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Analysis of the situation of deforestation and road transport greenhouse emissions for the next decade in Colombia

A systemic analysis using historical trends

by

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Colombia committed to reduce 20% of its emissions by 2030 in the framework of Paris Agreement. The study provides a systemic approach that considers the two main drivers of the emissions in the country to know how realistic is the mentioned intended National Determined Contribution (iNDC). It analyzes deforestation and road transport with a methodology that combines analyses of their current situation and their historical trends. The investigation uses previous research and official information of the government. Besides, it estimates the level of the emissions of 2030, by using historical data of forest area from the year 1900 for deforestation, and Diesel and Motor Gasoline energy consumption from the year 1975 for road transport. The main results are that according to 50 years and 100 years historical trends, deforestation emissions could be reduced ~10% and ~30% respectively of the expected level of 2030. In the case of road transport emissions, they could double in ~10 years when considering the period between 1975-2017 and 2000-2017 for Diesel and 2007-2017 for Motor Gasoline. In addition, the research works as a handbook to understand greenhouse emissions in Colombia.

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1 Introduction

Colombia is a country very vulnerable to climate change for his location in the tropics. According to the agency of the government that deals with risks from disasters, from 2000 to 2015, the country increased its number of natural emergencies by more than 700% (UNGRD, 2017). Most of these disasters are from floods which have affected about 25% of the population of the country. Also, global warming is assumed to be influenced by greenhouse emissions. For this reason, the Paris Agreement aims to reduce GHE at a global level to reduce its potentially catastrophic effects. In its framework, Colombia seeks to reduce 20% of its projected emissions by 2030 (Colombia First NDC, 2018). In the country, agriculture, forestry and energy account for 90% of the emissions. Half of these emissions come from deforestation and road transport.

In order to understand the two main drivers of greenhouse emissions, they must be analyzed in terms of numbers but also with the context of what are the socioeconomic variables involved. The country has been increasing its deforestation rates after 2012, when the negotiations for peace with the Revolutionary Armed Forces of Colombia started, until the present. The population of the nation is not aware of its environmental impact, and nobody wants to take direct responsibility for it. In the case of road transport, people are aware of the pollution coming from it, but the government has no clear route with specific targets to reduce its contribution of greenhouses.

Historical trends show how Colombia might not fulfil its commitment to the Paris Agreement. Besides, as the country urges to grow economically in all sectors, the demand for transport and land will keep increasing. The challenge has no clear solution, but the information on calculating emissions and understanding where they come from is the first step to educate and promote awareness for relevant actors with the capacity of producing positive changes.

The first part of the research is composed of a contextualization that includes a review of the Paris Agreement, a comparison with similar countries, the land use in Colombia, the decoupling of energy, emissions and GDP, the transport sector and major global warming consequences. The second part reviews different previous research regarding emissions in deforestation and road transport. The third, fourth and fifth parts show the data used for the estimation of emissions of deforestation and road transport, their current situation and their forecast. Then in the final part, the research will conclude with implications and future research recommendations.

1.1 Research Problem

1.1.1 Paris Agreement

Climate change is the biggest threat to our human generation and the ones to come. According to the United Nations, if the planet increases its temperature by 2 degrees Celsius this century the effects for all the population are catastrophic. In general, this will cause food scarcity, sea level rise, expansion of diseases and extinction of species, among other economic unprecedented challenges. The following information will present the global institutional effort to prevent a major disaster from climate change and is based on Garcia et al. (2016).

Decisions to stop the heating of the earth started in Rio de Janeiro with the United Nations Framework Convention on Climate Change (UNFCCC), which is a treaty signed in 1992 which the main goal was to stabilize greenhouse gas emissions. This treaty divided countries in three groups: developed with the duty of mitigating and helping other countries, developed with the duty of mitigating and developing countries with the duty of reporting their emissions and internal policies to mitigate climate change. Then, the Kyoto Protocol came in 1997 to accord specific targets for developed countries to mitigate their emissions. The countries compromised to reduce by 5% of their emissions, compared with the year 1990, between 2008 and 2012. Later, to extend their compromise to mitigate their emissions, some developed countries signed the Doha Amendment to the protocol. However, it has not entered into force yet because of its acceptance by at least three-fourths of the parties to the Kyoto Protocol, which accounts for 144 countries.

After this, in 2015, the Paris Agreement was negotiated by most of the nations of the world. This agreement is characterized by clarity, transparency and understanding of the goal of each of the participants. Even though no punishment would be executed if a country does not follow its word, the document is binding to the fact that every country must do its best comply with the contract. Its goal is to achieve global warming well below 2.0 degrees Celsius in comparison with pre-industrial levels and to limit the temperature even further to 1.5 degrees Celsius. Within the United Nations Framework Convention on Climate Change (UNFCCC), every country has the freedom to establish the reduction of its emissions. By April 2016, 190 countries had submitted their Intended Nationally Determined Contributions (iNDCs). This promise would be checked regularly at some points in time to see how well the countries are doing and to check if they need extra help to reach their goal.

Colombia represented by the president Juan Manuel Santos supported and signed the Paris agreement. The country is responsible for 0,46% of CO2 emissions in the world according to the official information given by the government. Even though it is not one of the leading polluters nowadays, its increasing economic growth can make these emissions to double for the year 2030. For this reason, Colombia promised to reduce emissions 20% by 2030, and 30% if it receives international cooperation, according to its economic growth forecast using a Business as usual scenario developed by the government and Universidad de Los Andes. These emissions include the greenhouse gases established in the Kyoto Protocol: Carbon dioxide (CO2), Methane (CH4), Nitrous oxide (N2O), Hydrofluorocarbons (HFCs), Perfluorocarbons

(PFCs), and Sulphur hexafluoride (SF6). The goal is for all the sectors in the economy. In the case of agriculture, rorestry and other land use, Colombia promised to reduce 32,4 MT of emissions by 2030 of avoided deforestation. Also, to have gross deforestation of zero (Bosques Territorios de Vida, 2018). However, a specific goal by every sector has not been submitted yet as the government will keep track of the emissions of the upcoming years.

1.1.2 Colombia and Similar Countries in Context

In this subsection, Colombia is compared against similar countries in terms of GDP, emissions and type of forest. In terms of total carbon emissions from fossil fuels, Colombia is a country that, in comparison with its similar peers, it does not produce a significant amount of emissions. In Figure 1., we to see how countries with bigger economies like Brazil, South Africa and Mexico produce way more emissions than Colombia, Peru and Ecuador.

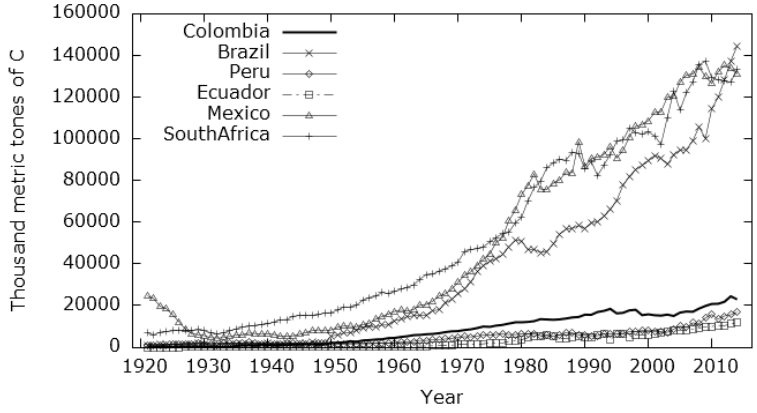

Figure 1. Total emissions from fossil fuels per country (Boden et al.,2017)

If we look at these countries in terms of GDP[1] per capita, Colombia is almost in the middle of all of them, having an increasing GDP per capita over the last 50 years. In Figure 2., Colombia shows a stable value for emissions per capita, even though its GDP per capita keeps growing. However, it has been a trend in all countries, not only in Colombia. It is relevant to remind that the aim of the Paris Agreement and efforts to stop climate change is not to have stable emissions but to reduce them in the long term. Also, the goal is not to reduce emissions per capita, but in fact, the total emissions that the countries are producing.

[1] According to the World Bank, the GDP of Colombia for the year 2017 was 373 Billion (Constant 2010 US$).

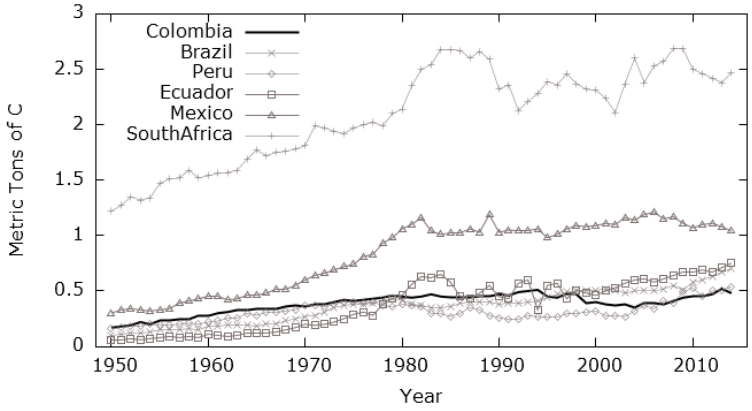

Figure 2. Per capita CO2 emissions per country (Boden et al., 2017)

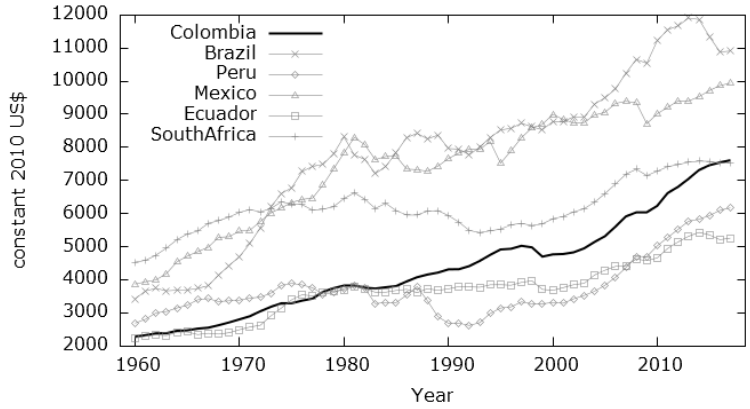

Figure 3.GPD per capita per country in constant 2010 US$ (World Bank).

