Climate Change and Human Health:

The Differences Between Rural and Urban Poor

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Abstract:

Discussions about climate change are often dominated by how humans have impacted the environment. As the effects of climate change become more visible in recent years, the effects are no longer exclusive to the environment. People are now on the receiving end of climate change related health problems, and poor people are especially vulnerable to poor health outcomes. This thesis will focus on the differences in diseases as well as outcomes that poor communities in rural and urban areas experience to conclude what group is at a higher risk. It will look at the prevalence of commonly associated climate change diseases as well as the resources available to residents that could help or worse their health outcomes.

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Chapter I:

Introduction

Climate change, the crisis of our lifetime. Ever since the Industrial Revolution, there has been a steady rise of carbon dioxide within the atmosphere. Record high CO2 levels began in the 1950s and they have not decreased since. The term "global warming" first appeared in an article written by Wallace Broecker in 1975, explaining the climatic effects caused by mankind, and the global significance (Broecker, 1975). Since then, climate change has been at the forefront of environmentalists' agenda. Activists, scientists, politicians, and everyday people have all demanded efficient action against climate change, but most of their efforts have fallen flat. More recently, in September of 2019, millions of people across 185 countries marched down the streets urging action against climate change with one of the biggest demonstrations on the planet (Laville & Watts, 2019). However, the world is already seeing serious penalties. Everyone on this planet is experiencing the effects of climate change in one way or another. Extreme weather, natural disasters, and sea levels have all increased in recent history. But, maybe the greatest threat is the impact on human health.

One of the most iconic symbols of the consequences of climate change is a polar bear standing on a melting ice cap. That image, alongside with images of factories spewing out pollutes, natural disasters and those of the world on fire have dominated the public's perspective of the effects of climate change. Images usually focus on the environmental aftermath, but the impact on human health is usually absent from these warnings. The direct impact of climate change on human health is often overlooked. A large percent of the global population is mostly ignorant as to how climate change is having an impact on everyone's health, and therefore it can be left out of the greater discussion. When Hurricane Katrina nearly wiped out all of New

Orleans, killing an estimated 1,200 people, or when diseases like Lyme disease are becoming more prevalent, its relationship to climate change may not be well understood by most people. However, climate change has a direct hand in the death or disabling of millions of people every year. And, for certain vulnerable populations, it is impossible to ignore.

Therefore, my thesis will focus on the differences and similarities between rural and urban populations within Latin America, using Mexico and Brazil as a case study. My research question is: how is global climate change affecting the health of rural vs urban poor in Latin America? I predict that due to the lack of resources like hospitals and other forms of first aid, and the general disconnect to government and non-profit facilities, people from rural communities have a higher prevalence of disease and health problems as a result of climate change.

Background

Extreme weather, rising temperatures, mass extinction are all side effects of climate change. Since the pre-industrial era, with the greatest jump since 1986, the Earth has warmed by 1°C. Over 42 billion tons of greenhouse pollutions are created every year, increasing more and more every following year. The increase in air temperature has resulted in an increase in ocean temperatures as well. Melting ice caps on the two poles have led to rising ocean levels. Since then, millions have either died or seen a decrease in their quality of life. All around the world climate change has changed people's lives for the negative, without relief in sight.

Climate change's impact on health can be related to four main categories: rising temperatures, more extreme weather, rising sea levels, and the increasing levels of CO2.

Rising Temperature

Extreme heat and severe weather can cause heat exhaustion, heatstroke, hyperthermia and dehydration. Minor short terms symptoms can include headache, fatigue, dizziness, confusion, cramps, exhaustion and fainting. However, in the most extreme cases, these conditions could lead to death. Extreme heat can also worsen pre-existing conditions like cardiovascular disease, respiratory issues, and diabetes-related conditions. These pre-existing illnesses can make people less tolerant to heat. Also, some high blood pressure and anti-inflammatory medication can increase an individual's risk (*Pre-Existing Conditions Can Worsen Heat Exposure Effects*, 2017). Rising temperatures allow for a more suitable environment for infectious diseases, such as Zika virus and Lyme, allowing them to breed long and live in the area their previous could not (Lafferty & Mordecai, 2016). While most human infectious diseases have declined since 1999, extreme heat could change that.

More Extreme Weather

While extreme heat and extreme weather may be similar, the following refers more towards the increase of quantity and severity of natural disasters. Natural disasters like hurricanes, floods, droughts, wildfires, and more can either be a result of climate change, or its severity can be linked towards it. Apart from also destroying the natural wildlife and biodiversity, these disasters can either kill or disable people directly, or make their homes unsuitable for human life.

Rising Sea Levels

The rise of sea levels increases the risk of flooding in storms, and like extreme weather, increases the risk of drowning, injury, and death. Additionally, rising sea levels into fresh water can increase the salinity in portable water, which could result in less drinkable water as well as a

decrease in crop yields (Vineis et al., 2011). As many people in low-income countries already have limited access to drinking water, this only heightens their struggles. Cities alongside major coasts are particularly vulnerable to displacement and job loss as a result.

Increasing CO2 Levels

A certain level of CO2 levels is needed in order to enrich growth for nearly all plants. However, high levels of CO2 can be just as dangerous as low levels, as they can result in health problems such as inflammation, reduction of cognitive ability, and kidney and bone problems (Jacobson et al., 2019). Increases indoor levels as a result of poor ventilation as well as increased outdoor levels due to air pollution can increase risk factors.

Case Studies

Despite climate change being one of the greatest threats to human health, it is a new area of study. The topic has only come into the public's consciousness in recent years, if at all. Personally, I was unfamiliar with the topic until my junior year of university when I took two classes focused on public health. The relationship is clear, but I believe most people do not connect the two together. Latin America, as well, is an understudied region in relation to climate change. Most literature on the topic does not tend to focus on a specific region, rather opting to focus on the overall global impacts. When they do focus on a specific region, it is usually not Latin America. For example, a quick search of "climate change heat wave" in Google Scholar will result in a long list of relevant articles, ranging from Chicago to the UK to Germany and northern China. While this might lead to implying that Latin America is not experiencing the worse effects, it might actually be an indicator of how understudied the region is.

Another under studied topic the difference between urban and rural areas, and how specifically poor people are experiencing it. When conducting studies and research about other diseases, sample sizes from different population groups are compared to not only see the differences between populations, but to see why some populations are more affected than others. For some diseases, we can attribute differences in health outcomes to age, sex, ethnic and socioeconomic class, but I would argue one of the main factors to climate change related health problems has to do with where people live, especially rural versus urban settings.

Chapter II:

Literature Review

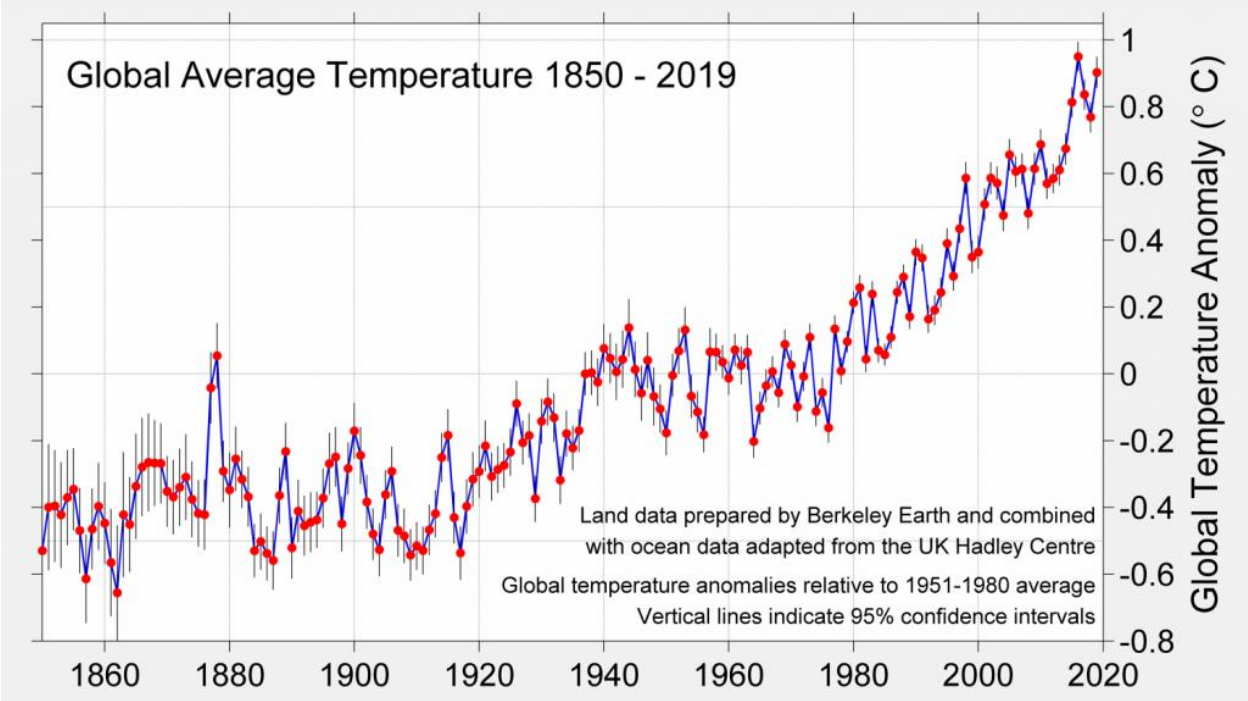
The conversation about the effects that climate change has on human health is not a new topic; researchers and academics have already made the connections between climate change and an extensive list of different diseases and health conditions. From the increase of cardiovascular to mental illness to the consequences of natural disasters, climate change could be considered a primary contributor to the diseases with the highest morbidity rates in one way or another. There is been an increase of all factors which could be considered a pathway to the illnesses, as an increase of frequency and intensity of heat waves, droughts, floods, which do not only lead to a high mortality rate as a direct consequence, but can also result in long lasting effects by impacting a person's home, community and food supply.

