square kilometre in each continent, calculated from trees per $km^2$ of each country in each continent. [10, 11]

| Continent | Trees per $km^2$ |
|---|---|
| Africa | 18,691 |
| Asia | 18,275 |
| Australia | 9,941 |
| Europe | 28,340 |
| North America | 27,889 |
| South America | 38,069 |

Table 1 gives the densities of trees across each continent showing, expectedly, that South America has the highest tree density, due to rainforests, while Asia and Africa have the lowest tree density, caused by some countries having a desert climate, where there are little to no trees present. Oceania is only represented by Australia as the Landsat Archive Dataset [9] only took Australia into account in its results, as it ignored small island nations.

# 4. Analysis

The number of trees per square kilometre for each continent, from Table 1, was multiplied with the change in forest area between 2000 and 2020 per continent, from Figure 2, to find the average change in trees for each area.

**Table 2:** Average change in the number of trees in each continent between 2000 and 2020.

| Continent | Change in Trees [x10$^9$] |
|---|---|
| Africa | -5.98 |
| Asia | -2.74 |
| Australia | -0.10 |
| Europe | +1.70 |
| North America | -4.18 |
| South America | -16.75 |

Taking the average tree to have a mass of 5000 kg and applying the same method to find the mass of carbon in a tree as in section two of this report, the average tree would consist of 1187.5 kg of carbon, meaning that it would have removed 4358 kg of carbon dioxide from the atmosphere, or conversely, each tree that is burnt would add 4358 kg of carbon dioxide, on average, back into the atmosphere.

Converting the change in trees from Table 2 to its equivalent mass of carbon dioxide removed or added to the atmosphere gives,

**Table 3:** Estimate for the amount of carbon dioxide, measured in gigatonnes, added, or removed from the atmosphere based on the change in the number of trees in each continent between the years 2000 and 2020.

| Continent | Mass of $CO_2$ [Gt] |
|---|---|
| Africa | 26.06 |
| Asia | 11.94 |
| Australia | 0.44 |
| Europe | -7.41 |
| North America | 18.22 |
| South America | 73.00 |

This was done using the method for finding the amount of carbon in one tree outlined in section 2 of this report. Summing up the individual masses for each continent gave the overall amount of carbon dioxide added to the atmosphere, due to the deforestation of trees between the years 2000 and 2020, and was found to be,

$$122.25 \text{ Gt}$$

# 5. Discussion

In total, the carbon dioxide emissions due to deforestation between 2000 and 2020 is 122.25 Gt, so on average, the yearly emissions equate to 5.82 Gt yr$^{-1}$. In this timeframe, the average $CO_2$ emissions due to energy production was 29.34 Gt yr$^{-1}$ [12]. So, the calculated emissions due to deforestation is equal to 19.8% of the emissions produced for energy through burning fossil fuels. Energy production makes up 41.7% of the total greenhouse gas emissions produced every year [13], meaning deforestation was calculated to account for

8.3% of total emissions. However, external sources estimate that deforestation only accounts for 2.2% of yearly emissions [13].

This discrepancy between the calculated result and ones from external sources is most likely due to the assumptions used to find the result in this report. Firstly, depending on the species and age of tree, their mass and composition can vary dramatically; ranging from under one tonne to a few hundred tonnes. There are an estimated 73,300 different species of trees [14] all with different compositions, so assumptions such as the dry mass and total weight of the average tree used in this report may not represent the variety of trees very well. Another assumption used was that every tree that was cut down was burnt, releasing the carbon it stored back into the atmosphere, however this is not realistic as the wood may also be sold and used for materials, keeping hold of its carbon.

Comparing the forest loss between the years 2000 and 2020, from Figure 2, with the cropland and built-up area gains, seen in Figures 3 and 4 respectively, shows that much of the deforestation occurring is due to making space for more agricultural lands instead of expanding infrastructure. Every continent, except for Asia, showed a greater increase in cropland area over the 20 years than built-up areas. Indicating the lost forest land is more likely to be turned into croplands instead of being built over.