In Figure 3., all countries without exception, have shown a growing trend in their total emissions. Therefore, if we expect economies to keep growing, which for developing economies, translates into more energy consumption, more transport demand, more residential demand, population growth and a higher demand for food, these economies have the purpose to be developed without the need of producing the high amounts of emissions like in other already developed countries. The opportunity to these countries, including Colombia, is to track where their emissions are coming from and create strategies to stop them directly. For this reason, this research focus on the transport sector and deforestation in Colombia.

1.1.3 Land Use in Colombia

Deforestation is one of the major causes of global warming because the forest is optimal to stock CO2 when trees are taking down, they release all the CO2 to the atmosphere causing greenhouse effects. At a global level, about 30% of the land is composed of a forest. Likewise, forest in the world has an area of 4 billion hectares, and about 1,9 Gt of carbon dioxide has been released from its biomass in the last 25 years (MacDicken, K. et al. 2015). In the case of the Amazon forest, the net role of emissions saved and released from this area remains uncertain. All the CO2 absorbed by the forest could have been overtaken by the release of emissions due to deforestation (Naughton-Treves, 2004). Besides, when the new land use become pasture with livestock, more emissions are produced. Therefore, land use changes in the world are significant triggers of global warming.

About the Amazon forest, Colombia has been estimated to be the fourth in the countries with the highest deforestation (Song et al. 2015). The authors discussed that, after Brazil, Bolivia and Peru, Colombia has been having 287 ± 67 K Ha of deforestation the last decade and equals 2% of the deforestation in the Amazon. On the other hand, the authors also highlighted that even though countries like Brazil or Bolivia (70% and 12%) represent in area terms a higher loss of Amazon forest, Colombia has double its deforestation rates in the Amazon from 2006 to 2009. Besides, they showed that Colombia´s and Peru´s Amazon forest has the highest emissions per hectare of countries in the periods from 2005 to 2010 having 141 Mg C /Ha. Similar countries, Brazil (129 Mg C /Ha) and Bolivia (94 Mg C /Ha) which proved to have more deforestation had lower emissions on average.

Land use accounts, depending on the source, for about 20% of the greenhouse emissions at a global level. Usually, in developed countries the source of the most significant emissions is the energy sector but in developing economies is the land use. For these reasons, the REDD+ program was created. It was established under the United Nations Framework Convention on Climate Change. In Colombia and most developing countries, the program has the following focus: reducing deforestation, reducing degradation of forest, conservation of forest, sustainable management of forest, and increasing the forest stock of carbon.

In Colombia, the report Bosques Territorios de Vida (2018) by the government divided the drivers of deforestation into direct and indirect causes. The direct causes are related to the action itself. Those are changes in the land to make it appropriate for pasture, illegal extraction of minerals, expansion of the infrastructure, wood extraction and forest fires. Behind these actions, the indirect causes are different factors related to the sociopolitical and socioeconomic situation. The technological and economic factors are markets and illegal economies, technology development, consumption and production costs. The political factors are related to public policies, the presence of the state in those remote areas and social conditions related to the use, distribution and rights over the land property, armed conflict and recently, with the peace deal, the reintegration of lands and people that were related to the armed conflict. The cultural factors are related to education, old techniques of the indigenous population and vision of the forest. The demographic factors are migration and population growth. The biophysics factors are the weather, the accessibility, the type of forest, the access to water sources and the presence of fine woods. Therefore, to reduce the emissions coming from deforestation in Colombia remains an incredibly complex challenge. Among the causes, the most relevant, according to Pacheco (2019) is to destroy the forest to obtain property rights over the land with the hope that its market price will increase in the future.

Even though all these variables are unpredictable, the government through its ministry of the environment presented a strategy with specific goals in order, not only to reduce emissions, but to accomplish the Sustainable Goals of the United Nations. Those are:

- Colombia will have a positive forest commercial balance
- Colombia achieves gross deforestation of zero.
- The quality of life of the population in forestry areas improves.
- The state will provide better governance for the people that live in forestry areas.

- By 2030, 32.4 Mton of CO2 emissions are reduced by avoided deforestation.

The plan of the government lacks a clear target in the reduction of forest fires. Those account every year on average for 42.000 Ha (Ministerio de Ambiente). Forest fires are incredibly harmful to the environment because they produce deforestation, pollution and long-term damage. According to the Colombian Hydrology, Meteorology and Environmental Studies Institute IDEAM (2015), only in the department of Casanare there less than 100 fires that accounted for more than 35,000 Ha of land in 2015. Meanwhile, according to the same institution, in Cundinamarca, which is a department located in the center of the country registered more than 800 forest fires. Besides, most of those fires are the product of dry seasons called "El Niño", and with the rising temperature of the earth, they are expected to be happening more frequently.

By the year 2002, the government had a clear strategy with short term (3 years), medium term (5 years) and long term (10 years) plans to control the fires, to reduce its consequences and to reduce the risk of them. Those included the education of the communities in the topic, the use of modern technologies to stop them in case they appear and the integration of different levels of institutions to produce prevention and risk reduction in the vulnerable areas(Plan Nacional De Prevención, Control De Incendios Forestales y Restauración de Áreas Afectadas, 2002). Even though the government considered the importance of reducing fires in the country more than a decade ago, with the climate change reality and knowledge, the policies must be stronger.

In summary, the land use in Colombia represents a threat to the planet. The country is taking measures to protect the forest, but they are not clear enough. If the government keeps lacking direction on them, the people responsible for deforestation will continue to do so. On the other hand, when deforestation is aggregated with agriculture and livestock production, they become the number one emissions producer in the country.

1.1.4 Decoupling in Colombia

In developed economies, especially in Western Europe, the decarbonization of the economy is taking place since 1960 (Kander, Malanima & Warde, 2013, p.279). However, the decoupling of GDP and greenhouse emissions is not happening in Colombia. Furthermore, there is no supporting information to argue that the decoupling is happening globally through a "Dematerialisation" of the economy, primarily because of evidence in developing economies (Bithas & Kalimeris, 2018).

Then, the starting point of the analysis is to see how far is Colombia to achieve decoupling between energy and GDP and, how the energy intensity of the different sectors of the economy have been evolving over the last years. To answer these questions, Román-Collado et al. (2018) did a decomposition analysis using decoupling elasticity index. The index analyses the relationship between energy consumption and economic growth. It measures the percentage change in energy consumption resulting from a 1-per cent increase in GDP between two periods. Their results were that in the period from 2000 to 2015, in only a couple of years, there was evidence of decoupling. Therefore, the authors argued that with the analysis, they found no strong evidence of the phenomenon in the country. This information is not surprising as

Colombia is still in a phase of rapid economic growth characterized for an absolute lack of the most efficient technologies and methods of operation in general.

After that, they did an additive decomposition analysis index (LMDI) to check what were the drivers of energy consumption in Colombia. They considered Population, Activity, Structure and Intensity for the period 2000–2015.

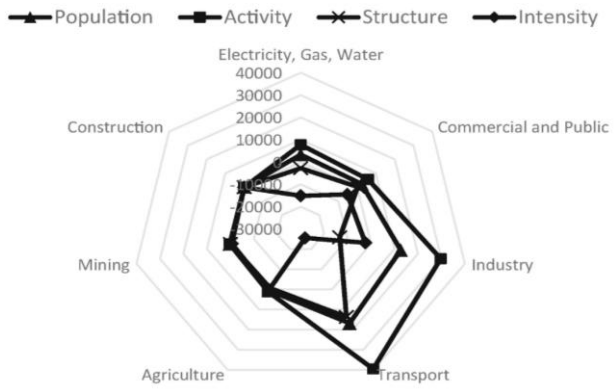

Figure 4. Decomposition effects of energy consumption changes by sectors between 2000 and 2015 (Teracalories) (Román-Collado et al., 2018).

According to their results, it is the Transport and the Industry which raised the energy consumption in the country. Other sectors like Mining and Construction increased very little their energy consumption. The authors showed how the increased transport consumption was motivated but the Activity variable which is related to the increase of flights around the country and public transport in the cities. Behind the Activity, Population growth remains as a significant driver of energy consumption in the country.

Figure 5.Transport GDP change vs Transport emissions change in Colombia (Banco de la Republica de Colombia and Muntean et al., 2018).

Furthermore, a special analysis of the GDP of transport sector and its emission level can be seen in Figure 5. There is no sign of decoupling of transport sector economic growth and its level of emissions. Colombia is not even close to decoupling. Besides, in terms of energy consumption the transport sector is the main driver. And consequently, the transport sector is responsible for the most part of the emissions coming from energy consumption in the country.

1.1.5 Transport Sector

In history, transport is vital for the economy, and the reduction of its cost around the world allowed the development of capitalism. Different authors argued that it was because transportation cost decreased that we now see many different brands producing their products abroad. This caused an increase in transportation distances, which produce more emissions. Besides, transportation cost also allowed developing countries to export their raw materials used as energy carriers to develop products in developed countries. Likewise, transportation has been seen only as monetary costs, and its positive consequences for the economic development of the world are indisputable. However, with the crucial times for change we live in now, and the need to follow the Paris Agreement National Contributions, it has to be understood for its contribution to global warming.

The transport sector has an essential role in reducing emissions. It accounts for around 20% of the CO2 emissions in the world (Tian et al., 2018). Usually, the developed countries were the ones boosting emissions from this sector. However, nowadays, the developing countries are increasing the transport infrastructure through the construction of bigger airports and more highways. The construction of those assets is required to have a healthy economy. Therefore, the responsibility lies down on the means of transport and not on the infrastructure itself. Hence, the development of low emission planes, boats and cars are vital to reduce the pollution of the world.