The Lancet, arguably the leading journal of global health, has been the primary source of monitorization of the effects climate change has had on health across the world. The Lancet does an annual update of 41 indicators of five key domains: climate change impacts, exposures and vulnerability, adaptation, economic and public and political engagement (Watts et al., 2019). With the data they have collected, this year as well as compared to previous years, children born in 2020 will see a world four degrees Celsius warmer than the pre-industrial average. That, alongside the downward trend of global crop yielding since the 1960s threatens food security and production, will contribute to malnutrition in infants, which has the potential for permanent health effects.

The rapid decrease of the quality of the environment has been primarily driven by the combustion of fossil fuels, consumed at a rate of 171,000kg of coal, 116,000,000L of gas and

186,000L of oil per second. The energy system's reliance on carbon intensity has been consistent since 1990. As of today, the world is experiencing a one degree Celsius increase from the pre-industrial baseline, which is impacting millions of people.

Figure 1



Note. Graph on the increase of global average temperature from 1850 to 2019 from Earth, B. (2020, January 15). Global Temperature Report for 2019. Berkeley Earth. http://berkeleyearth.org/2019-temperatures/

The increase of temperature will also cause the spread of diseases, air pollution, and extreme weather conditions. For example, the changes in vector ecology have made children more susceptible to contracting and having server effects of diarrhea and dengue fever. This is because the weather is allowing for more insects, carriers of these diseases, to reproduce at a higher rate as well as in an environment where they typically would not be able to. Problems associated with

air pollution, on the other hand, have been prominent health risks for adolescence and beyond, partially for those living in major cities. Air pollution driven by fossil fuels can damage the heart, lungs and other vital organs, which can lead to diseases related to cardiovascular and pulmonary issues. Extreme weather conditions have increased the risks for frequent and serve natural disasters such as hurricanes and wildfires. Over 77% of countries have reported an increase in exposure to wildfires from 2001 to 2018. Almost all economic losses related to extreme weather conditions are uninsured, therefore placing a high burden on low-income households. They also tend to be have a higher report of mental illnesses following natural disasters and the subsequent impacts, increasing the diagnosis of PTSD, depression and anxiety.

In the book *Enviromedics* by Lemery and Auerbach, the authors also explore how specific issues caused or are intensified by climate change are linked to various diseases and health conditions. While the book's narrative is broad, not focusing on a specific region or disease, but rather giving an overview of the greater topic, it demonstrates exactly the many ways climate change impacts health (Lemery & Auerbach, 2017). In general, climate change has four main ways it can impact health: rising temperatures, more extreme weather, rising sea levels and the increase of CO2 levels. All of the previous authors have explained the correlation between the risk factors and an increase in mortality and morbidity in vulnerable regions.

Poverty, Climate Change, and Health

While climate change does affect all people across the world, regardless of age, gender, race or any other external factors, how it impacts different socioeconomic groups is drastic. People of lower socioeconomic status are at a higher risk factor than those who are not. Poverty, in relation

to health, could be considered a vulnerability. This is because poverty increases any other risk factor which would make a person more susceptible or at a high risk of contracting or worsening any health effect. Poverty is the greatest contributor to poor health outcomes. According to Tom Boyce: “Socioeconomic status is the most powerful predictor of disease, disorder, injury and mortality we have,” (Conway, 2016).

Poverty, for many, will be compounded with other unrelated factors, such as gender and race, to multiply an individual’s vulnerability. A poor household is less likely to have access to healthcare, to education, to food security. Without access to healthcare, a treatable disease could be deadly. Without education, a person could be unknowable as to how to prevent or treat certain diseases. Without food security, a person can not have a healthy diet. Poor people are more likely to live high risks area suspectable to natural disasters. Ultimately, poor households are trapped, they are unable to escape or improve their current living situation. If a poor person loses their job as a farmer due to lack of water, or if a family loses their home in a wildfire, this could realistically be a death sentence. People living in poverty do not have the luxury of moving for another job or safe environment, without money it can be nearly impossible for people to change their health outcomes.

Poverty and health are not a one-way relationship, as the authors of Climate Change Adaptation and Poverty Reduction explain: poor people are not only more vulnerable to climate change but also climate change is leading more people into poverty which is putting them at higher risk for illness (Eriksen et al., 2007). For example, if a local farm is unable to yield the same number of crops as the previous years, they may need to lay someone off. In this case, the person who lost their job would be unable to buy food for their family. In turn, this could lead to

malnutrition. This is just one example of how climate change, poverty, and poor health are a circle. One can impact the other, regardless of direction.

A poor person is not more suspectable to a disease than a rich person for simply being poor, but because they are more likely to have certain behavior risk factors. For example, poor people are more likely to rely on inexpensive food, or to live in an area with unclean water or high levels of population. Apart from that, poverty directly relates to the level of care a person receives. A poor family living in the Brazilian countryside will not get the same level of care as a millionaire living in Sao Pablo. Poverty, along with other social factors like race and gender, make people more vulnerable to the effects of climate change. Poverty, nevertheless, is the main contributor to poor outcomes related to climate change. The impacts of climate change can not just look through a biological lens, it must also be observed through a biosocial point of view.

Poverty can also be considered a contributed to poor health outcomes in these situations, since poor people are unable to access resources in the aftermath. Latin America is at the forefront of these changes. In recent history, every country in Latin America has been victimized by at least one major natural disaster. While the severity varies in nature, one cannot deny its existence. Latin America is an excellent case study since it not only looks at the correlation between climate change and health, but also how money contributes to the equation. By looking at Mexico and Brazil, they can act as an example for the region as a whole. They are home to the two largest metropolises by population, and a variation in geography, and an incredibly steep wage gap between the 1 percent and the remaining population. By comparing differences between the rural and urban health in Mexico and Brazil, similar issues and outcomes are likely to be the same across Latin America. Since these are the more extreme risk factors, this thesis

will primarily focus on extreme heat, natural disasters, infectious diseases and air pollution. These serve as an overview of the effects climate change is having on poor people.

Mexico

In order to understand how climate change is impacting Mexico, a baseline is necessary. In the article, Historical Data and Climatic Change in Mexico: A Review by Metcalfe, the author highlights the importance of understanding the climate of Mexico before understanding the major effects of climate change to fully understand its impact. In order to understand how climate change is affecting Mexico today, there needs to be a baseline for a comparison. Scientists have concluded that the main effects of climate change have been observable since the 1970s. Through meteorological observations, and through collaborations with an archaeologist, researchers have been able to create a baseline for climate change today. While records show extreme natural disasters, like the flooding in 1607, or droughts in 1624, they do not compare to the natural disasters of modern days. In the last 50 years, Mexico has experienced extreme weather conditions which clearly demonstrate the impact of climate change. By comparing the prevalence of diseases from previous years to now, the connection between the increase of disease to climate change is clearer. How climate change has specifically impacted the country depends on specific regions Mexico has a wild range of geographical variations, from the deserts in the north to the tropical south. The US Agency for International Development has created a fact sheet about climate change in Mexico, including which risks are affecting the country. Since the country is bordered by two oceans, it is particularly vulnerable to extreme hydrometeorological events such as tropical cyclones and floods.

