The Causes of Climate Change

1 Introduction

Global warming, the phenomenon of increasing average air temperatures near the surface of Earth over the past one to two centuries. Climate change is the biggest threat of our generation. Emissions are increasing according to the newest IPCC report (`www.ipcc.ch/sr15/`). As per IPCC 1.5°C rise may put 20-30% of species at risk of extinction.If the planet warms by more than 2°C, most ecosystems will struggle.We are heading towards a major catastrophe and political outrage is slowly forming but we also need technological interference. No corner of the globe is immune from the devastating consequences of climate change. Rising temperatures will cause environmental degradation, natural disasters, weather extremes, food and water insecurity and many other impacts on human life and Ecosystem.

In the following document we will discuss about climate variations before industrial revolution period 1760-1840.We then focus on global temperature variations in 19th and 20th century.Our main objective of this paper is to investigate how animal farming and food crops production responsible for global warming.We aim to reveal how food production and its necessary resources have evolved, and the relation to global warming.We will carry this research by analyzing data published by Food and Agriculture Organization of the United Nations (FAOSTAT) `www.fao.org/faostat/en/#home`. FAOSTAT provides free access to food and agriculture data for over 245 countries and territories and covers all FAO regional groupings from 1961 to the most recent year available. By doing so, we could potentially increase public awareness about this topic and urge people to keep the stated issue in mind when acting as consumers.

2 Pre-Industrial Climate change

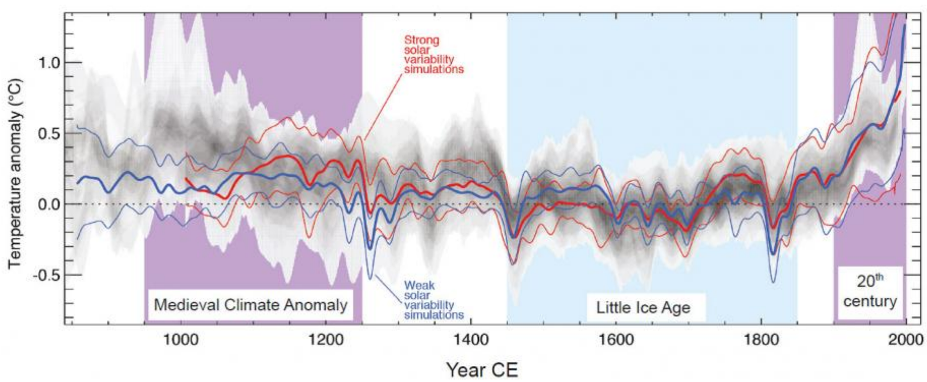

Figure 1: 1000 year old temperature variations.

As we know the industrial revolution began in the late 1700s in UK and spread around the world. But this only marked the beginning of a gradual rise in our greenhouse gas emissions.Various studies have found climate change signals appearing on a global scale as early as the 1830s. Besides the evolving and booming human influence on the climate, we also know that a plethora of other natural factors can affect Earth's temperature.This natural variability in the climate makes it harder to determine a single precise pre-industrial baseline.

Figure 1 shows northern hemisphere temperature variations over last 1000 years.The image is captured from `www.ncdc.noaa.gov` (national centers for environmental information). The below image is reconstructed by climate scientists using various temperature studies and proxy data sets. Simulations are shown by colored lines,thick lines showing the mean of multiple model simulations and thin lines showing the 90% confidence range of this mean. Red lines show models forced by stronger Solar variability and blue lines show models forced by weaker solar variability. Reconstructed temperatures are shown by grey shading.

From figure 1 we can see during medieval period the temperature is high as compared to Little Ice Age.Possible causes of the Medieval Warm Period include increased solar activity, decreased volcanic activity, and changes to ocean circulation (SkepticalScience 2017).Climate proxy records show peak warmth occurred at different times for different regions, indicating that the Medieval Warm Period was not a globally uniform event(Solomon, Susan Snell 2007).The period was followed by a cooler period in the North Atlantic and elsewhere termed the Little Ice Age. The time period for this Ice Age is anywhere between 14th century to 19th century.Based on radiocarbon dating of roughly 150 samples of dead plant material with roots intact, collected from beneath ice caps on Baffin Island and Iceland, Miller et al.(2012) state that cold summers and ice growth began abruptly between 1275 and 1300, and then from 1430 to 1455. In contrast, a climate reconstruction based on glacial length(`www.realclimate.org/index.php/archives/2005/03/worldwide-glacier-retreat/` and Oerlemans,2005) shows no great variation from 1600 to 1850 but strong retreat thereafter.