In Colombia, the investment in infrastructure for road transport has been increasing historically to its highest levels. With economic development, the need for transport infrastructure increase too. Accordingly, there is a long-term plan of the government to keep increasing the offer of roads in order to allow the movement of passengers in all the regions. The investment in roads went from 2,43% of GDP in the year 2000 to 3,51% of GDP in the year 2009 (Transporte en cifras, 2010). The country plans to reach locations where the roads are still in bad condition or do not even exist and expand the ones already built. The demand for roads is primarily driven by the new peace era of the country, which allows its population to go to places that used to be managed by illegal groups. However, about the quality of roads by the Global Competitiveness Index, Colombia went from the position 87 in 2006 to the position 110 in 2017. Also, the overall score of the Index puts Colombia frequently around position 60 (Transporte en Cifras, 2017).

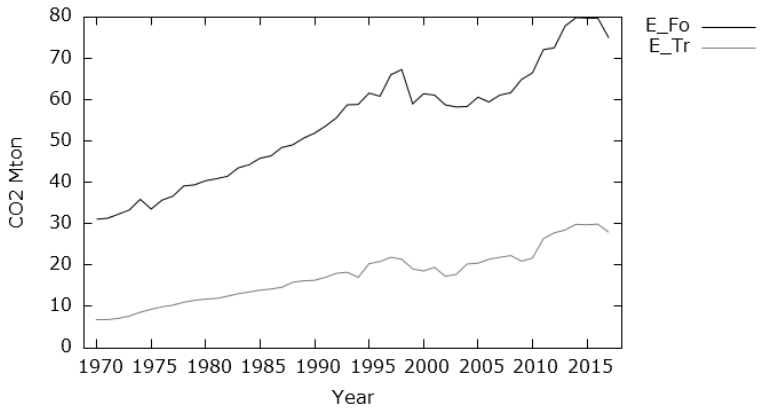

Figure 6.Total fossil fuel emissions vs Total transport emissions (Muntean et al. 2018).

As seen in Figure 6., the transport sector in the country accounted for about the 37% of the total emissions in 2017 and used to account for the 22% of the emissions in 1970. Therefore, based

on a growth rate of the GDP in the years to come of 3,1% per year, there is a clear picture that the transport sector is growing at a higher rate than the total emissions of the country and the economic development process of the country. About its relationship with energy consumption, the transport sector is the biggest consumer of energy in the country. It accounts for about 40% of the energy consumption and about 65% of the energy losses according to the Energy Balance (2015).

From 2016 to 2021 in the transport sector, the maritime, fluvial and rail accounts for about 2% of the energy consumption and the air freight and passengers accounts for 10%. The big consumer, and therefore significant pollutant in the country, is the urban and not urban passenger inland transport, which accounts for 63% of the energy consumption. This subsector is followed by the transport of inland urban and not urban cargo, which accounts for 25% of the emissions (Energy Demand Situation in Colombia, 2017).

The consequences of having a high amount of emissions coming from the transport sector not only account for the rising temperature of the planet but also the health state of people living in major cities. Liu et al. (2018), expressed the concerns related to the relationship between the increase of emissions from transport, especially, the carbon monoxide (CO), sulfur dioxide (SO2), nitrogen oxide (NOX) and particulate matter (PM10 and PM2.5). They mention how previous studies, like Huang & Guo (2014), analysed the air pollution risks for public health. The effects not are only limited to respiratory diseases like bronchitis and asthma attacks but also they mention a study by, Kok et al. (2006), in which the consequences of polluted air can lead to the cardiovascular and nervous system complications and even the mutation of cells which causes an increase in the incidence of cancer. This is a severe threat to the finances of the country because the poor health of the population leads to more spending of the government and the households in Colombia in treatments.

Notwithstanding, the government did not show a clear route in the Paris Agreement to decrease the emissions coming from the transport sector. However, there are internal efforts, some of them included by the CONPES, which is the supreme authority for socio-economic planning in the government in Colombia. They promote the use of an integrated public transport system in the large urban areas, the renovation of the cargo vehicles in the logistics sector and the effort to improve the environmental performance of the vehicle stock in general (Behrentz et al., 2014). The time is running and in the cities of Bogota and Medellin, private transport has been suspended in recent times for days due to the high pollution of the air. Colombia needs to develop strategies to reduce emissions with technological and behavioural solutions and with a timescale composed of short-and long-term vision (Anable & Shaw ,2007).

There is an evident lack of incentives and targets to promote the use of electric motors in the public and private transport, a lack of a target in the efficiency of the fuels and a lack of innovative policies that can reduce the pollution of the transport sector. In practical terms, all analysis of the transport sector development and environmental crisis argued that there is no apparent progress to implement trams and metros in the main cities of the country. Also, the expected number of electric vehicles to join the roads in the years to come are not significant in comparison with the other types of private cars (Energy Demand Situation in Colombia, 2017). Therefore, the substantial impact of electric cars may take 15 to 20 years.

The behaviour of the population in Colombia in respect of the transport sector remains the same: people rely highly on private means of transport like car or motorcycle. The population are not price-sensitive when it comes to fuel tax and price increase. The usage and demand for cars have not declined while the price of fuel has done so. People are not aware of the pollution

coming from their cars and have private transportation as their mean of going to work every day. Government decisions have been taken to control the traffic and not the emission levels. Some of these measures, for example, is the “pico y placa”. It was a restriction implemented in Bogota which limited the days of the week that people could use the car and ended having rebound effects that increased the number of cars owned and therefore the pollution.

Moreover, due to the lack of capital to buy a car and the benefits of mobilization, there is an outstanding increasing number of motorcycles in the country. A study showed that there were 7,1 million of motorcycles in the country while 5,2 million of private cars (Situacion Automotriz Colombia,2018). According to the same study, as people start increasing their income, they change from motorcycle ownership to a car ownership.

1.1.6 Main consequences of Global warming

Global warming caused by an increase of emissions in the world is a major threat for our planet for many different reasons. Among them, there is an increase in inequality, natural disasters and the loss of biodiversity.

Inequality

Climate change makes the richer countries richer and the poorer countries poorer. According to King & Harrington (2018), developing countries tend to be around the Equator line in tropical regions where the climate does not usually change through the year. On the other hand, rich countries are usually located in extratropical areas where the forest and the habitat, in general, are used to the continuous change of temperature from season to season and from year to year. This makes the tropical regions more vulnerable to global warming because all environment is less resilient to different changes. The authors suggest that if the earth warms more than 1.5 Celsius degrees, the changes in the local climate of tropical regions are higher than in the extratropical regions. For these reasons, the authors recommend to limit global warming to 1.5 Celsius degrees, and not 2 degrees as the Paris Agreement looks for, in order to decrease the negative impact in the less developed regions. They also argued this would become a significant problem for all the developed countries because the less developed ones are going to need climate change adaptation while maintaining economic development. In the case of Colombia, global warming affects the energy production through “El Niño” phenomenon, which consist of long periods without precipitations. This affects the country because around 70% of all of his energy come from hydroelectric power which must have a considered flow of water to supply the demand for energy of the country.

In addition, Diffenbaugh & Burke (2019) studied how global warming has increased economic inequality and addressed the need to understand the causes of economic inequality. Their study focused on the role of anthropogenic climate in increasing economic inequality among countries. The authors show how, even though inequality between countries has decreased in the last 50 years, global warming with a likelihood of around 90% has made the process slower. They proved this fact, by showing a curve in which with global warming, cold countries increase economic growth and warm countries decrease growth. The main conclusion of this recent study is to bring to light that richer countries are the ones who benefited disproportionately from the activities that caused global warming. Moreover, they are

benefiting from global warming, in terms of increasing GDP, while less developed regions are having negative impacts on their economic development.

Biodiversity and Natural Disasters

In the case of Colombia, the consequences of global warming on natural disasters have been mentioned in multiple investigations and sadly, on the news. The country has during all year places covered with snow, like La Sierra Nevada de Santa Marta, and extremely hot places like the Tatacoa desert. Some of these high mountains have glaciers that, faster than thought, are disappearing. Marulanda et al. (2016) exposed the melting risk of Nevado del Ruiz glacier and its possible devastating consequences which could translate in loss of life and property damage on a large scale. This will tend to happen in less developed zones and to more vulnerable people. The numbers from UNGRD (2017) already show a rising trend in human deaths from different natural disasters but they are mainly from floods.

In terms of biodiversity, nature in Colombia is and will be facing numerous extirpations and possibly extinctions (Root et al., 2003). The authors argued about the need to act proactively and not reactively to the global warming phenomenon. They also warned about the potential division of communities of plant and animals that will get separated looking for ways to stay alive. In the case of Colombian forest areas, animals have already started to move to higher, which have caused changes of more than 30% in animal population sizes. Some of them, if the temperature keeps rising, would not be able to survive at higher altitudes (Gary et al., 2019).

1.2 Aim and Scope

An increasing amount if people want to obtain and to produce knowledge related to greenhouse emissions and global warming in developing economies like Colombia. This research is motivated upon the need to create a starting point for them. Above any other aim, this dissertation wants to show the emergency we are living in, and we will live in the future if actions are not taken accordingly. Climate change is an emergency, and drastic measures should be considered. We aim to show the problem with a pragmatic world view that mix qualitative and quantitative data (Creswell, 2009).

Every country has its situation and responsibilities to act to protect our planet and stop global warming. In Colombia, the situation is clear: the deforestation of forest and the transport sector are the main drivers of emissions. As the government set a target of cutting down emissions 20% by 2030, this research wants to see, according to our forecast, how realistic this could be. We will calculate the number of emissions produced by the transport sector and the deforestation of forest in Colombia. The goal is to forecast until 2050 the emissions coming from these two variables in the country according to their historical trends to see how idealistic the promise is. The research question is:

How realistic is for Colombia to cut down 20% of the emissions coming from deforestation and road transport by 2030 using 2010 as a base year?

We aim to create awareness in the regions who can sequestrate emissions, in terms of deforestation, and avoid future ones, in terms of road transport. We create simple but powerful equations that can be replicated in other countries, or smaller regions, to a fast and easy calculation of these two main emission drivers.