While 80 percent of its citizens live in cities, the rest who reside in the rural areas have experienced extreme temperatures and erratic rainfall which causes inconsistency in agriculture productivity (Climate Risk Profile Mexico, 2017). Although climate change is impacting the whole country, the ways they impact cities is different from how it impacts rural areas. While the causes and diseases do not vary, the prevalence and severity does. Perhaps, the actual difference between how climate change impacts the two areas is more related to adaptation strategies and mitigation effects in the two regions.

In Mexico, the majority of the population lives in urban cities. Mexico has several large cities with large urban centers to compare. Even though they vary due to geography and location, they do have several overlapping issues. Extreme weather events have caused damage or destruction to infrastructures like housing, hospitals, and communication networks. Cities along the coast are experiencing rising sea levels, ocean acidification, and changes in ocean circulation and patterns resulting from extreme weather, such as hurricanes. However, the main contributors to diseases in Mexico City are related to air pollution and water scarcity. The authors connect the increase in population and urbanization in Mexico City to the increase of industrialization which has led to the decrease in air quality. In the 1980s, the automatic air-quality monitoring network was established to detect harmful chemicals within the air, which shows that particle levels exceed the recommended stated by the World Health Organization. Since the mid-90s, the Mexican federal government, the state, as well as the Federal district have implemented regulatory actions, technology changes, and increased monitorization to improve the air quality. In recent years, Mexico City has been working at improving the air quality, and through management programs has made successful strides, but the continued increase of urbanization may be problematic.

Rural areas in the country are not doing a lot better, many of them are suffering from the same impacts, just in a different form. According to “The Impacts of Climate Variability on Welfare in Rural Mexico”, individuals in rural Mexico are more prone to climate change related health issues due to changes in agricultural production and therefore nutrition. Extreme temperature and erratic rainfall have made it difficult for consistency in agricultural growth. The study found that household and individuals characteristics impact as much as regional (Skoufias et al., 2011). Rural towns along the coast are also experiencing a rise in sea level and storms. The extreme temperatures have also resulted in the degradation and loss of biodiversity across the country. Droughts in the tropical forests have made it more habitable for invasive species which are not only destroying the forest, but also result in the increase of communicable diseases like dengue. Droughts, apart from affecting agricultural growth, can also impact human health with dehydration. Overall, the issues impacting urban households are also impacting rural households, but the difference is more visible when you take into account obstacles due to geography and infrastructure barriers.

Brazil

The majority of Brazil mostly consists of a topical north, with about 60 percent of the country covered by the tropical Amazon, the greatest tropical rainforest in the world and home to 20 percent of all freshwater. The Amazon is the traditional home to over 350 indigenous communities, and it provides essential services to nearly 30 million people (Climate Risk Profile, 2018). The southeast region where Sao Paulo is located is mostly humid subtropical but does experience oceanic climates. Similar to Mexico, the impacts of climate change depend on the region. Deforestation, droughts, and extreme weather have greatly affected the Amazon

ecosystem, resulting in the spread of disease and loss of biodiversity. Higher temperatures created more suitable environments of vector borne and other infectious diseases. Increased flooding can also spread waterborne diseases, such as cholera. The rising of sea levels has also resulted in the surge of storms for the lowland areas. However, unlike Mexico, Brazil's total agricultural outcome has nearly doubled since the early 1990s. While it is likely due to technological advancements, the changes in weather and rainfall have actually benefited the agricultural sector. But, if climate change causes a decrease in agricultural output in the near future, which is likely, it could be detrimental to the health of Brazilians. Due to its natural geography, Brazil has always been particularly vulnerable to the effects of climate change, and therefore was particularly active in the fight against it. Brazil is the world's largest consumer of renewable energy sources with one of the cleanest energy profiles in the world. And, between 2005 and 2012, activist campaigns were successful at reducing deforestation by 80 percent (Graham, 2019). However, since the inauguration of President Jair Bolsonaro, it seems as though Brazil is taking steps backward from being a progressive leader in the fight against climate change. With President Bolsonaro belief that environmental policies are "suffocating" the economy, echoing the United States' position during the Trump administration. This inaction on behalf of the Bolsonaro administration could lead to dire consequences in terms of health.

Graham continues to discuss Sao Paulo, the most populous state in Brazil and how it is leading the fight against climate change. Sao Paulo is not only is the most populous city, but it is also home to the country's largest wealth center. Graham discusses the policies that city is adopting alongside the improvements and recovery efforts of the Atlantic rainforests, and the differences between the approaches of the two locations. While Brazil was in the past already implementing effective preventive actions, for example through its renewable energy program,

the state is not taking any counteractions against deforestation. According to “Changing Trends in Rainfall Extremes in the Metropolitan Area of São Paulo: Causes and Impacts, the major problems in the city are related to urban mobility,” water and energy supply, and natural disasters. The numbers of rainfall above 50mm per day in Sao Paulo were close to zero in the 1950s, but now occur between two to five times a year, putting people at risk of flash flooding and landslides (Marengo et al., 2020). This has also contributed to the increase of natural hydrometeorological disasters. Most of the natural disasters in the region are associated with rainfall. Seasonal droughts, on the other hand, result in water insecurity and vulnerability. In 2001, the drought was associated with an energy crisis and at risk of blackouts. When comparing the data from 1961-1990 to 1998-2018, there has estimated increase of 1.1°C due to increasing greenhouse gases. Apart from extreme heat, the increase of greenhouse gas has also caused in air pollution in the city. Like in Mexico City, air pollution has resulted in the increase of chronic diseases in several vital organs.

While the majority of people live in Brazilian mega-cities, like Rio de Janeiro and São Pablo, most indigenous populations are being pushed further and further into the Amazon. How climate change affects the Amazon and its people depends of the specific region, there are several similar issues affecting it as a whole. Apart from the standard risk factors associated with being poor in a rural setting, living in or close to the Amazon has an added levels of risk factors, like high incidences of infectious diseases such as dengue and cholera. The northeastern region is the most vulnerable is relation to tropical infectious diseases as a result of climate change (Confalonieri et al., 2009). Apart from that, natural geography makes the region more susceptible to natural disasters. Seasonal droughts have increased forest flammability and wildfires. The surface temperature, just like in the cities, has risen alongside air pollution. Wildfires, floods, and

an increase of infectious diseases not only put the inhabitants at direct risk for injury or death, but they can also result in secondary effects to the environment, agricultural growth and the overall biodiversity in the region.

Conclusion

Despite the numerous articles and research into the field of climate change and health, there has not been one specifically comparing the outcome differences for poor people in urban versus rural communities. If poverty is the primary contributor to poor health in association to climate change, it leads to the question of what is the other main contributor to poor health. Is it where someone lives? Are people in rural communities or in urban communities at a higher risk of disability and death due to climate change related impacts? And is it because their environment is naturally more susceptible to climate change related problems, or because of their access to aid? Since everyone is vulnerable to the effects of climate change, there is not a clear answer as to who is the most vulnerable, and who is facing the worst health outcomes. If the same problems of extreme weather, rising sea levels, increase of CO2 and extreme heat are impacting the whole world, then what results in a worse outcome? There is not a singular factor which can determine an individual's health outcome, in fact, one must look at all related factors when studying health. When comparing two different communities, the differences will not only be what is affecting and contributing to poor health, but also how it affects them and how they will be treated afterward. Mexico and Brazil are meant to be examples and to highlight the differences in outcome and treatment for the two communities across Latin America. By looking at the two countries, it can create the groundwork for other countries in Latin America, or even other countries across the world.

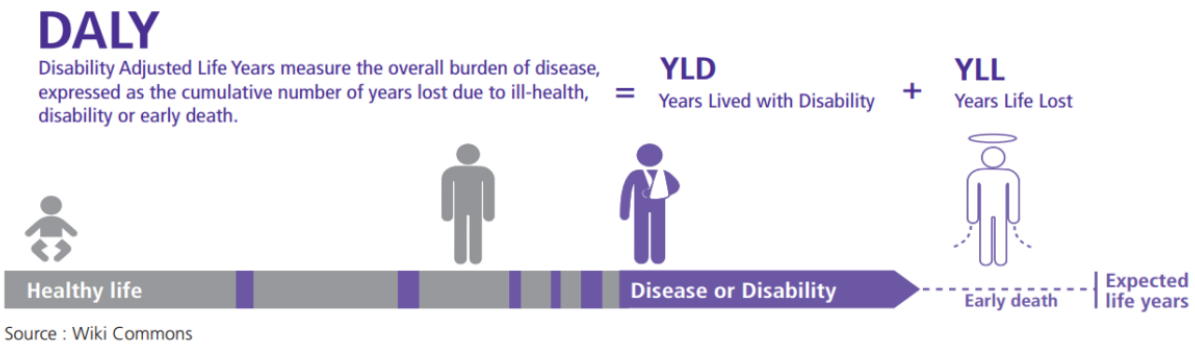
Chapter III:

Methodology and Research Design

When asking the question of who is suffering the worse from the effects of climate change, the questions of how to measure who has the worst effects arise. There is no way to measure who is experiencing the worst burden of the disease since “burden” is not comparable. No two diseases are alike, even when two individuals have the same disease, their quality of life will still vary. However, we do have a powerful tool to help us: the DALY. The DALY (disability-adjusted life year) gives an indication of the burden of disease as the loss of years of full health. DALYs are the sum of YLD (years lived with disability) and YLL (years life lost). DALYs measurements compare the differences between the actual population and the ideal person, someone who reaches the standard life expectancy in perfect health. In this way, the DALY allows us to compare an illness such as asthma to diabetes and see which has a greater burden. By using years as a unit to illustrate the burden: the time with the disease, disability caused by the disease, or premature mortality, we are able to compare two unique situations. Hence, a larger DALY indicates a longer total time a disease has disabled an individual. When looking at a total population, we can measure the total disability of any specific disease.