Therefore, any of several dates ranging over 400 years may indicate the beginning of the Little Ice Age:

- 1250 for when Atlantic pack ice started to grow; cold period possibly triggered or enhanced by the massive eruption of Samalas volcano(Jonathan Amos, 2013)
- 1275 to 1300 based on the radiocarbon dating of plants killed by glaciation
- 1300 for when warm summers stopped being dependable in Northern Europe
- 1315 for the rains and Great Famine of 1315–1317

- 1560 to 1630 for beginning of worldwide glacial expansion known as the Grindelwald Fluctuation(agamar Degroot,2016)

The Little Ice Age ended in the latter half of the 19th century or early in the 20th century(Hendy, Erica J et al. 2002)

3 Post-Industrial Climate change

Scientists generally agree that the earth has warmed by about 1°C since 1880.This warming has led to a warming of the earth's oceans, rising sea levels, and diminishing snow and ice. This rate of warming is approximately 50 times faster than the rate of warming during the previous 21,000 years (Scotese, 2016). Let's dive into data sets about temperature variations that we downloaded latest data from `https://data.giss.nasa.gov/gistemp/` and `www.ncdc.noaa.gov/cag/global/time-series/globe/`.

The first data set contains annual mean temperature variation globally since from 1880 to 2020 and second data set contains mean temperature variation since from 1920 to 2020 for different regions which are: Asia, Africa, Europe, North America, South America, and Oceania. We will now do some statistical summary and visualization about these variations according to year and locations and draw some insights.

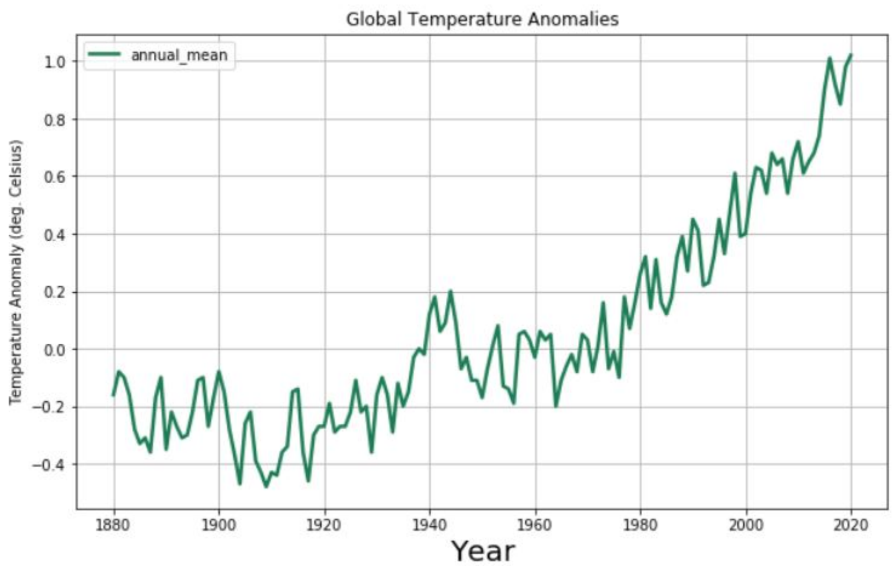

Figure 2: Global Temperature anomaly from 1880 to 2020.

From Figure 2 we can clearly observer that,the temperature indeed increased anywhere between 0.85°C to 1°C. The graph starts from -0.2°C in year 1880 and rise above 1°C in the year 2020. The 10 warmest years on record have all occurred since

2005, and 7 of the 10 have occurred just since 2014. Global average temperatures did cool by about 0.2˚C after 1940 and remained low until 1970.It is largely due to a high concentration of sulphate aerosols in the atmosphere, emitted by industrial activities and volcanic eruptions. Sulphate aerosols have a cooling effect on the climate because they scatter light from the Sun, reflecting its energy back out into space.The rise in sulphate aerosols was largely due to the increase in industrial activities at the end of the second world war. In addition, the large eruption of Mount Agung in 1963 produced aerosols which cooled the lower atmosphere by about 0.5˚C, while solar activity levelled off after increasing at the beginning of the century.