History is the best predictor of the upcoming trends in the main macroeconomic variables. We believe that the complexity of models and the increasing number of variables considered when developing forecast can distortion the real scenario of future events. Beyond the scope of this thesis is the modelling of different scenarios to see what policies work and what would not work. We expect that actions can be taken and then in the future, they will be evaluated.

2 Previous Research

Research regarding emissions and global warming effects is becoming more relevant as new and more reliable data is being obtained. Some authors have already addressed the challenge of uncertainty in climate change modeling (Burke et al.,2015). However, the output of these works remains highly valuable. Different authors are building a large stock of publications relating the political, economic and social impacts produced by climate change that hopefully will be taking as input on the public policy decisions around the world.

2.1 Deforestation emissions

In past research on deforestation emissions, multiple variables have been considered to influence the results. One of the most important ones is the concentration of CO2 according to the biomass type. It is not the same to have deforestation in the Amazon forest than in a desertic territory. Therefore, different investigations have studied different types of emissions coming from different territories and biomass types. Also, most research takes into account satellite images that create maps illustrating the areas in the world with the different types of biomass. Then, what researchers do is to estimate how much biomass is in each pixel of the land, and this becomes their step one of the calculations. Besides estimating emissions, other concern, of the authors specialized in forests, is the REDD+ program. They look for the right incentives that can make it successful enough for developed and developing countries.

The REDD+ program needs information about the calculations of emissions from Deforestation. Guttierez-Velez and Pontius (2012) showed the practical way of doing it. The authors stressed the importance of using historical deforestation and drivers of deforestation to build scenarios that can estimate the potential emissions of the phenomenon. Also, when using historical data to predict deforestation rates, they argued that for the accuracy and relevance of the REDD+ program, the emissions should be forecasted using land change modelling. This is because those models include the amount of area that will be deforested and also include its location. Therefore, it allows a more robust estimation of the emissions produced by deforestation. They recommend to understand and predict conversion processes and land cover trajectories before and after clearing of a forest. It is relevant that in their study, they assumed that carbon emissions are directly related to carbon density and that the phenomenon of releasing carbon to the atmosphere happens instantly after deforestation. They stressed that this is not the case in reality in terms of time but, in terms of the amount of carbon released they found literature to prove that carbon density pixels in maps of forest are proportional to the number of emissions (Soares-Filho et al. 2006).

More than a decade ago, in the year 2006, it was explained how the Amazon trees host 1.5 decades of current worldwide anthropogenic carbon emissions to the atmosphere (Soares-Filho et al. 2006). The authors of this paper calculated deforestation in the Amazon region of Brazil by dividing the region into 47 sub-regions with different deforestation forecast based on historical information taken from satellite-based deforestation maps. This study incorporated the development of the country in terms of planned road paving schedule and the existing and proposed protected forest areas. They highlighted how the proximity to highways was a significant driver of deforestation in the region. The value of this study is that they give fundamental importance to our co-habitants in the planet and the water. It did not only focus on emissions and deforestation, but it also explained how some watersheds, ecoregions and mammalian species are far more vulnerable to disruption than others.

One of the most vulnerable and relevant actors is the Mangrove forest. Mangrove is a type of forest that has up to four times more organic carbon per unit area than other terrestrial forest ecosystems (Hamilton & Friess, 2016). In its case, a high carbon density combined with high rates of Deforestation contributes significantly to global warming. The authors used information from the Continuous Mangrove Forest Cover for the 21st Century (CGMFC-21) database. The information they got shows the area of the mangrove forest and its evolution over time. Then, they clean the information by filtering it into above ground biomass, underground biomass and soil carbon estimation. They calculate the above-the-ground biomass by using different variables like latitude, geographic region, mean temperature of the warmest quarter, the average temperature of the coldest quarter, and precipitation of the driest quarter. For the underground biomass, they did use an allometrically ratio of underground biomass to above-the-ground biomass. To estimate the soil carbon stock of the area, they used a predictive model of spatially explicit global mangrove soil carbon stocks. Once they know how big the area is and how much carbon it has according to the different type of biomass, they use another conversion ratio to estimate what will be the total emissions of the Deforestation of a complete mangrove tree.

Furthermore, other studies did not focus on the level of emissions of the forest but in its direct impact in global warming. For example, a study analyzed the impact of deforestation and forestation in local climate (Prevedello, J. A. et al.,2019). This work estimated the effects of the changes in a forest in by analyzing Land Surface Temperature, Albedo and Evapotranspiration. Among their findings, is that changes in EV and Albedo are correlated with changes in LST. In the context of the tropical forest, the authors found evidence that Deforestation increases the Albedo and reduces the EV leading to a local climate rise. Among their positive discoveries, they found that in a tropical forest with deforestation rates of around 50% produced a rising temperature of $1.08 \pm 0.25°C$ but that forestation rates of the same percentage can lead to a cooling of $-1.11 \pm 0.26°C$ in the LST. Therefore, here we found some evidence that efforts on increasing forestation may lead to a cooling of the planet if they are done in the right amounts and at the needed time.

Previous research has also highlighted the fact that most forests are not uniform anymore. They are a mix of natural forest, degraded forest and fallows (Goussanou et al., 2018). This makes estimations of potential emissions and historical emissions more complex to measure. The authors also discussed the fact that forest distribution maps do not show the distribution of carbon stocks. However, they also said that these maps could serve as an accurate measure of

different policies and decisions by the government to respond to deforestation. Precisely, in their study, they measure, by sampling, the diameter of the trees in the Lama Forest in Benin to estimate the stem biomass which allowed them to find that the higher the diameter of the trees, also filtered by vegetation type, the higher the carbon stock in them. One of their relevant conclusions is that small diameter trees must be taken seriously by governments plans because most of them represent young trees that can contribute to reforestation and other aspects that assure the survival of the forest.

Another effort to improve the REDD+ program was seen in Griscom et al. (2009). One of the characteristics of this program is the movement of resources from developed countries to developing countries which can cut down emissions from a baseline level. The authors addressed the need of having a baseline for calculating carbon emissions in developing countries to assure the success of the program. They analyzed the level of business as usual emissions for developing countries using the information only related to deforestation and not of forest degradation, which is the second "D" in REDD+. The authors paid particular attention to divide the developing countries according to their deforestation rates and their remaining forest areas. They classified the countries in subgroups combining, for example, high rate deforestation with a low amount of remaining forest. In the case of Colombia, they classified it as a country with a significant area of remaining forest and a medium level of deforestation rate. Besides, they expressed concern about the lack of data related to degradation, which also accounts for a significant amount of emissions in those territories. On the other hand, one relevant aspect of their research in the reliability they found in forecasting deforestation with historical data.

Finally, with the Paris Agreement the role of tradeable carbon credits became even more relevant. One of its ways of contributing to the global warming reduction is by creating forestry projects that can sequestrate carbon emissions in the long term. Guttierez-Velez and Pontius (2012) stressed out how developing countries with low rates of deforestation can benefit from these carbon markets since, in the past, they did have high deforestation but reduced it in the past years. Therefore, they can have an economic benefit by the fact that they are not creating more forest but stopping its historical tendency to do so; hence they can trade those savings of the release of the emissions plus the sequestration of them in the carbon market.

2.2 Transport sector

In the literature, the transport emissions have been studied with three key elements: trends and drivers of emissions, scenario analysis of future emissions and strategies to limit or reduce transportation-related carbon emissions (Tian et al., 2018). The authors mentioned how policy support and behavioral change are needed to reduce emissions and highlighted that the main drivers are km travelled, GDP per capita and population growth. Also, the attention goes to the role of cities, of all sizes, in reducing global emissions (Butterfield and Low, 2017). The authors mentioned that the availability of different innovations, a budget, geographical expertise and cultural understanding make cities the ideal playground to set the most significant reductions in greenhouse emissions.

About road transport emissions, Barisa and Rosa (2018) used a Dynamic Transport Emission Model to understand the future behavior of the emissions in Latvia. The authors were motivated by the obligation for European countries to reach 10% of renewable energy use in the transport sector by 2020, which they argued only a few countries would achieve it. They used a causal loop diagram to simulate the behavior of the consumption of fuels when policy measures take place. They included the travel time, car dependence, the policy approval perception, environmental effect, among other variables to simulate what is going to be the level greenhouse emissions in 2030. This methodology brings a clear picture of how the system interacts when most of its actors and variables are taken into account. However, as it is a simulation, it is extremely sensitive with the parameters used and the no inclusion of variables that will have relevance in the level of emissions. For instance, they used the GDP growth, the vehicle occupation and utilization rate and the no existence of new fuel taxes in the years to come. They simulate scenarios when the government promotes the shift from private cars to public transport, the use of alternative fuels and the mode of passenger and freight transport. This methodology brings a clear picture of how the system interacts when most of its actors and variables are taken into account. However, as it is a simulation it is extremely sensitive with the parameters used and the no inclusion of variables that will have relevance in the level of emissions. This model can get notably complex because it can accept more and more variables that are going to be dependent on other variables as well.

Other authors reviewed the modelling approaches available for accounting for emissions of CO2 from road transport across different scales (Linton et al., 2015). They exposed the advantages and disadvantages of Traffic network models: Microsimulation, Behavioral models, Agent-based modelling, System dynamics modelling, Techno-economic and Integrated assessment models (IAMs). The authors specified that the first four allow insights at a small to medium scale level, which can be used to forecast emissions in regions or cities. The last two could bring a picture of the situation in the country and international level. They also mentioned the benefits of using multiple models to offer innovative ways of calculating emissions in the sense that macroeconomic variables like GDP and population could be integrated into a model with the behavior of people and their specific income in order to offer a more reliable forecast. However, again, the more complex the model gets, the higher the uncertainty and difficulty of the discussion of results.