The DALY

Figure 2



DALYs = Years of life lost due to premature mortality (YLL) + Years lived with disability (YLD)

Note. A figure explaining how the DALY is calculated from NCCID. (2015). DALY [Image]. National Collaborating Centre for Infectious Diseases. https://nccid.ca/publications/understanding-summary-measures-used-to-estimate-the-burden-of-disease/

To compare the differences between urban and rural poor, I needed a data set dating back to the 1990s in order to see specifically the impact of climate change. While climate change has been impacting human health since the 1970s to 80s, most database only has information starting from the 1990s. The data I use in this thesis is primarily drawn from the Institute for Health Metrics and Evaluation (IHME), the independent population health search center from the University of Washington. IHME has created several interactive tools which analyze the world's top diseases from 1990 to 2019. The "GDB compare" is one of these interactive tools which can even look at specific regions within countries, which will be useful when looking at Mexico

City, Sao Paulo, and rural Mexico and Brazil. Apart from the IHME, the other source I will be looking at is the World Bank. Similar to the IHME, the World Bank has also collected a large database of different data including life expectancy, GDP, and CO2 emission. All of the data are essential when connecting poverty and climate change to health. The WHO (World Health Organization). The WHO has also collected a large range of data for the top diseases, and like the other sources, also have a long history of previous years to compare. All of these organizations are reputable within the public health sphere and provided me with the most accurate set of data available. With all the data collected from these sources, I compared and link the increase of certain diseases to climate change. Then, I can compare the urban and rural poor populations to one another to see who has the greater burden.

Case Study Selection Process

The primary question is if people in urban or rural communities experience an overall greater burden in relation to climate change, therefore the selective case studies need to be representative of the whole. When looking at case studies, it is important to take into account what countries will give the most comprehensive overview of the region as a whole. Latin America stretches across North to Central America, hosts deserts as well as rain forests. Each country and every region are experiencing the effects of climate change differently, and their government's responses will vary. While it is impossible to compare every poor rural population to every urban population, comparing two countries can serve to get an overall idea. Mexico and Brazil are the best case studies to represent Latin America since they are the two largest countries by population, land, and economies. Additionally, the first is located in North America while the other is in South America, thus they can represent the diversity of the continent. While

no single place will be a perfect representation for every individual, they will serve to show the overarching trends.

For the urban case study, Mexico City and Sao Paulo will be the two representatives. They are both the most populous cities within their respective countries and the two biggest economies within Latin America. They also highlight the drastic differences between economic classes, both having some of the richest people and the poorest of the poor. Both are also taking great strides in the fight against climate change, passing policies and regulations at the state level, influencing the resting of the country to follow. But, even with efforts to prevent it, people are still suffering from climate change related diseases. Air pollution, extreme heat and natural disasters account for the majority of diseases in an urban center. The diseases will the top DALYs in the two cities can all be attributed or worsened by one of those climate change related effects. Data should not be difficult to access since both cities have a public health administration keeping track of the health of their citizens. The outside database also has extensive statistics.

A rural case study is much more difficult to choose, as there is such a variety in geography, climate, population. No one rural area can truly represent everyone in Latin America. What an individual living in the Sonoran Desert will experience will vary greatly someone in the Andes will. However, by looking at two case studies it will be an example of how climate change is affecting different people. The Yucatan Peninsula and the Amazon will fit that role. The two regions have been the epicenter for climate related problems as they are both seeing the aftermath of extreme heat, natural disasters and an increase of infectious diseases. They also have a large indigenous population, one of the most impoverished ethnic groups in all of Latin America. Data will also be sourced from the same databases, however, due to the access difficulties, I expect information will be less accessible as urban case studies. However, there are

two areas of interest nationally as well as internationally due to their natural resources, so there is still plenty of information.

Chapter IV:

Case Study: Urban – Mexico City and Sao Paulo

The majority of Latin America's population lives in an urban center, they are densely populated areas that simulate economic and cultural growth. They are historical and cultural capitals, a place for opportunities. But climate change may soon how we perceive urban centers. While a populated urban center may be beneficial for the region's economic success, it has had an unintentional consequence on the environment. The explanation has resulted in land change, cars have created air pollution, and so on. Extreme heat, natural disasters, infectious disease and air pollution have all increased since the twentieth century primarily as a result of the industrial revolution. Therefore, it is no surprise that industrialization, urbanization and climate change have all increased at a similar rate.

Even though industrialization and urbanization have contributed to the economic growth of these major cities, there is still a large income gap in Latin America which limits how much money is given to the people on the bottom. Rapid urbanization growth comes with inherited harm for the environment and poor people since they are both being exploited in order to create rapid growth. Poor people have fewer options for housing, healthcare, and jobs so they are often forced to choose unsafe living conditions for their survival. For example, the rapid population growth and poverty levels have resulted in an increase in informal settlements. And, because of where settlements exist, residents are placed at a high-risk factor for health complications as a result of natural disasters (Revi et al., 2014). Simply for being poor, people are at high risk for a poor health outcome associated to climate change. There is an intersectionality between poverty and climate change and its impact on health and extreme heat, natural disasters, infectious diseases and air pollution are the best examples to highlight the risk factors.

To best understand how climate change is affecting the health of poor people in urban settings, there are four distinct subsections: extreme heat, natural disasters, infectious diseases and air pollution. While they are separated into different categories, every health concern can overlap with another, and they often linked. Instead of thinking of each risk factor as its own separate box, it is more helpful to think of them as a four-circle venn diagram.

Extreme Heat

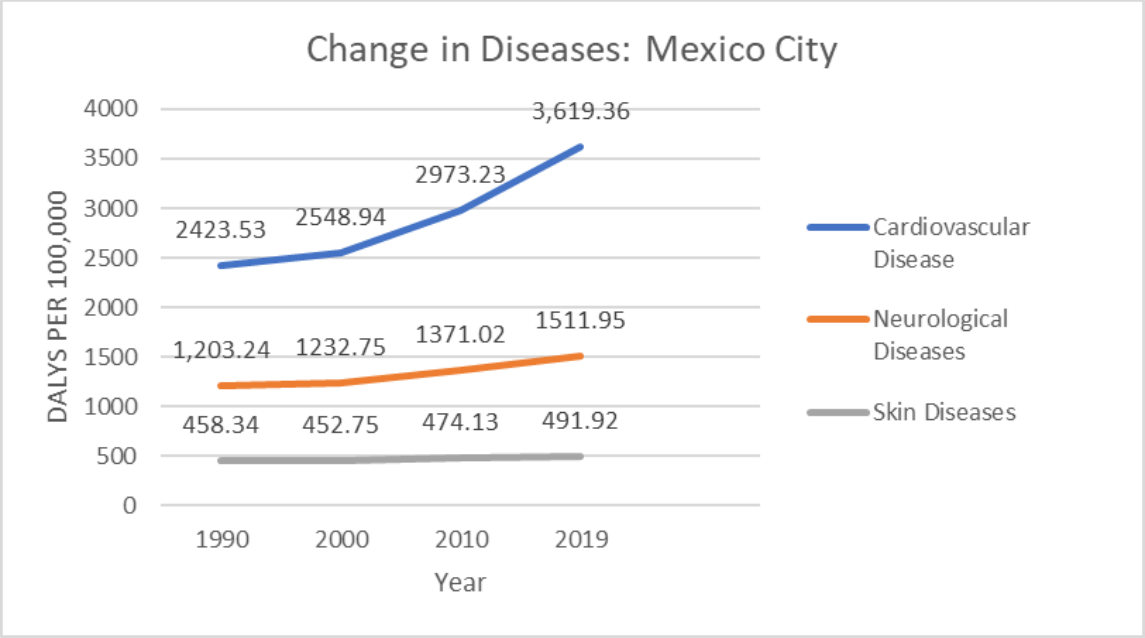
Latin America is known for its warm climate, tropical plants, and animals— a perfect summer vacation destination. And this is not necessarily true for the whole continent since it spread across while there is a great diversity in the continent, this is somewhat true for Mexico City and Sao Paulo. Especially for an urban center where the temperatures have been documented to increase in parallel to urbanization. As climate change implies, average temperatures are rising, and heatwaves are becoming less rare. The average temperatures year-round do not vary too much; Mexico City has a high average of around 25° C and the low average is around 9° C. In Sao Paulo, it also averages around 25° C with an average low around 10° C. But recently, heat waves are becoming a frequent occurrence. The two cities are climate change hot spots and highly vulnerable because of the extreme change.