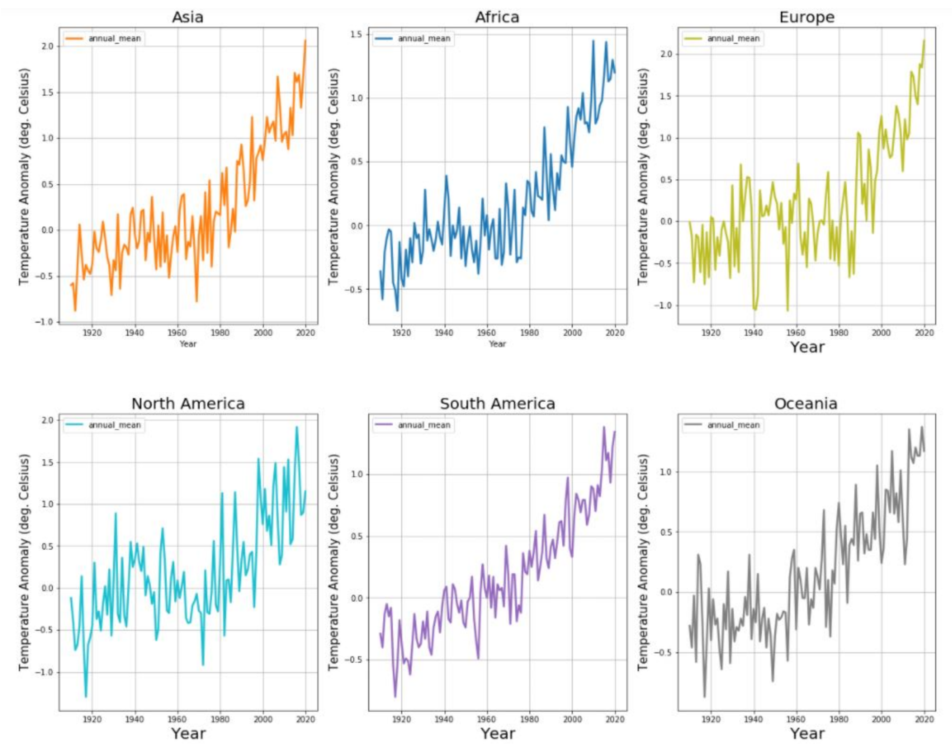

Figure 3: Temperature anomaly by Continents.

Figure 3 shows temperature anomaly of different continents from 1920 to 2020. All continents have similar trend with respect to rise in temperature from past 100 years. The temperature rise in Africa, South America and Oceania is lower than Asia,Europe and North America. Asia as of now has highest temperature anomaly i.e. above 2°C. This shows that global warming has not been uniform across the planet, the upward trend in the globally averaged temperature shows that more areas are warming than cooling.

Scientists attribute the global warming trend observed since the mid-20th century to the human expansion of the greenhouse effect (IPCC,2013)- warming these results when the atmosphere traps heat radiating from Earth toward space.The gases that contribute to the greenhouse effect include CO_2, methane, nitrous oxide, chlorofluorocarbons, water vapor etc. let's check the definition for some of these gases.

- Methane - A hydrocarbon gas produced both through natural sources and human activities, including the decomposition of wastes in landfills, agriculture, as well as ruminant digestion and manure management associated with domestic livestock. On a molecule-for-molecule basis, methane is a far more active greenhouse gas than CO_2.
- Nitrous oxide - A powerful greenhouse gas produced by soil cultivation practices, especially the use of commercial and organic fertilizers, fossil fuel combustion, nitric acid production, and biomass burning.
- CO_2 is released through natural processes such as respiration and volcano eruptions and through human activities such as deforestation, land use changes, and burning fossil fuels. Humans have increased atmospheric CO_2 concentration by 48% since the Industrial Revolution began

4 Factors affecting climate change

With rising life expectancies and a rapid increase in population across the globe, it is getting harder for humanity to sustain its nutritional needs. The inefficient upscale of food production is having a noticeable negative impact on the planet. Deforestation, increased livestock farming, and the excessive use of fertilizers, which are all related to food production, are the main causal factors behind rising emissions in greenhouse gasses and consequently, global warming. In this topic, we focus on below points :