As Asia is leading in road transport expansion, research in the Chinese region have focused on the reduction of pollution coming from transport in urban areas. Those are relevant because Bogota, and other big cities in Colombia, share some characteristics, or challenges, of the Tokyo and Shanghai area. Particularly, a recent study done by Su et al. (2012) estimated the pollution in Shanghai. The study addressed the need to replace private cars with slow traffic and to promote the right incentives to increase the public transport network. To calculate the carbon dioxide emissions, they use a formula of the IPCC 2006 and carbon dioxide emission factors based on China's combustion heat values. Other authors, focused on doing a decomposition analysis and on the causal relationship of the urban emissions (Xiao Luo et al.,2017). Their motivation was the lack of other analysis on emissions in China and Japan, which were lacking the causal mechanism. In their results, the causal relationship founded was that economic development and population growth causes the need for land use and transportation. Then, this affects the travel time, trip rate, travel distance, mode shift, fuel efficiency and occupancy rate (decomposition factors), which then affect the level of emissions which produce global

warming. Besides, the authors pointed out the responsibility of urban land of being responsible for 80% of the emissions in an area of around 2% of the world surface. In China, the government has paid attention and proposed targets in carbon emissions for the transport sector. However, people keep moving from rural areas to urban areas which have caused a continuous increase in the emissions produced by the motorization of transport.

Even though we are not forecasting air transport emissions, they are no less important and account for 10% of the emissions in Colombia for the next years. Different authors have modelled its future development with multi-group analysis. Singh et al. (2017) used a structural equation model to check what are the key factors that can reduce greenhouse emissions from air transport. The results of their research showed that aircraft technology and design, aviation operations and infrastructure, socio-economic and policy measures, and alternative fuels and fuel properties are the relevant factors to reduce emissions. These practical considerations are relevant when understanding road transport emissions.

In the case of Colombia, La Universidad de Los Andes and the government are the actors forecasting the emissions from road transport. The relevance of uncertainty in their models to predict greenhouse emissions by the transport sector was addressed by Valenzuela et al. (2017). They pointed out the challenge for policymakers and political negotiators of dealing with uncertainty to use viable and cost-efficient real decisions based on simulation models. As the authors expressed, the uncertainty in models come from two main aspects. First, the mathematical formulas used to recreate the phenomenon can also be too rigid to express reality. And second, the inputs researchers use to bring those models to life. In the case of transport emissions, the inputs related to uncertainty are emissions, economic, social and demographic factors. The tools for researchers are sensitive analysis to demonstrate what happens in the output when small changes are done in the output and also, the ability to generate probability density functions based on a large number of iterations, for example, the Monte Carlo method which is used by the authors. One can say then, that multiple models recreate the reality taking into account different variables, but at the end, the total emissions forecasted will always have a particular uncertainty on them. For this reason, not all estimations and even, previous results, can be taken into consideration as a complete and undebatable true.

In general, the literature has had a strong focus in the Asian megacities that keep growing in terms of population and emissions. Authors try to decompose the emissions in order to make predictions about what are the main drivers and how are the causal relationships. Also, uncertainty remains a challenge to build up predictions about the emissions coming from the transport sector. As incredible as it may seem, none of the researches used a historical trend to forecast emissions.

3 Data

3.1 Source Material[2]

3.1.1 Deforestation

Deforestation is a phenomenon that still lacks detailed information. In the case of Colombia, the agency in charge of tracking the maps of deforestation did not conduct a formal inventory of forest until the year 2000. In this year, it compared the data from 1990 to 2000 and established an average rate per year. After this, every five years, from 2000 to 2005 and from 2005 to 2010, the agency recollected information regarding the forest. As the concerns with deforestation grow globally, now the agency is releasing forest inventories from year to year. And also, it checks the maps with real-time data that allows them to check for early prevention on deforestation.

The information of deforestation was taken from Blum et al. (2017). It is a database that contains the evolution of the forest area in square kilometers from 1900 until 2012. This database was completed with information from "Forest and Carbon Monitoring System" of IDEAM. It provided the deforestation rates from 2012 until 2017. On the other hand, the emission factor of the forest deforested area for Colombia was taken from Song et al. (2015) and Yepes et al. (2011). As mentioned before, different authors estimate different amounts of carbon to be released according to the location of the soil in the forest maps. After reviewing different publications, these data showed to be in the range of estimations of different authors. It contains information provided by the Colombian government agencies and international authors.

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[2] All data used and referenced in this research can be found in https://drive.google.com/open?id=1Apb8HbWEiewM204efa1jQIIlDy57DYxX

3.1.2 Transport sector

The “Mining-Energy Planning Unit” UPME provides in Colombia the Energy Balance per year. This database contains the energy consumption and production of the economy from 1995 until 2017. From 1975 until 2005 the information for energy consumption related road transport is classified in Diesel Consumption and Motor Gasoline Consumption. From 2005 ahead, the information about road transport is further classified into Private Transport Inter Urban, Private Transport Urban, Public Transport Inter Urban, Public Transport Urban, Cargo Inter Urban and Cargo Urban. Besides, the database provides the specific conversion rates of the Diesel and Motor Gasoline fuels to emissions.

3.1.3 Total Emissions from Fossil Fuels

The total amount of emissions was taken from Boden et al. (2017). Because it shows information from 1921, it allows us to see the full evolution of emissions from fossil fuels through the XX century and the beginning of the XXI century.

4 Methods

Methodology to estimate emissions from deforestation and road transport is composed of a current situation analysis of both variables and then their forecast. The methodology uses different historical trends to predict what is the expected growth of the variable. Because both datasets are different, different process are implemented. In the case of deforestation, that lack year to year data, an estimated growth rate is used to calculate the future emission level. In the case of road transport, with year to year data, a semi-log function is used to calculate the expected growth rate and the expected time to double the emissions.

4.1 Current Situation Analysis

4.1.1 Deforestation

The dataset of deforestation contains information from 1900 until 2016. This data is built through the process of comparing the forest level between two years. From 1900 until 1960 there were two measurements between these two dates. Then, the average rate of deforestation per year is obtained. The same happened between 1960 and 1985. For the data between 1990 to 2000, 2000 to 2005 and, 2005 to 2010 the data suffered the same process. Only for the years from, 2010 to 2016 the deforestation rate is obtained yearly. Therefore, time series cannot be applied to forecast what is going to be the level of deforestation in the upcoming years.

In order to know the level of emissions for the year 2050, the forecast for deforestation is made by taking the average rate of deforestation of the last 50 years and the last 100 years. The average rate of deforestation between 1966 and 2016 is 0,3859% per year, and the one between 1916 and 2016 is 0,2960% per year. The emissions coming from deforestation are based on the factor by Song et al. (2015). This was 141 Mg C/Ha for the tropical forest in Colombia. A proxy used to calculate the total emissions from deforestation was based on Yepes et al. (2011). From this publication, it is assumed that the tropical forest in Colombia is ~75% of the forest and the other ~25% correspond to a forest with an amount of carbon of 6% of the tropical forest which corresponds to 8,46 Mg C / Ha. This is based on the fact that most deforestation has been taken place in the frontier of the Amazon forest (Yepes et al. 2011). On the other hand, it is assumed that the emissions produced by the land to be released immediately after the deforestation takes place. degradation of forest and reforestation are not taken into account in the forecast because until now its effect is around 4% reduction in the level of emissions (Yepes et al., 2011).

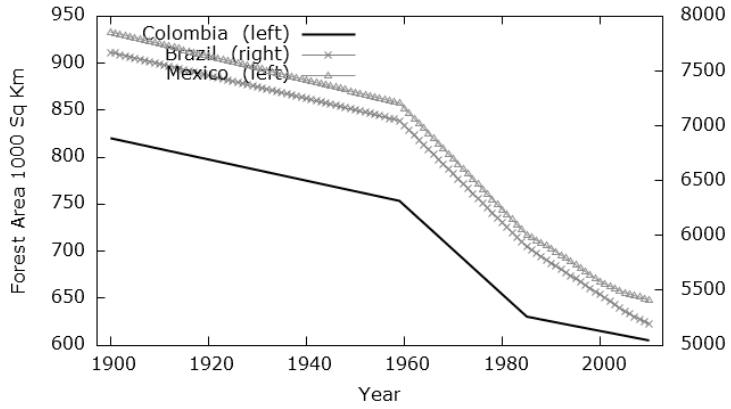

Figure 7. Evolution of forest area per country (Blum et al., 2017).

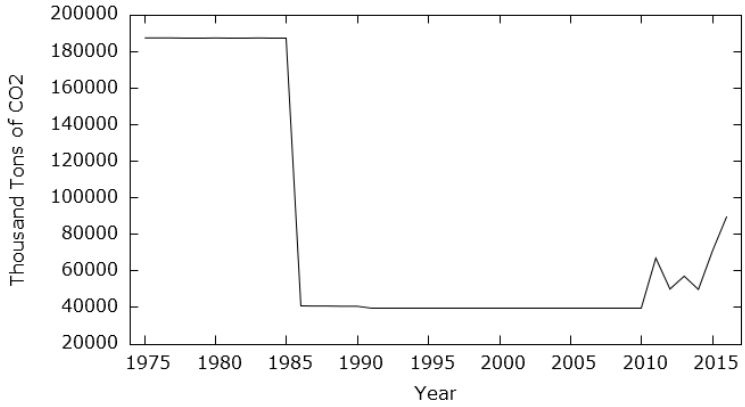

Figure 8. Estimation of CO2 emissions from deforestation in Colombia

When comparing the forest area of Colombia, Brazil and Mexico the deforestation rates estimations follow an average rate for 60 years, then after 1960, there is a dramatic deforestation rate for all three countries. This may be due to the success and extension of the livestock production in the countries which might have lacked technology and capital to make it more efficient. Therefore, the only way to extend livestock production was by destroying more forest to have more space for the livestock. After 1980 and before 1990, the deforestation rates are higher in Mexico and Brazil than in Colombia. Them, from 2000, Mexico and Colombia seem to have a lower rate of deforestation than Brazil. Consequently, deforestation is a regional occurrence that has evolved very similarly among Latin American countries. (Blum, Ducoing, & McLaughlin, 2017)

As expected, the emissions until 1985 were extremely high due to the high rate of deforestation. Then seems to be a period until 2010 where deforestation decreased. Then, in recent years, it has increased again. Accordingly, it seems that when deforestation changes its trend, it remains like this for a significant time. Also, to have had an estimate of 180 million tons of CO2 per year before 1985, coming from deforestation, puts Colombia as a country with a clear responsibility on dealing with it.