There is a grand variation in climate and temperatures across Mexico, but Mexico City has historically been known for its more mild and pleasant conditions when compared to other regions in the country. But as climate change increases, resulting in higher average temperatures and more frequent heatwaves, and with the rise of urbanization as more of the most metropolitan cities in the world, extreme heat is becoming a real threat. The Mexico City, which is located in a

subtropical high inland valley, extreme heat is defined when temperature values reach above 30°C and have three or more consecutive days above 25°C, Jauregui, 2009). Mexico City has measured air temperatures and rainfall since the 1920s and they have noticed that the mean annual temperature has increased by 0.6° C since 1960 (SEMARNAT & INE, 2009). At current rates, the average temperatures in Mexico City are expected to increase by 1.1 to 3° C by 2060 and then 1.3 to 4.8° C by 2090. If extreme heat is already having such a serious impact now, one can only imagine what the consequences will be in the future.

While rich residents have methods for cooling down, such as access to air conditioning, this is not available to everyone. Currently, some citizens have resorted to alternative methods to cool down, such as drinking beer or playing in the fountains. But, extreme heat cannot just be combated with beers and fountains, extreme heat can be deadly for those who are not able to properly protect themselves. Dehydration, heat strokes, and sunburns are all risks for vulnerable populations. Susceptibility to extreme heat may be due to underlying medical or biological factors, like age, sex, and disability status, but it may overlap or be a result of other inequalities, such as water and food access, proper housing conditions, and access to health care. Heavily populated areas with high rates of poverty in urban centers are at a disproportionate risk because of their socio-economic status. Very high temperatures can lower an individual's blood pressure, resulting in a faster heartbeat and greater risk for heart attack. As a result, cardiovascular diseases have risen from 2,423.53 DALYS per 100,000 in 1990 to 3,619.36 per 100,000 in 2019 (*GBD Compare | IHME Viz Hub*, 2019). Heat strokes, which fall under the category of neurological disorders, have increased from 1,203.24 DALYs per 100,00 in 1990 to 1,511,95 DALYs per 100,000 in 2019. Sunburns, skin cancer, and other skin diseases have also increased from 458.34 DALYs per 100,000 to 491.92 DALYs per 100,000 in the same time period.

Figure 3

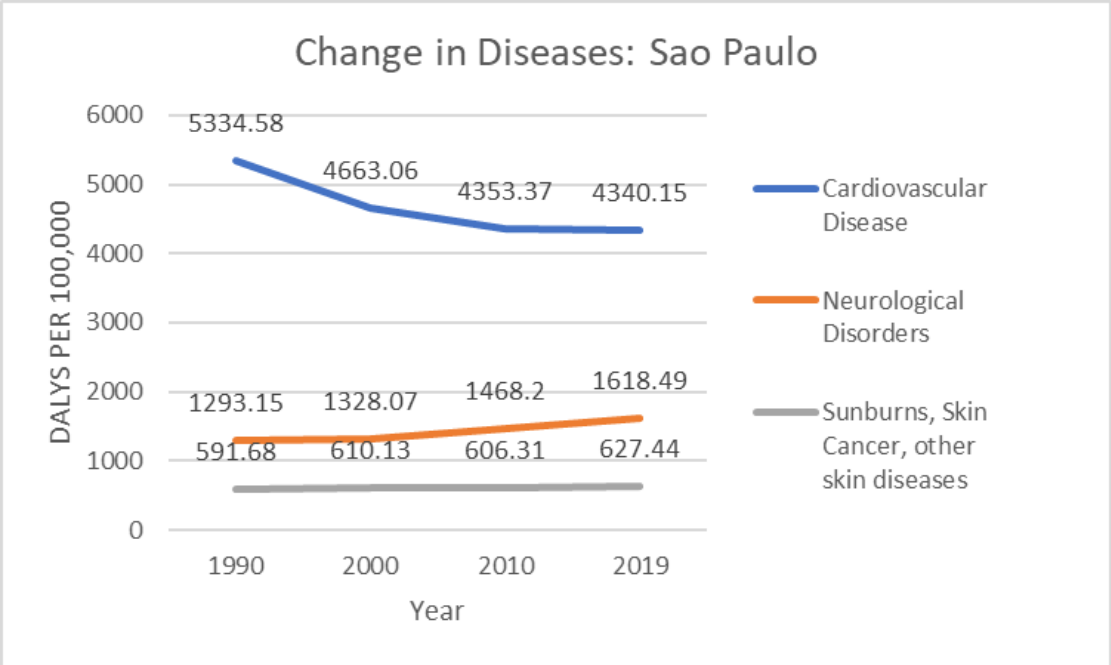


Note. Graph of changes in trends of different extreme heat related diseases in Mexico City from GBD Compare. (2020). Institute for Health Metrics and Evaluation. http://www.healthdata.org/data-visualization/gbd-compare

Sao Paulo, just like Mexico City, has been increasing in extreme heat as a result of climate change and urbanization, but contrary to Mexico City, it is a result of marina heat waves. Extreme ocean temperatures due to drought have resulted in extreme heat in the land as well as the ocean. However, average temperatures have increased since the twentieth century and they are expected to continue increasing. One study conducted by the Intergovernmental Panel on Climate Change predicts that on their current path, Sao Paulo can expect an increase of the average annual temperature by 4° C by 2100 (“Climate Change,” 2018). And with an increase in the average temperature, residences are at a high-risk factor for exposure to heat related illnesses.

Like Mexico City, extreme heat has been tied to an increase in cardiovascular diseases, heat strokes, and sunburns, or other skin-related diseases. Heat strokes included in the neurological disorders have increased 1,293. DALYs per 100,000 in 1980 to 1,618.49 DALYs per 100,000 in 2019 (*GBD Compare | IHME Viz Hub*, 2020). Skin diseases, including sunburns and skin cancer, have also risen from 591.68 DALYs per 100,000 to 627.44 DALYs per 100,000. Cardiovascular diseases are the only heat related disease to see a decrease from 5,334.58 DALYs per 100,000 to 4,340.15 DALYs per 100,000 in that time period. However, it is important to note that even though the overall DALYs have decreased, it is still the disease with the top overall DALY in Sao Paulo. As non-communicable diseases, all these diseases should logically see a decrease in prevalence and mortality as medical technology and living conditions increase, but extreme heat may overall be increasing the likeliness of people developing or dying from heat related illnesses.

Figure 4



Note. Graph of changes in trends of different extreme heat related diseases in Sao Paulo from GBD Compare. (2020). Institute for Health Metrics and Evaluation. http://www.healthdata.org/data-visualization/gbd-compare

Natural Disasters

For Mexico City, the two main natural disaster risks are a paradox: Mexico City is simultaneously running out of water and is at constant risk of flooding. Mexico City traces its history back to the Aztec empire, where the city was built as an island surrounded by a lake. But with the arrival of the Spanish, the lakes were drained in order to expand the city. Because of the construction, Mexico City has to drill beneath the land to access freshwater. The entire city is sinking several inches every year. At least 21 million people, about a fifth of Mexico City's population, do not have access to reliable tap water. Even though the city is continuing to drill for freshwater, it is not being equally distributed across people of all socioeconomic statuses. But unlike some other places, more rain is not the solution.

Mexico City is located in the Mexico Valley Basin, it is naturally surrounded by the trans-Mexican volcano belt as well as a mountain range that is above 5,000 meters. The city itself 2,200 meters above sea level, and it receives average annual precipitation between 600 millimeters in the northern area to 1,200 millimeters in the southern area (Romero Lankao, 2010). For the last 600 years, the city has seen an alternation of wet year and droughts, but due to climate change, the two periods are becoming more extreme. In this last century, there has been an increase of 1.6 ° C, resulting in changes in the hydrological cycle. The hydrological cycle, commonly referred to as the water cycle, is the process by which water passes from vapor in the

atmosphere to precipitation (*The Water Cycle*, 2010). The earth operates on a sensitive balance, when one side of the equation is altered, it will throw off the whole system. Therefore, when the atmosphere becomes warmer, it will result in an increase in evaporation rates, which will increase the overall moisture in the troposphere. An increase of moisture in the atmosphere means more frequent and intense precipitation events, such as flooding. The warmer temperatures also mean that rains fall more often than snow. When snow glaciers melt in one region in the world, it also increases the overall atmosphere moister.