- how world recently evolved in terms of factors that are relevant to agriculture and climate change i.e agricultural activity, CO_2 emissions,deforestation etc.
- What are the most popular food types and their relative impact on CO_2 emissions.
- Are there any trends in the production of different food types and their efficiency in terms of CO_2 emissions

The datasets that we use in the following topic are extracted from `www.kaggle.com/unitednations/global-food-agriculture-statistics`. we will discuss the factors one by one that are affecting climate change.

4.1 Population

No doubt human population growth is a major contributor to global warming, given that humans use fossil fuels to power their increasingly mechanized lifestyles.We downloaded population dataset from `http://www.fao.org/faostat/en/#data/OA` which illustrates the population levels for countries.We particularly look at the evolution of total world population over time and the proportion of world population that is represented by Low Income Food Deficit Countries (LIFDCs). LIDFCs are countries that have a per capita Gross National Income (GNI) below a predefined threshold and that are net food importers in terms of calories. These are of particular interest as these countries are dependent on other countries food production and thus increases other nation's CO_2 emissions.

Additionally, these countries would cause an increase in general flow of food products between countries which drives up emissions caused by transportation.

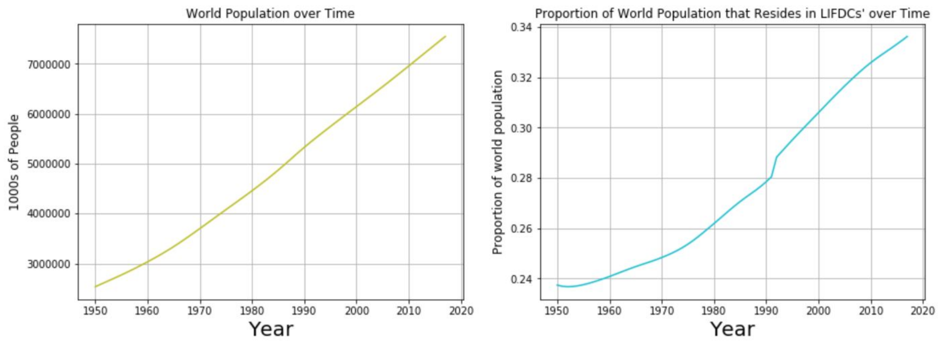

Figure 4: Population Growth and Proportion of LIFDCs Population

From figure 4 we can see that population significantly increased over the past 60 years roughly from 2.5 billion to 7.5 billion.Alongside this, we notice that the proportion of the total population that reside in countries that are LIDFCs is also on the rise.This highlights the fact that there is a greater number of humans that rely on limited food production resources. Both, world and LDIFC population growths are striking and signal upcoming challenges in the ability to sustain these in an efficient manner in terms of greenhouse gas emissions.

4.2 Agriculture

Now we investigate the evolution of the CO_2 equivalent emissions coming from Agriculture across the world. We also look at the contribution of these emissions to the total CO_2 equivalent emissions. Greenhouse gas emissions in Agriculture consist of non-CO_2 gases, namely methane (CH_4) and nitrous oxide (N_2O), associated with crop and livestock production and associated management activities. These are converted into CO_2 equivalent emissions according to their global warming potential as outlined in `http://fenixservices.fao.org/faostat/static/documents/GT/GT_e_2019.pdf`.