4.1.2 Transport Calculation

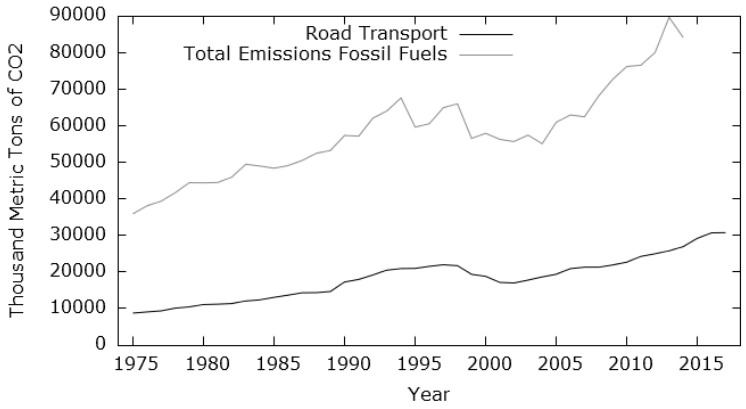

Figure 9.Road transport emissions vs Total fossil fuel emissions in Colombia.

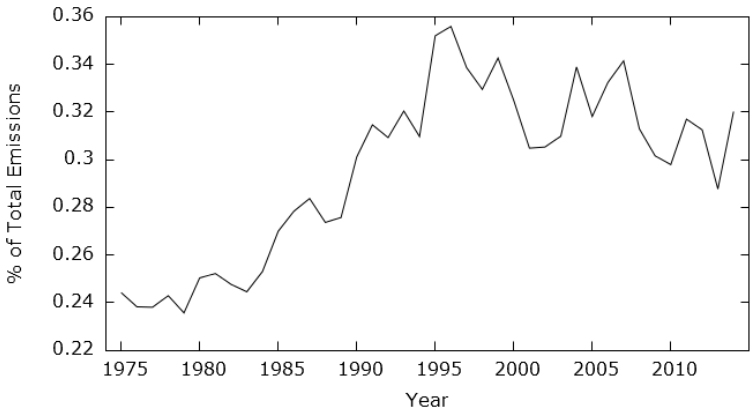

Figure 10.Road transport emissions portion of total fossil fuel emissions in Colombia.

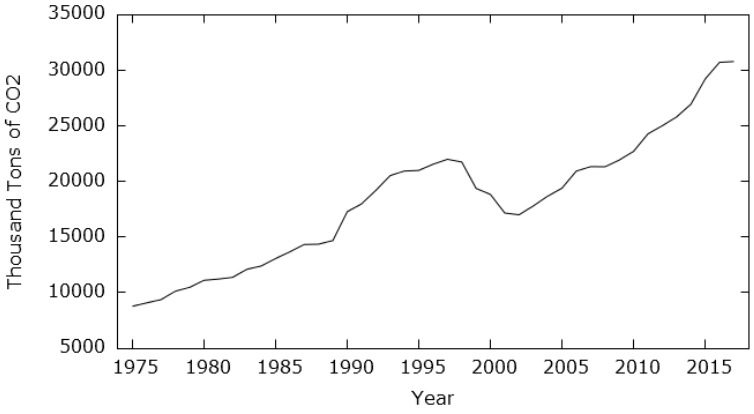

Figure 11.Total emissions from road transport – Diesel and Motor Gasoline in Colombia.

As we can see in the Figure 9., the level of emissions from the road transport sector, as a portion of the total fossil fuel emissions of the country, were increasing until 1995 from where it seems to show a decreasing trend with an average portion of around 33%. After 2005, the overall emissions increased more than the transport sector which, as seen in the Figure 10., suffered a boost. The road transport sector energy consumption and emissions increased considerably from 2000 until 2015. In the last years, the country has shown a deacceleration of the economy,

but as mentioned before, the stabilization of emissions must be considered as a negative aspect of the road transport sector.

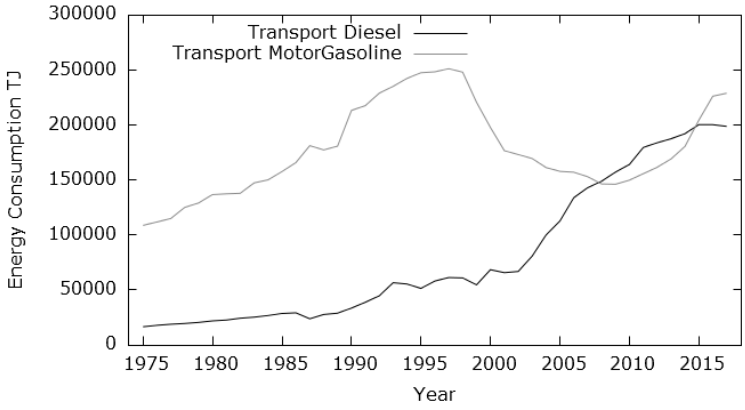

Figure 12.Transport energy consumption of Diesel and Motor Gasoline in Colombia.

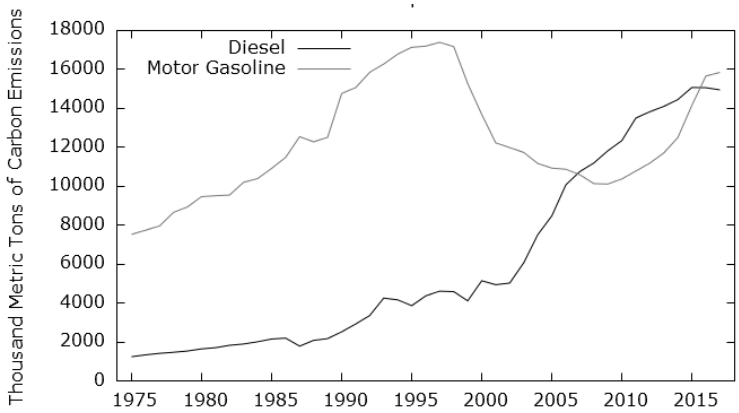

Figure 13.Total emissions from road transport in Colombia.

According to the energy planning agency of the country (UPME), in Colombia, the Diesel and the Motor Gasoline fuels are the two main drivers of energy consumption and emissions in the country. As seen in the Figure 12., Diesel fuel consumption had continuously increased through the years while Gasoline had a peak in 1995 when it started to lose participation in the fuel market against Diesel. Then, Diesel has shown dominance in fuel consumption. Even though different motors from different times have different efficiency levels, the UPME specifies a conversion to emissions rate from Diesel of 0,075 KTon of CO2/TJ and 0,069 KTon of CO2/TJ in Colombia. Then, as Diesel establish dominance in the road transport sector emissions will only tend to increase. As seen in the Figure 13., recently, the emissions from both fuels are almost similar because the Gasoline has a slightly higher consumption but also a slightly lower ratio of emissions.

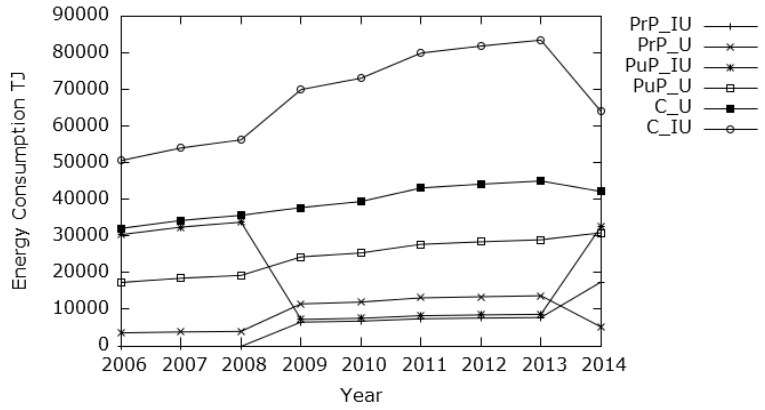

Figure 14.Road transport Diesel consumption by sector in Colombia.

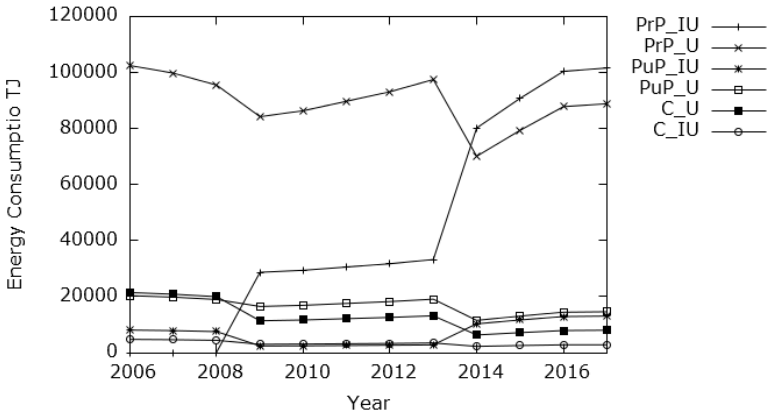

Figure 15.Road transport Diesel consumption by sector in Colombia.

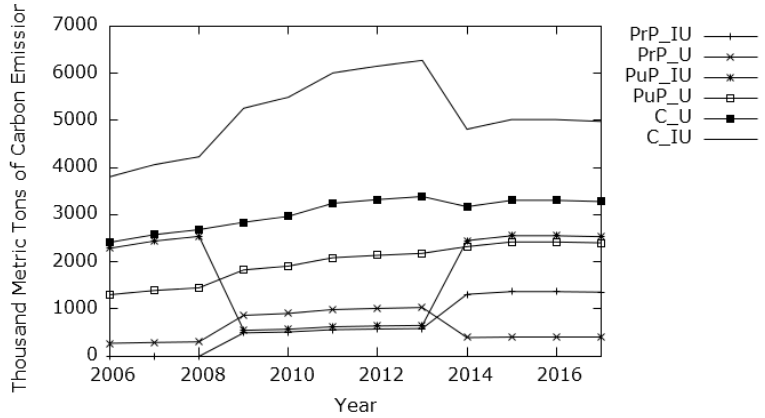

Figure 16.Road transport Diesel CO2 emissions by sector in Colombia.