Due to all these factors, Mexico City has been suffering from more frequent and greater floods; an issue compounded by its basin floor location. Damage to the lakes systems on the summits on the surrounding mountains has resulted in an abundant water supply meaning an increase in flooding (Ritter, 2018). As Mexico City sinks, the more flood prone it becomes. Poor communities are especially vulnerable because low income neighborhoods do not have reliable infrastructure like sewer systems to minimize the damages.

There are not any articles that have published the number of causalities as a result of floods, but it is important to remember that poor health as a result of climate change is not solely dependent on an increase of DALYs and causality, but how it affects the overall circle of climate change, poverty, and poor health. However, we can look at the change in DALYs for other diseases which are commonly associated with natural disasters. Natural disasters can have a significant impact on mental illness because it creates a negative situation and contributes to increasing stress levels. When an individual loses a loved one, their home, their livelihood as a result of a natural disaster, they are more vulnerable to developing a mental health disorder. Natural disasters should be treated like any other traumatic event, and mental illness should be studied alongside physical damage. Major depression disorders have increased from 414.15

DALYs per 100,000 in 1990 to 565.82 DALYs per 100,000 in 2019 (*GBD Compare | IHME Viz Hub*, 2020). Anxiety, similarly, has increased from 289.8 DALYs per 100,000 to 363.58 DALYs per 100,000 cases. While there is no evidence to say that all depression and anxiety is due to natural disasters, it is highly likely that it plays a contributing factor.

Just like Mexico City, every summer Sao Paulo is vulnerable to flooding. Urbanization results in land usage changes which increase flood hazards by altering stream channels that would traditionally drain the water after heavy rainfall (Haddad & Teixeira, 2015). Extreme temperatures, just like in Mexico City, have also affected the perpetration patterns in the region, increasing the likelihood of extreme rainfall (Rodrigues, 2020). Sea levels on the coasts of Sao Paulo, for example, have risen 30cm in the last century, higher than the global average. This is causing damage to the infrastructure of coastal cities (Garcia, 2007).

As established in the previous section, there is a strong link between natural disasters and mental illness; as a major life stressor, people are likely to see the effects following a traumatic experience. Due to socioeconomic barriers, poor people in Sao Paulo are less likely to have access to mental health professionals and are unlikely to receive appropriate help. Again, while not all mental health issues are related to natural disasters, it is still incredibly likely that they overlap. Major depression disorders in Sao Paulo have increased from 667.18 DALYs per 100,000 in 1990 to 693.81 DALYs per 100,000 in 2019 (*GBD Compare | IHME Viz Hub*, 2020). Anxiety has also increased from 547.99 DALYs per 100,000 to 740.4 DALYs per 100,000 cases. Even if not all depression and anxiety disorders are connected to natural disasters, it important to look at the shift in trends.

Infectious Diseases

In urban centers, infectious diseases are not as prevalent when compared to rural areas. People in urban centers are more isolated from nature, instead surround by buildings and people. Typically, in urban centers, there is a "buffer" between humans and infectious diseases. Infectious diseases common in rural areas like malaria and dengue are rare in the cities. For example, Mexico City has only reported 0.023 DALYs per 100,000 for Dengue in 1990 and 0.042 DALYs per 100,000 (*GBD Compare | IHME Viz Hub*, 2020). Malaria had 0.3 DALYs per 100,000 in 1990 and there is not report for 2019.

In Sao Paulo, Dengue has increased from 6.49 DALYs per 100,000 in 1990 and 11.72 DALYs per 100,000 (*GBD Compare | IHME Viz Hub*, 2020). Malaria, on the other hand, has dropped from 6.8 DALYs per 100,000 to 1.34 DALYs per 100,000. While infectious diseases are significantly smaller than their rural counterpart, it is still a bit higher than Mexico City. Brazil has seen some of the most severe outbreaks of infectious diseases. Research associated with infectious diseases has been underfunded in the city and the existing programs are not sufficient. The local government needs to invest more into new drugs and vaccines to prevent transmissions and minimize poor health outcomes. In 2018, The United Kingdom and Sao Paulo/Brazil announced a jointed partnership to fund any public or private research institutions aimed to research Neglected Infectious Diseases (FAPESP, 2018). Over £3.5 will be granted to the winning proposal. Information on what exact nature of this program is still unknown, but hopefully, this program will lead to positive outcomes for the people of Brazil.

It is important not to imply that infectious diseases cannot spread across urban centers as we have seen the current effects of the novel Coronavirus Disease 2019. The current COVID-19 pandemic is the most recent and most extreme example of an infectious disease from the last

century of a disease that may be related to climate change. Research about COVID-19 is still ongoing, and the exact origin of the virus has not been discovered yet but some scientists think it may be related to how extreme heat and land use change have resulted in increased contact with other animals which can carry diseases (Jabr, 2020). Currently, the hypothesis believes that COVID-19 originated in bats, and when humans invaded their habitat, the disease may have jumped to one human creating a contagion link to a greater population. When humans invade animals' natural habitat, diseases can arise.

As of March 22, Mexico City has seen an approximate total of 595,000 COVID-19 cases with a death toll 29,787. Sao Paulo has not published the exact number of the city, but the state of Sao Paulo has seen an approximately 2.31 million cases and 67,602 deaths (CSSEGISandData, 2020/2021). The numbers in Sao Paulo are of course higher since it accounts for the whole state versus just Mexico City, the numbers are still astronomical. Brazil overall, has had one of the worse responses to the pandemic, resulting in the ramped spread of the disease. Both Sao Paulo and Mexico City have been citizens both by their residents as well as outside observes for their lackluster response, lack of financial aid, and for rumors that they are not accurately reporting their numbers. Even though Brazil has more intensive care unit(ICU) beds than Mexico, 1.05 per 100,000 compared to .06 per 100,000, it still experiencing a greater toll (*ICU Beds in Hospitals in Latin America*, 2019).