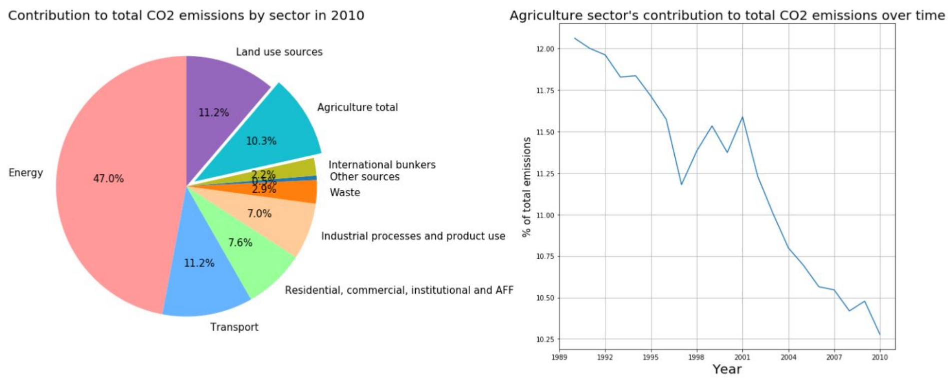

Figure 5: CO_2 emissions by sector

From the pie plot above we can see that agriculture represents a sizeable proportion of total CO_2 emissions (about 10%). It is worth noting that since agricultural products are imported and exported across the globe, Agriculture also impacts the emissions emanating from the Transport sector. Note that the biggest proportion of emissions comes from energy (energy, manufacturing and construction industries and fugitive emissions). Although we see that agriculture's share of emissions has decreased over the years (roughly from 12% to 10%), this could be potentially caused by the increase of another sector's share. We explore the evolution of the actual emissions from the agricultural sector below.

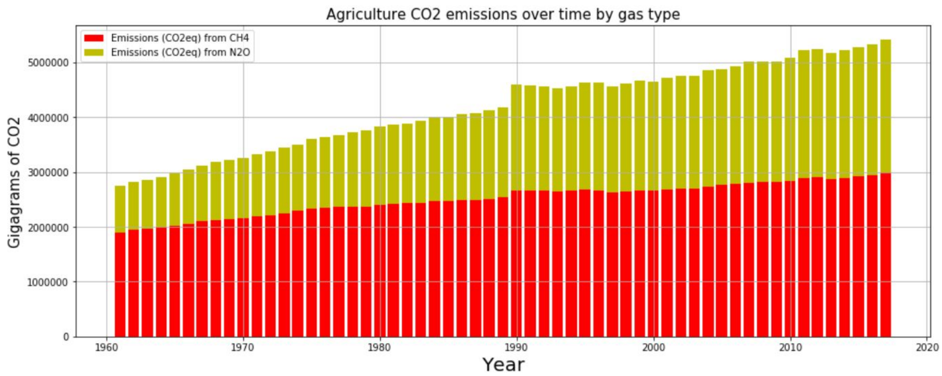

Figure 6: Agriculture CO_2 emissions over time by gas type

From the plot above we see that there is actually a steady increase in CO_2 emanating from the agricultural sector. This confirms the previously stated assumptions that although the agricultural sector's share of CO_2 emissions has decreased, the actual value of emissions has increased. Additionally, we notice that in 1990 there is a slight abnormal jump in the level of CO_2 emissions. Investigating the FAOSTAT(`http://fenixservices.fao.org/faostat/static/documents/GT/GT_e_2019.pdf`) documentation related to this dataset, we learned that data for two types of emissions, namely "Cultivation of organic soils" and

"Burning–savanna", start in 1990 which explains this jump.

We will remove these two types of emissions from dataset and replot. So that we can see more illustrative view of the trend in CO_2 since from 1960. Additionally, we also compute and plot the CO_2 emissions from Agriculture per capita over time. This would allow us to observe how increase in world population that we have observed earlier compares to the above increase in agricultural CO_2 emissions.