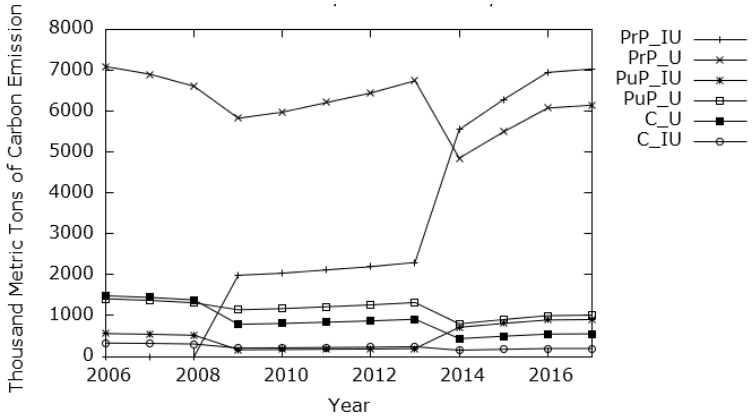

Figure 17.Road transport Motor Gasoline CO2 emissions by sector in Colombia.

The information of subsectors of the road transport that drive Diesel and Gasoline consumption is only available from 2006. However, the trends are clear. The leading consumer of Diesel is the cargo sector. Trucks that transport goods between cities drive the consumption of Diesel followed by the trucks that transport goods inside cities. After those two, the public transport of cities is driving the demand for Diesel fuel. In cities like Bogota, most of the busses of its Integrated Transport System are powered by diesel motors. It is commonly conceived in the country that Diesel motors, usually called in the sector as "Motores de ACPM", have a lower price and last longer than Gasoline. However, as it is a less refined product than Gasoline its consequences on the emissions are, as shown before, more negative for the environment. On the other hand, private transport is the primary driver of Motor Gasoline consumption. Colombian population drive gasoline cars and motorcycles powered by Gasoline. Almost no cargo transport and a lower amount of public transport use Gasoline as its energy provider. Besides, it is relevant to highlight that with the peace agreement, new territories are being discovered by the people in the country. This accounts for a considerable increase in private transport between cities and the trend is only expected to increase. Therefore, specifically, the main drivers are both private: Diesel Cargo Transport and Gasoline Private Transport between cities. In terms of emissions, as shown in Figure 17., the level of emissions coming from gasoline private transport, urban and interurban, are significantly higher than the diesel cargo transport. Consequently, private interurban is the highest pollutant actor in the transport sector in the country, followed by urban private transport and cargo interurban transport.

4.2 Emissions Forecast

4.2.1 Deforestation

The dataset for deforestation could not be used to make a forecast with time series analysis. As the dataset is composed of continuous repetitive rates during a long time, it becomes a problem when making the series stationary. Therefore, to forecast the emissions for the year 2050, the average deforestation rate was calculated for the last 50 years and the last 100 years. We are aware that this provides a decreasing trend over time for the deforestation because the forest area to calculate the deforested area will be every time smaller. Then, these two scenarios were projected together with the same emission factor per deforested area. The assumption for the emissions was that the patron of deforestation would continue which is divided in 75%in the border of the Amazon forest with high carbon in the biomass and 25% in other types of forest with less carbon stock on its biomass.

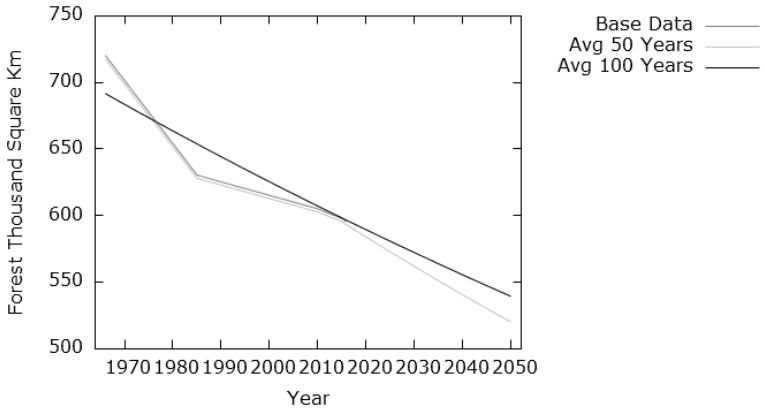

Figure 18. Forest area projections.

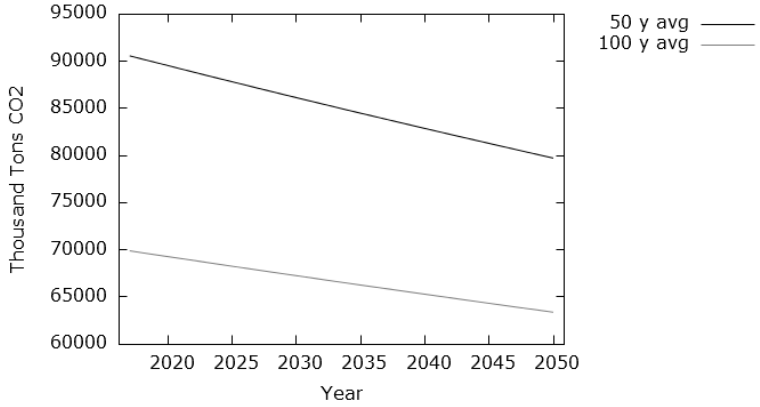

Figure 19.Emissions forecast to 2050 from Deforestation.

The two scenarios projected show that emissions from deforestation are far from stabilizing. They are expected to be reduced eventually but a long time after 2050. We take 69 Mt of CO2

as the emission level in 2010 from deforestation from Yepes et al. (2011) and, ~ 95Mt [3]of CO2 to compare it with both projected scenarios of 2030. For 2030, the projected scenario of emissions is 85,80 Mt of CO2 using the average of the last 50 years and 67,04 Mt of CO2 using the average of the last 100 years. That means Colombia could reduce ~10% and ~30% of its emissions accordingly to historical trends.

Even though the final expected reduction seems positive for the commitment of the government, it is important to highlight that the calculations are biased by the fact that the destruction of the forest is considered as a rate of a total area and not as total area itself which is the real scenario. I.e. the reduction percentage is calculated over the total forest area, which creates a negative loop for the estimations. However, it was calculated this way because it could consider socio-economic evolutionary [4]effects in the calculations.

4.2.2 Road Transport

The semi-log function is used to forecast the emissions coming from road transport. This provide the expected yearly growth rate of the emissions and energy consumption for the next years. By using the Semi Log function, the time when the emissions are going to double can be calculated by dividing ~69 into the growth rate. The level of emissions and the energy consumption growth is assumed to be equal. This might not be the reality because as more efficient motors are developed, the emissions will tend to decrease. However, the adoption of more efficient vehicles is expected to take many years, therefore, the forecast can be used as a proxy for those estimations. The results are presented in Table 1.

[3] The number was calculated by assuming that the share of the emissions from deforestation will remain the same for 2030. The value comes from taking 330Mt, from the iINDC, as the total emissions projected for 2030 by the government and 29% as the share of deforestation emissions by the time.

[4] The Paris Agreement, Drastic Policy Measures and Population Awareness are examples of socio-economic evolutionary effects.

Table 1. Expected energy consumption/Emissions growth by type of fuel

Historical Trend	Growth Rate		Years to double	
	Diesel	**Motor Gasoline**	**Diesel**	**Motor Gasoline**
1975-2017	6,76%	0,77%	10,21	89,61
2000-2017	7,45%	0,99%	9,26	69,70
2007-2017	3,63%	4,86%	19,01	14,20

5 Discussion

5.1 Deforestation

In terms of emissions, in both scenarios, all the values after 2016 and until 2030 are above 60 M ton CO2/ Year. The emissions are not considering the emissions from the forest fires and the use the land is receiving after it is deforested. As Pacheco (2019) showed, deforestation is made to produce more livestock. The enteric fermentation of the livestock could increase the emissions only coming from agriculture and deforestation to levels extremely critical. It could make it double, for instance, for the Paris Agreement. Therefore, the emissions seem to be always sub estimated because of the broad range of different outcomes from this phenomenon.

Deforestation will remain a big challenge for Colombia for the present century. As the country keeps expanding its economy and population keeps growing, the need for new land will appear. About the desire of the government of cutting down at least 20% of the projected emissions from deforestation, it is incredibly ambitious and not idealistic as shown with the historical trends. The REDD+ program, with its carbon trading bonds, are not going to be enough to stop deforestation. The income these carbon trade may produce will not reach the areas where it is needed because the government needs to have a more significant action capacity. As Pacheco (2019) showed, the deforestation phenomenon has increased due to the lack of presence of the government in lands that were previously dominated by illegal armies. The number one driver of the phenomenon is the desire to bet that land will be valuable in the future as civilization keeps expanding in south direction (Pachecho, 2019). Besides, people who live in the areas of the highest deforestation rate do not have the education to use the land in different ways than livestock production with low capital and technological features. The numbers are clear. Colombia is not going in the right direction because deforestation keeps increasing. The information regarding the description of the problem and the emissions forecast from it already show the urgency to implement drastic measures.

On the other hand, about the results obtained for the emissions, it shows similar values given by the government organization like in Yepes et al. (2011). The use of maps to calculate forest loss remains as the primary source of uncertainty to the calculations of the level of emissions. Different sources have shown different estimations for carbon levels in the different biomass types of the country. This study used aggregated data for the type of forest, and the results are among the range given by other studies. The forecast for the level of emissions will always have many assumptions including the release time of the carbon, the location of the forest, the level of carbon in the forest and the way of doing the deforestation. Therefore, the results work as a reference level of what can be expected to happen until 2030.