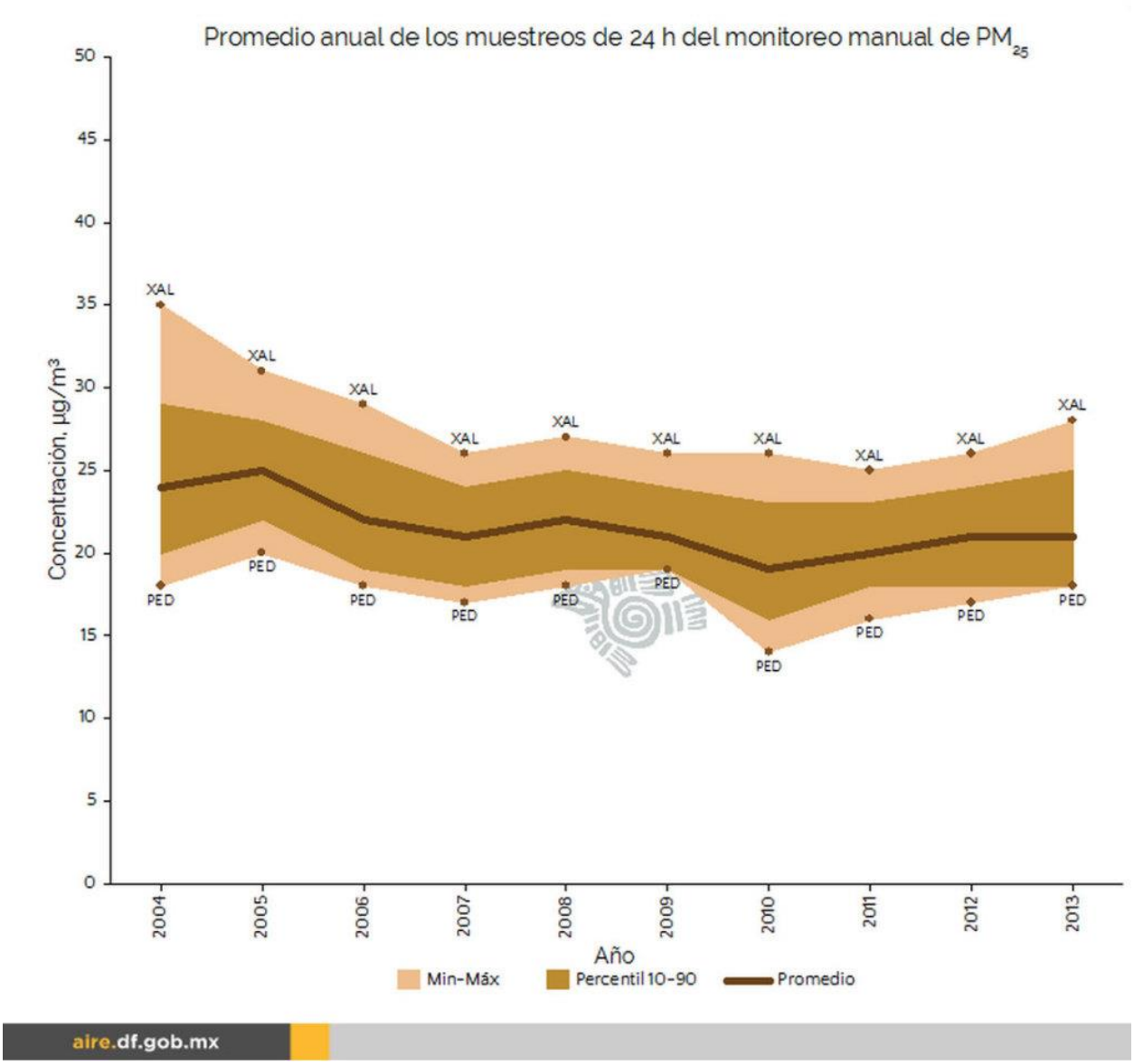
Air Pollution

As one of the two largest metropolitan areas in the world, Mexico City and Sao Paulo are infamous for air pollution. Urbanization, transportation, industrialization, and overpopulation are

all contributing to the increase of air pollution in urban centers. Air pollution refers to the mixture of small airborne particles. Air pollution is not only an environmental risk but it also responsible for deaths related to heart attacks, strokes, diabetes, and respiratory diseases. Particulate matter (PM10, PM2.5) are small airborne particles formed from the direct burning of fossil fuels, dust, diesel emission, and secondary particle formatted from gases and vapors. Coarse particulate matter (PM10) are particles less than 10 microns can cause nasal and upper respiratory problems. Particles finer than 2.5 microns (PM2.5) are even more dangerous, as they can penetrate the lungs, and even result in heat attacks, strokes, asthma, and other respiratory diseases (*Health Impacts of Air Pollution*, n.d.). Heart attacks and stroke can also be attributed to extreme heat. It is impossible to know when diseases are a result of extreme heat versus air pollution. Therefore, it more productive to look at the intersectionality of all risk factors and how they contribute to disease. Since the DALYs on cardiovascular diseases and neurological disorders have already been included in the extreme heat section, they will not be repeated in this section.

In Mexico City, air pollution has risen alongside urbanization. Air pollution quality reached its worst point in the 80s and 90s, where it would constantly reach “red” alerts, red alerts referring to dangerous levels. Fortunately, measures have been implemented to decreases air pollution and “red” alerts only occur a few times a year (*Air Quality, Weather and Climate in Mexico City*, 2015). As seen in Figure 5, PM2.5 has decreased from 24 in 2004 to 20 in 2013. The trend is decreasing but it is still far from the recommended 10 concentration, μg/m^3.

Figure 5



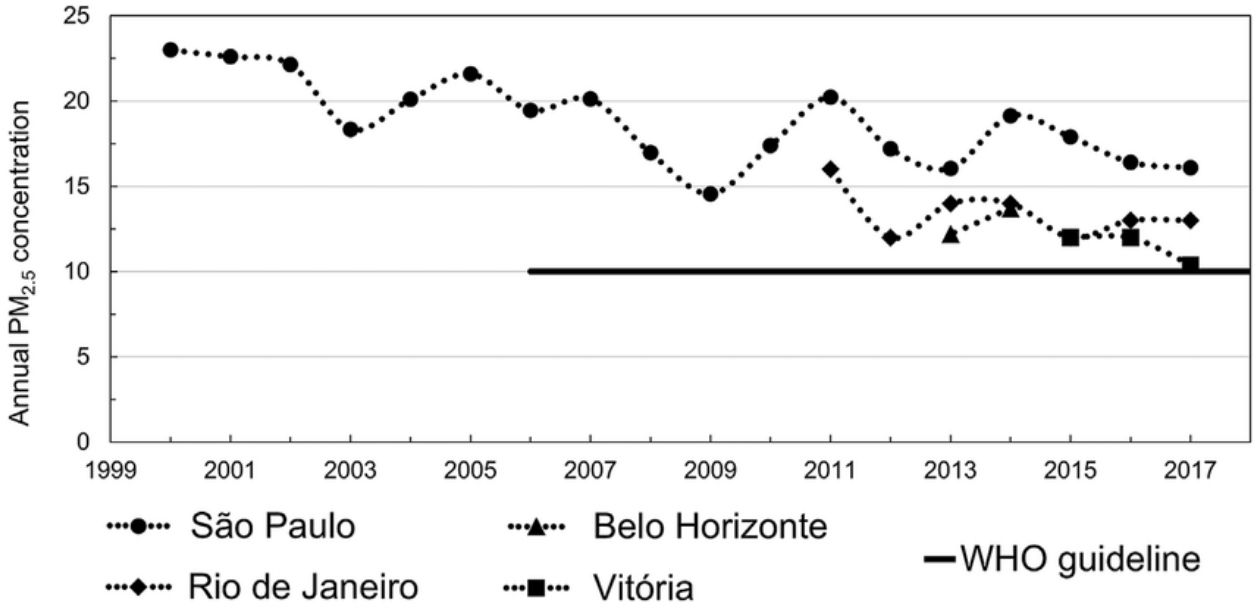
Note. Annual Fine Particulate Matter (PM25) trends in Mexico City from 2004 to 2013 from Air Quality Surveillance. (2014, September 18). Mexico City-Harvard Alliance for Air Quality and Public Health. https://www.hsph.harvard.edu/cdmx/about-us/air-quality-surveillance/

While air quality has improved in recent years, there were still an estimated 15,000 deaths are a result of air pollution in 2020. Chronic respiratory diseases have also seen an

increase from 648.76 DALYs per 100,000 in 1990 to 833.14 DALYs per 100,000 in 2019. Diabetes type 2, similarly, has increased from 1,660.6 DALYs per 100,000 in 1990 to 3,009.13 DALYs per 100,000 in 2019. Chronic obstructive pulmonary diseases increased from 413.54 DALYs per 100,000 to 603.71 per 100,000 (*GBD Compare | IHME Viz Hub*, 2020). Even if air pollution has decreased overall from the 80s, it still an active threat to its citizens.

In Sao Paulo, air pollution kills more people than traffic accidents, breast cancer, and AIDS combined (Messenger, 2018). In a densely populated city with an ineffective public transit system, air quality continues to decrease. While the general trends of PM2.5 have decreased in recent years, as seen in Figure 6, shifting from 22.5 PM 2.5 in 1999 to 16 PM 2.5 2017. The decrease in harmful chemicals certainly is a positive direction, but residents are still suffering from the excessive levels of contamination.

Figure 6



Note. Annual Fine Particulate Matter (PM25) trends in Sao Paulo from 1999 to 2017 from Andreão, W. L., Albuquerque, T. T. A., & Kumar, P. (2018). Excess deaths associated with fine

particulate matter in Brazilian cities. Atmospheric Environment, 194, 71–81. https://doi.org/10.1016/j.atmosenv.2018.09.034

Similar to Mexico City, there was an estimated 15,000 deaths due to air pollution in 2020. Certain air pollution related issues have also increased: diabetes type 2 rose from 754.31 DALYs per 100,000 in 1990 to 978.63 DALYs per 100,000 in 2019. Lung cancer also rose from 323.72 DALYs per 100,000 to 424.51 DALYs per 100,000 (*GBD Compare | IHME Viz Hub*, 2020). Since children are one of the most vulnerable groups affected by air pollution, it might be too soon to see the true consequences of air pollution.

Conclusion

Overall, Mexico City and Sao Paulo are seeing the effects of climate change in a similar way. In both cases, the poor are the ones experiencing the worse health outcome. Out of the four subsections, there both seeing the worse outcomes from air pollution as a result to urbanization. Almost every major disease related to climate change has increased since 1990 in the two countries, and there are no indications suggesting that these trends will change in the near future.