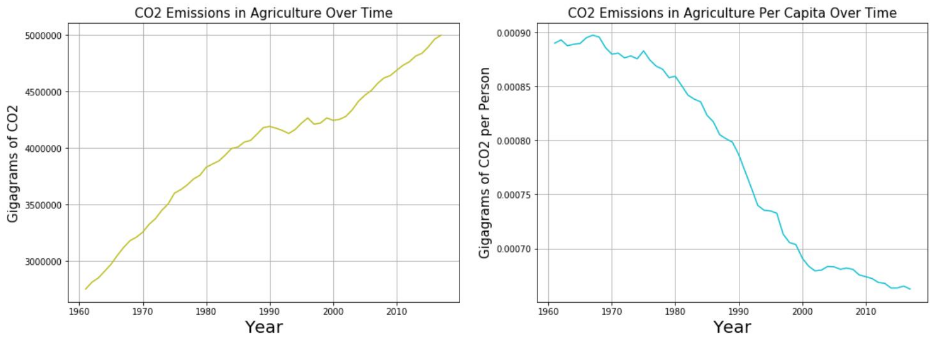

Figure 7: Agriculture CO_2 emissions by per captia

Having removed the effect of the additional emissions caused by "Cultivation of organic soils" and "Burning–savanna", we can now observe a smoother increase in agricultural CO_2 emissions over time. Additionally, we also plot the number of gigagrams of agricultural CO_2 emissions normalized by the world population as a function of time. We can observe that this curve decreases, as opposed to the one relating to the emissions of CO_2. We have already observed that the world population has significantly increased over the same time period. This means that the increase in world population is greater than the increase in agricultural CO_2 emissions. Since it is safe to assume that the vast majority of the world relies on agriculture for their nutritional needs, this could illustrate the fact that, in terms of efficiency of agricultural activity relative to CO_2 emissions, the world has made progress over the last half century. This ties in well with the fact that the world has also made significant technological progress over the same time period. As our initial plot demonstrates, the CO_2 levels are rising.

4.3 Deforestation

Tropical forest trees, like all green plants, take in carbon dioxide and release oxygen during photosynthesis. Plants also carry out the opposite process known as respiration - in which they emit carbon dioxide, but generally in smaller amounts than they take in during photosynthesis. The surplus carbon is stored in the plant, helping it to grow.

When trees are cut down and burned or allowed to rot, their stored carbon is released into the air as carbon dioxide. And this is how deforestation and forest degradation contribute to global warming. As outlined above, plants and trees having carbon-absorbing properties. As a result, they represent a major factor in balancing the CO_2 levels of the planet. Therefore, we investigate how the forest area of the planet and its ability to absorb carbon have evolved over time.

we downloaded the data from FOASTAT(`http://www.fao.org/faostat/en/#data/RL`). we will plot the evolution of world forest area and carbon stock living biomass since from 1990.

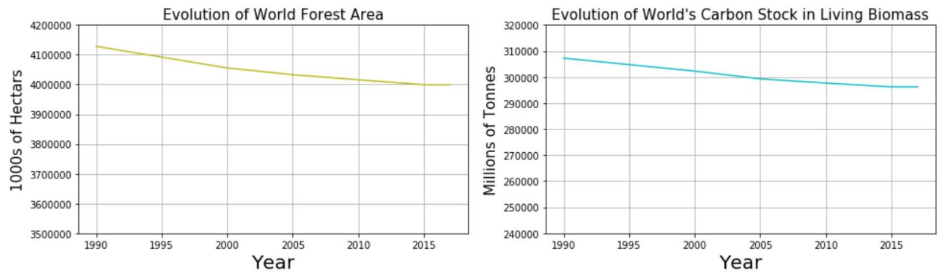

Figure 8: Forest Evolution and Carbon stock

From the above plots, we can observe that both the area represented by the world's forests and its ability to absorb carbon have decreased over time. Is this change in

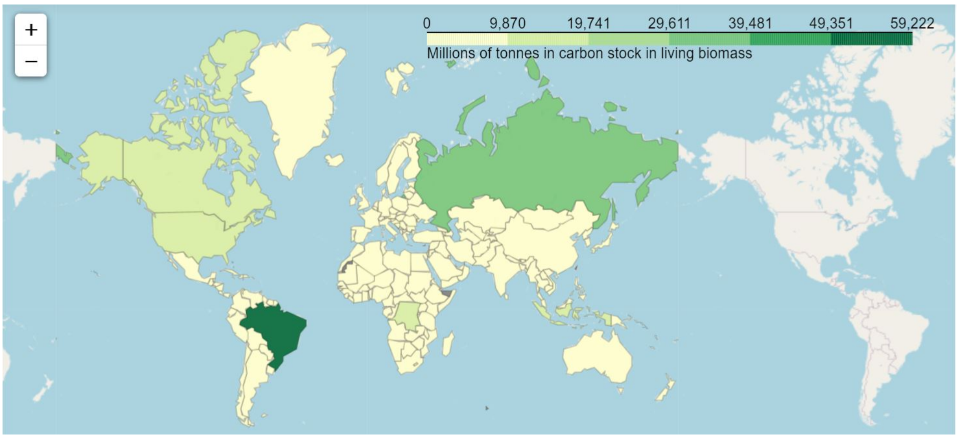

Figure 9: World Map - Carbon Stock living in Biomass

From the plot above we can observe the distribution of the carbon stock in living biomass across the various countries of the world.The plot illustrates the fact that heavy reliance is placed on very few countries forests. Predominantly, the Brazilian Amazon rainforest seems to play a crucial role in absorbing the world's carbon. Additionally, Russia seems to be a key player as well, with Canada, the United-States, Indonesia and the Democratic Republic of Congo holding also holding a significant portion of the world's carbon stock. We investigate below how these few select countries forests have evolved over time.