The data in Table 2 shows that South America is cutting down their forests at a much faster rate than other places in the world, cutting down 1.5x more forested areas than the rest of the world combined. Most of this is happening in the Amazon rainforest, where 17% of the forest has already been cut down, and a further 17% is degraded [15]. Deforestation is causing the forest to lose resilience to weather events and changes, potentially coming close to reaching a tipping point, like the one described in section two of this report. It was also found that the closer the rainforest is to human land use, like agricultural lands, the less resilient the system is [15], providing good evidence that deforestation and human activity are driving this change.

Reversing deforestation could be as simple as planting more trees to replace the ones we have lost; more trees will absorb more carbon dioxide from the atmosphere, reducing the impact of our global emissions. And with the cost of planting a tree being as low as 8-16 pence [16] means there is a low financial cost compared to other solutions, like carbon capture. However, reforestation in the form of planting monoculture forests, which are forests made up of only one species of tree, can have negative effects on biodiversity, potentially creating inhospitable environments [17]. While planting multiculture forests can increase the number of species found living in them by 78% [17]. Unfortunately, biodiversity is often neglected due to carbon offset schemes aiming to find the cheapest solution to reducing carbon emissions [17]. Reforestation is also used by companies like Shell and BP, which have large greenhouse gas emissions, as a way to offset their emissions without having to change their business practices [18], which does not help with trying to find a long-term solution to the energy sector's impact on climate change. But if reforestation efforts take the local environment and biodiversity into account, ecosystems that were destroyed by deforestation can be brought back in as little as 20 years [18], helping both the stability of the local environment and wildlife, at the same time as reducing the levels of carbon dioxide in the atmosphere.

Legislation is required to stop unnecessary and illegal deforestation across the world. Pre-existing legislation, such as Brazil's Forest Code, which was introduced in 1965, restricts the amount of land in the Amazon that can be farmed on to only 20% of what the farmer owns [19]. The law aimed to allow farming in the Amazon, without having a significant impact on the forest. However, because of the sheer size of the rainforest, such a law has proven to be difficult to enforce, as the Amazon continues to be cut down. But with improving technology, it is becoming easier to map out the Amazon and identify if farmers are meeting the requirements set by the Forest Code [19]. Another way to fix this issue is to reduce the demand for products that are produced as a result of deforestation. This can be done across the globe, and in countries which do not experience deforestation themselves. For example, in 2023, the EU introduced 'Regulation on Deforestation-free products' which aims to have products prove that they did not originate from recently deforested land before being allowed to be sold on the EU market [20]. This provides less demand for illegally produced items, causing less incentive for deforestation as there is less money to be made from it.

# 6. Conclusion

Deforestation was found to account for 8.3% of total yearly greenhouse gas emissions between 2000 and 2020, totalling to 122.25 Gt of $CO_2$ emissions. The specific values calculated in this report have large uncertainties, but the datasets used do indicate that deforestation is having a negative impact on climate change. The main cause of deforestation was due to agriculture; creating more space for farmland, harming the stability of forests and biodiversity and may potentially trigger a tipping point in the Amazon rainforest in the future. Efforts to repair the effects of deforestation were found to work, as long as the local environment was considered, and legislation is being made and enforced to limit deforestation and reduce the incentives associated with it.

Despite deforestation not being a major contributor to greenhouse gas emissions, it still poses a threat to the Earth's climate through emissions but more importantly because of potential tipping points it can trigger in important ecosystems, like the Amazon rainforest. Therefore, this is an issue that we need to address quickly and cannot be left until other problems have been solved. Forests like the Amazon are home to a large proportion of the world's wildlife, and many people live around and depend on the Amazon for their livelihoods [15]. And if we continue on the current path, the consequences could be disastrous for these ecosystems and the people that rely on them.

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