Also, it remains relevant to highlight that people in the country have not been told about the deforestation responsibility in global warming. Research about how to stop it is crucial to have

a chance to follow the iNDC to the Paris Agreement. The real action is needed now in terms of funding for forest education and increase the presence of the government in tropical forest areas. As Pachecho (2019) showed, the population depending on these forests to live is lacking support to take better economic decisions. Alternative income and use of the forest are mandatory education to stop the deforestation. The production of new products which can use technology and capital more efficiently will make the national market aware of the situation. The goal of the government is to intervene with its institutions to make sure the production alternatives offered to the people have buyers in the market (Pachecho, 2019).

5.2 Road Transport

In the road transport sector, Diesel and Motor Gasoline show different patterns depending on the period analysed (Table 1). The historical trend from 1975-2017 shows 6,76% annual growth of Diesel and 0,77% for Motor Gasoline. However, the recent trend 2007-2017 shows 3,63% annual growth for Diesel and 4,86% for Motor Gasoline. Both fuels show a growth trend which will involve more emissions. The goal of the government to reduce emissions by 20% by 2030 does not seem realistic. Diesel and Motor Gasoline have the chance to double their demand in ten years from now if their highest growth historical trends are considered. Diesel and Motor Gasoline are not sustainable in the present nor the future.

Notwithstanding, as said, the fuels have different patterns. It seems that when one grows, the other does not follow, or lose demand. Therefore, it is possible to introduce new types of fuels that can be efficient, but if it is successful as Diesel was, it will take 30 years to have half of the market share. There is a chance to implement a sustainable road transport system that dominates the market, but it has to start now, and the introduction of drastic policies must accelerate it. The government must invest resources in researching what the future of mobility has to look like to fulfil the Paris Agreement commitment. Besides, the transportation policies should not only be analyzed in terms of profit and payback time, but it should also be considered the overall benefits that different measures may bring in terms of environmental impact, public health, local economic growth and rising living standards (Barisa &Rosa, 2018).

One example of transition measures towards new Road Transport systems free of carbon is California's Low Carbon Fuel Standard policy. It is a law dealing with the fuels used, and by 2019 its new target is to reach the level of 40% below of the emissions level in 1990 by 2030 (Parson et al., 2018). As already mentioned, other authors previously mentioned problems with this law with the models used to calculate what are the emissions produced by the fuels and how these emissions are projected in the future (Plevin et al.,2017). The approach of the policy is to keep reducing the carbon intensity of the fuels along the all production chain from the extraction sites until the final consumption by vehicles. It keeps reducing the value of the carbon intensity every year until it can reach its overall goal, which is measured in grams CO2 emissions per megajoule. Once the revision is conducted, fuel sellers who have to achieve the reduction target can negotiate permits, or carbon credits, with other players creating a market for those (Parson et al., 2018).

The same authors also discussed the methods to evaluate the effectiveness of the policy, which has been replicated in the European Union and Canada. They argue that its direct effect on the reduction of emissions is too complex to measure. They said the LCFS operates under conditions of mixed partial knowledge and uncertainty and, maybe with a biased target towards the direct desire to increase cellulosic ethanol and electric drive. As a conclusion, they exposed that carbon intensity will not reach zero because of the efficiency constraint of fuels which would force the government to move towards 100% electric vehicles or any other type of driving which are not related to the traditional energy carriers. Also, about the reliability of the outcomes of the policy, other authors argued that it is better to regulate or to tax observable emissions (Plevin et al.,2017). For these reasons, reducing emissions from the transport sector should be considered in total terms with specific total emissions reduction by sector. The more straightforward and more direct the measure, the better.

In Colombia, cities such as Bogota and Medellin periodically are warned about the pollution mainly derived from transport. It has forced the authorities to restrict private vehicle usage, among other temporary measures. Also, the hope of having a carbon free Road Transport system in the country is not achievable without a transition period. Therefore, these cities must become the places where the transition starts. Then, other cities in the country will follow their strategies and behavioural changes.

6 Conclusion

Colombia faces a significant challenge to decrease at least 20% of its projected emissions by 2030. This study analysed deforestation and road transport emissions and showed that they are the main drivers of them. In the case of deforestation, the analysis was composed of an understanding of the socioeconomic drivers of the phenomenon and the biological perspective of the emissions. For road transport emissions, it was considered the role of Diesel and Motor Gasoline consumption with an economic development approach.

Both variables were studied from a qualitative review of their current situation and their historical trends. Also, their greenhouse emissions were forecasted to check how realistic was the commitment of the government to the Paris Agreement. Overall, the research showed how the iNDC of Colombia remains directly related to the capacity to track deforestation and to take drastic measures for the road transport sector.

6.1 Research Aims

The goal of this research was to provide a starting point for academics and general public interested in global warming in a developing country. Putting deforestation and road transport emissions together in the research offers a concrete view of the main two drivers of greenhouse emissions in the country. If these two are understood they can be controlled to allow Colombia to comply with its commitment expressed in its iNDC for the Paris Agreement.

6.2 Further Research

Future research has the duty of creating practical knowledge that can be used by policymakers and educational institutions to take actions as soon as possible. Deforestation and road transport emissions must be analyzed with a systemic approach. The models estimating emissions must be simple and easy to understand for most of the people with elemental education. There is no need to increase complexity but to increase awareness of climate change. Notwithstanding, with the availability of better data, the models must be improved in terms of uncertainty and flexibility.

In terms of the Paris Agreement, as the data becomes available with the time running the responsibility of the government to take more drastic measures increases. Incredible changes can take place if all actors want the same goal, which in this case, is to reduce 20% emissions by 2030 to comply with the iNDC. However, every policy decision must be evaluated with a

sustainable approach. They must be sustainable from the financial, ecological and social perspective. Research regarding this balance before taking drastic decisions will facilitate their implementation. On the other hand, the Paris Agreement must be seen as a transition requirement but not as the primary goal, which is to achieve full sustainable development.

Literature in deforestation remains small for Colombia, therefore, decoupling food from the land, the role of illegal armies in the protection of land, the access to technology and capital to work the land are recommended topics for future work. Further research should consider the roles of Education Sector, Private Research and Development facilities, the government institutions, the citizens of regions with high rates of Deforestation and the financial sector in one single study.

In the case of road transportation, to analyze successful transition towards increasing efficiency of motors, reducing consumption, promoting other means of transport, using electric vehicles and cultural awareness is strongly recommended to establish ambitious and straightforward goals to reduce the impact of this sector.

7 Glosary

Albedo: The Albedo can be understood as the radiation or the reflexibility of a surface. In the case of trees, they have a low albedo, meaning that they absorb more of the light from the sun and reflect less. It helps to explain why the temperature of certain location can vary in high levels comparing day and night (North Carolina Climate Office).

Deforestation: *The reduction of the capacity of a forest to provide goods and services* (FAO, 2015).

Evapotranspiration: It is a process in the water cycle. In the case of trees, they send water to the sky through evaporation and transpiration of water. In the other part of the process, clouds are formed and send rain to the forest.

Forest: "*Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use*" (FAO, 2015).

United Nations Framework Convention on Climate Change (UNFCCC): According to their website[5]**,** its *ultimate aim is to prevent "dangerous" human interference with the climate system*. It *recognizes that there is a problem, sets a lofty but specific goal, puts the onus on developed countries to lead the way, directs new funds to climate change activities in developing countries, keeps tabs on the problem and what's being done about it* and *kicks off formal consideration of adaptation to climate change.* In other words, they are responsible to keep climate change at a rate that can be handled by the life in the planet without compromising food production and economic development.

Intended Nationally Determined Contributions (iNDCs): In the Paris Agreement each country had the right and the duty to submit what was going to be its goal in contributing to the decrease of greenhouse emissions. Every country has the ability to choose its own way of

[5]All information regarding the framework for climate change is in the link https://unfccc.int/bigpicture

measuring and evaluating its contribution. In the case of developing economies, they usually submit an expected contribution with and without the help of developed economies.

CONPES: It is the "Concejo Nacional de Politica Economica y Social in Colombia". It acts like an advisor for the government in aspects related to the social and economic development of the country. It is the entity in charge of reviewing the President's National Development Plan before it is passed to the Ministry of Finance and later to the congress to be approved.

Pico y Placa: It is a restriction imposed to private vehicles since the year 1998 in Bogota, Colombia. Its aim is to reduce the traffic in the "peak" hours of the day. It works by forbidding the transit of vehicles from Monday to Friday and at certain times according to the last number, be it even or odd, of the plate and the day of the calendar. It is a model that has been replicated in many other cities in Colombia including Medellin and San Jose de Cucuta.

Business as Usual Scenario: In the case of the Intended National Determined Contribution, Colombia forecasted what would be the level of its emissions to the year 2030 if everything remains *business as usual.* In this forecast, the government took 2010 as emission reference level. It took different assumptions on what would be considered as deforestation and its related aspects in the UNFCCC, energy efficiency improvements in most sectors and the data used was taken from national institutions, like IDEAM, that keeps track of climate and emissions.

Mangrove: *assemblages of salt tolerant trees and shrubs that grow in the intertidal regions of the tropical and subtropical coastlines (FAO).* This type of forest is usually found in tropical places and are extremely important because can storage high amounts of carbon. Its protection is vital to decrease greenhouse emissions.

UN-REDD program and REDD+: *REDD+ is a climate change mitigation solution being developed by Parties to the United Nations Framework Convention on Climate Change (UNFCCC), that incentivizes developing countries to keep their forests standing. These developing countries would receive results-based payments for results-based actions to reduce forest carbon emissions. The UN-REDD Programme, and other multilaterals including the Forest Carbon Partnership Facility (FCPF) and Forest Investment Program (FIP), facilitated by the World Bank, support developing countries with financial and technical assistance to build the capacities to design and implement REDD+ strategies* (UN-REDD Program Collaborative Space).

Forest Degradation: *The reduction of the capacity of a forest to provide goods and services* (FAO, 2015).

GDP per capita: GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant 2010 U.S. dollars (World Bank).

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