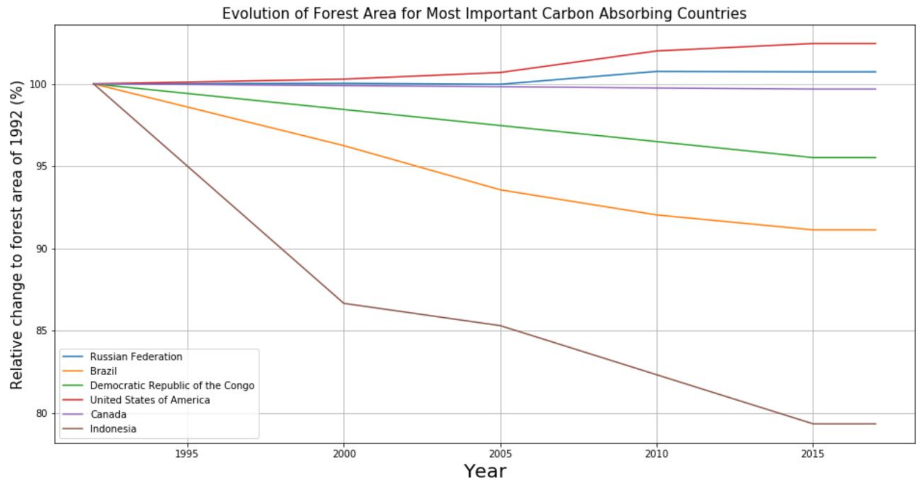

Figure 10: Top Countries Forest Evolution

The plot above illustrates the change of forest areas for the chosen subset of countries with a baseline of 1992. We can observe that certain countries like Brazil, Indonesia and the Democratic Republic of Congo have reduced over this time. On the other hand, Russia, Canada and the United States have managed to stay at the same level throughout this time period or even increase the forest area within their country. It is worth pointing out that as we have observed that Brazil holds the biggest proportion of the world's carbon stock, it is alarming to see that it is one of the countries with a steady downwards slope for their forest area over the last 20 years. This shows an alarming sign that global warming is increasing due to deforestation happening in Brazil,Republic of Congo,Indonesia, and many other countries.

4.4 Food

Food system activities, including producing food, transporting it, and storing wasted food in landfills, produce greenhouse gas (GHG) emissions that contribute to climate change. Of these sources, livestock production is the largest, accounting for an estimated 14.5 percent of global GHG emissions from human activities. Meat from ruminant animals, such as cattle and goats, are particularly emissions intensive (Tilman D et al. 2014)

We now look at which food produces more emissions, and we will use Emissions intensities dataset (`www.fao.org/faostat/en/#data/EI`) which contains relevant information regarding the amount of green gases produced by some common food such as meat, milk and rice.

We observe that there is a great imbalance in the amount of Emissions intensity of

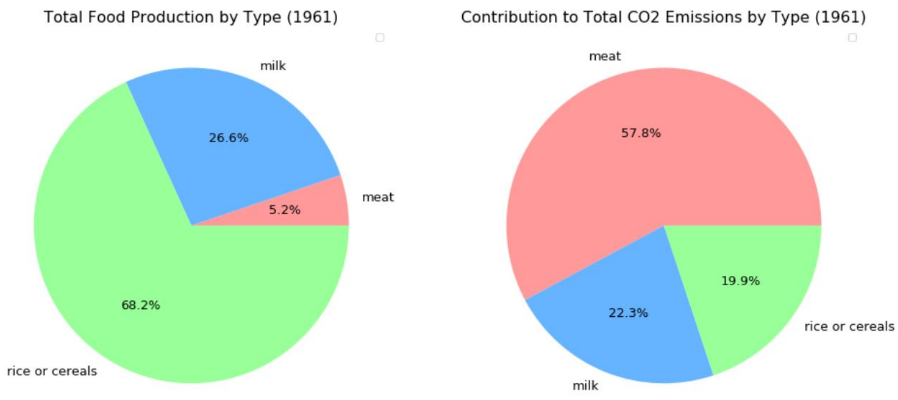

Figure 11: Food Production and CO_2 emissions in 1961

different food types. For instance, meat which represents a very small proportion of the total amount of food produced is responsible for almost 60% of the total food related emissions.

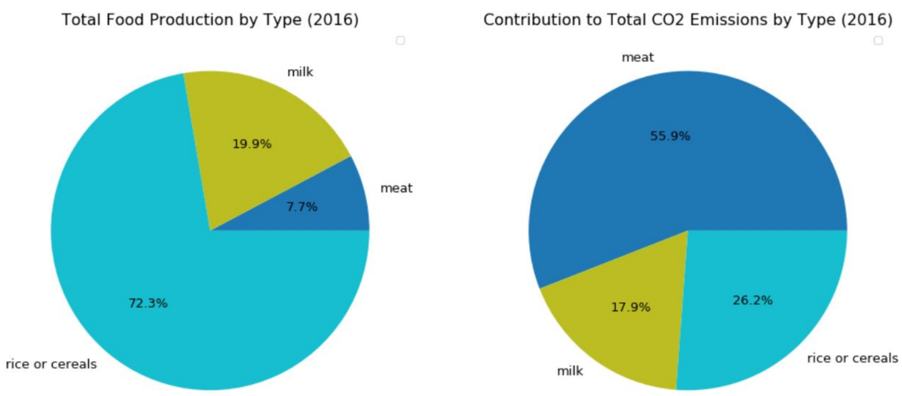

Figure 12: Food Production and CO_2 emissions in 2016

We observe a small shift in eating habits towards, nonetheless this is not reflected in the total emissions. This can be explained by the previously depicted improvement in the efficiency to produce meat.

5 Conclusion

Based on our analysis the Earth's average temperature has increased about 2 degrees Fahrenheit during the 20th century. We have also observed what are the factors that drives climate change. Some of the long-term effects of global climate change we may except in future are as follows:

- Temperatures will continue to rise.

- More droughts and heat waves will occur
- Sea level will rise
- Arctic likely to become ice-free.
- Frequent wildfires will rise

In order to combat above issues, the following changes will happen:

- Renewable energy source will grow.
- Plant based food source will grow significantly.
- Climate change education may start at early school years. i.e. may be at preschool or primary school.
- Plastic utilization will be reduced significantly and papers bags tend to rise.

References

"How does the Medieval Warm Period compare to current global temperatures?". SkepticalScience. Retrieved October 12, 2017.

Solomon, Susan Snell; Intergovernmental Panel on Climate Change (2007). "6.6 The Last 2,000 Years". Climate change 2007: the physical science basis: contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

Miller, Gifford H.; Geirsdottir, Aslaug; Zhong, Yafang; Larsen, Darren J.; Otto-Bliesner, Bette L.; Holland, Marika M.; Bailey, David A.; Refsnider, Kurt A.; Lehman, Scott J.; Southon, John R.; Anderson, Chance; Bjornsson, Helgi; Thordarson, Thorvaldur (2012). "Abrupt onset of the Little Ice Age triggered by volcanism and sustained by sea-ice/ocean feedbacks".Science Daily (30 January 2012)

Jonathan Amos (30 September 2013). "Mystery 13th Century eruption traced to Lombok, Indonesia"

Dagamar Degroot, Did the Spanish Empire Change Earth's Climate? (2016).

Hendy, Erica J.; Gagan, Michael K.; Alibert, Chantal A.; McCulloch, Malcolm T.; Lough, Janice M.; Isdale, Peter J. (2002). "Abrupt Decrease in Tropical Pacific Sea Surface Salinity at End of Little Ice Age".

Scotese (2016) “Some Thoughts on Global Climate Change: The Transition for Icehouse to Hothouse Conditions”

IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

Tilman D, Clark M. Global diets link environmental sustainability and human health. Nature. 2014;515(7528):518-522