As an urban center, Mexico City and Sao Paulo are experiencing similar outcomes due to climate change, and their poor residents are at the forefront of the negative effects. The general trends suggest that all major cities are experiencing the effects of climate change to an extent, but major cities in the global south are at a systematic disadvantage as a result of their physical location as well as the economic and political power. As researchers have noticed, there has been a rise in almost all climate change related diseases. Despite the actions the local government has or has not taken, poor people are still disproportionately experiencing poor health outcomes

because they lack the resources and aid that rich people have access to. The solution is not one of solving climate change or aiding poor people, but critically looking about how poor people are impacted and what can realistically be achieved to help them. Poverty and climate change need to be addressed together to properly address the problem.

Chapter V:

Case Study: Rural – Yucatan and the Amazon

Only around 19.1 percent of the total population of Latin America lives in rural areas, but poverty runs rampant through this population. There is a drastic economic difference between urban and rural populations, in Mexico, for instance, the average monthly income of an urban resident was 4,876 peso compared to 2,220 pesos in rural Mexico in 2014 (Iniguez-Montiel & Kurosaki, 2018). The gap is nearly identical in Brazil, according to data from PNAD rural income was only 53% of that in urban areas (Santos & Vieira, 2015). Climate change is not helping in the efforts to reduce social, class, and health inequality. Like in the previous section, Mexico and Brazil, are meant to be a case study for the rest of Latin America. And Yucatan and Amazonia are meant to be the specific case studies for a rural population. Not only is climate change particularly responsible for the increase of extreme heat, natural disasters, infectious diseases, and air pollution in these past decades, but one could argue is the main risk for poor health and poverty in rural Latin America. In terms of climate change and health, it hard to say which specific risk is causing what specific disease. These different risk factors should not be looked at as independent variables, but rather should be seen in conjunction with each other. Wildfires in the Amazon, for example, are natural disasters, but they result in air pollution and therefore respiratory illnesses. Flooding as an aftermath of hurricanes can make it more suitable for infectious diseases. Even those these are introduced as different subsections; they all tie together to illustrate the bigger picture.

Extreme heat

Outside of the hustle and bustle of the cities, millions of people still live in more rural areas of Latin America, with a great majority still relying on farming and agriculture as a means of living. Home to a wide number of indigenous tribes, and other groups who have a long family history to the lands, millions of people continue to live in these areas. In the Amazon Basin, more than 30 million and over 350 indigenous communities continue to live in these rural settings. Yucatan is the traditional home to Yucatec Mayan, as well as a couple of other indigenous groups. However, climate change and extreme heat are putting their livelihood as well as their health at risk. High temperatures range between 35 and 40°C across Mexico. In the Amazon, temperatures have increased by 0.5°C since 1980 (*Climate Risk Profile*, 2018). While these temperature rises may not look high, we can still feel the effects. The main issues from extreme heat are its effects on crops and direct effects on human health. 75 percent of all of Mexico's soil is already too dry to provide nutrients to crops (*Too Dry to Thrive*, 2020). Each year the rainy season is getting dry and dry from the lack of precipitation.

Not only is the rise in temperature detrimental to human and animal health, but it is also putting their main source of income at risk; an important difference from urban areas. For example, indigenous civilizations have been domesticating corn for over 9,000 years, with archaeologists tracing back to Tehuacan, Mexico, who laid the fountain for permanent settlements all across North and South America. However, extreme heat and droughts are making it harder for farmers to cultivate corn and other similar crops without the necessary water. Corn is the backbone of most Mexican and indigenous diets, not only are droughts affecting their source of income, putting them at an even greater risk of poverty, it is also causing food scarcity if they can not grow their own food.

On the other side, agriculture could be the reason for extreme heat in the Amazon. In the Amazon Basin, extreme heat and drought are directly linked to deforestation. Since more and more of the forest is being cut down to make way for growing crops, droughts and extreme weather are the results. Dr. Philip Duffy from the Woods Hole Research Center (WHRC) explains that, "Historically, the main source of CO2 emissions from Amazon forests has been direct human action, especially deforestation. However, in the future, climate change may cause large emissions that result from changes in the large-scale environment rather than from direct human action, and hence are much more difficult to control. This study, based on 35 climate models, suggests that future climate change will increase the frequency and geographic extent of meteorological drought in most of the Amazon. This may contribute to forest degradation and increased emissions of CO2 to the atmosphere, amplifying global warming," (Woods Hole Research Center, 2015). Apart from the consequences done onto the environment, deforestation is also displacing indigenous communities, what once was their home is now being using as farmland. Apart from this, extreme heat is responsible for the mortality and morbidity of millions.

Extreme heat is now considered a high hazard level in both Mexico and Brazil, resulting in heat stress at least once in the next five years according to the Global Facility for Disasters Reduction and Recovery (GRDRR). While the warming and rise in temperatures are regionally uniform, with some countries and regions in Latin America seeing a greater impact than others, even a slight increase can have dire consequences for its citizens resulting in both short- and long-term consequences. In terms of health, extreme heat is closely related to heat exhaustion, heat cramps, heat stroke as well as death. And these serious health concerns attack vulnerable populations, like the elderly, children, and people with pre-existing conditions, the most. It can

also intensify certain preexisting chronic conditions such as cardiovascular and respiratory diseases. In Yucatan, cardiovascular shifted from 2,276.37 DALYs per 100,000 in 1990 to 2,990.07 DALYs, and in Amazon, it shifted from 2,205.22 DALY in 1990 to 2,129.89. Chronic respiratory diseases in Yucatan also shifted from 604.2 DALYs in 1990 to 670.06 DALYs in 2019, but there was only a minor change in the Amazon from 663.61 DALYs in 1990 to 612.67 DALYs in 2019 (*GBD Compare | IHME Viz Hub*, 2020).

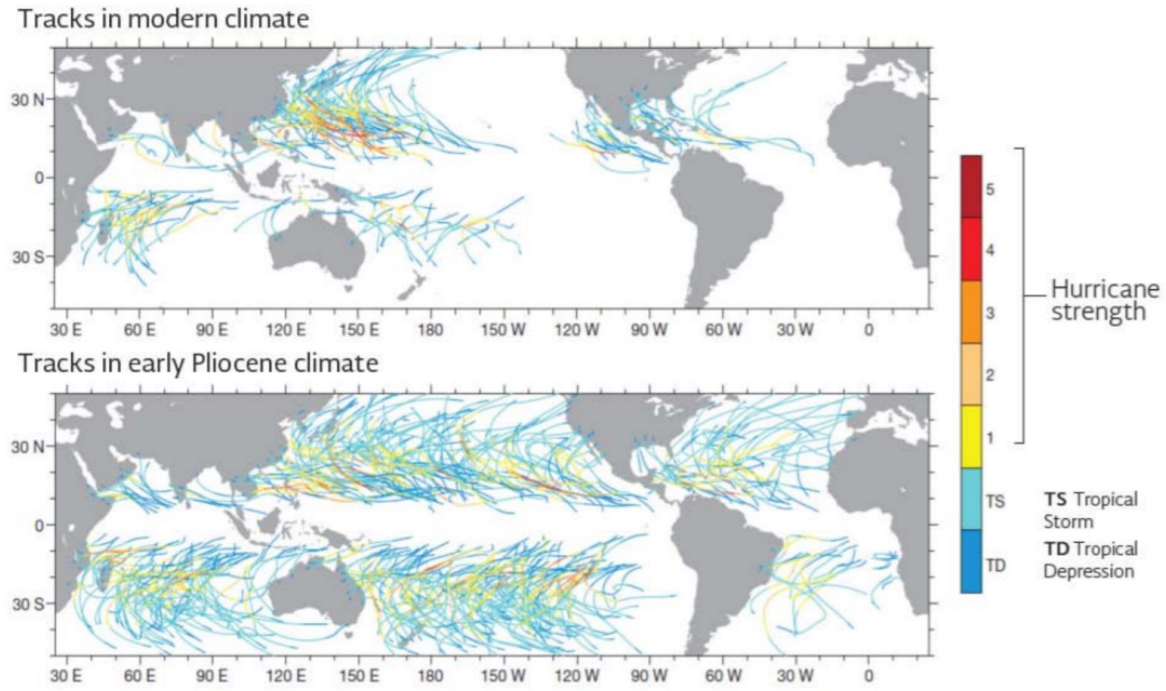
Most extreme heat mitigation and adaptation strategies from sources like the National Institute of Environmental Health Sciences include "increase air conditioning use" and "decrease time spent outdoors during extreme heat events;" strategies that simply are not possible for a great percentage of people living in the countryside (*Effects of Heat - Climate and Human Health*, 2017). Not all homes have air conditioning, and people who work outside do not have the option to spend less time outdoors. These are not realistic and effective options for most people. As global temperatures continue to rise, we should continue to see an increase in heat-related illnesses. Contrary to most people living in the cities, many houses are ill-equipped for the extreme heat. Common necessities like running water and air conditions are not available to each household.

Natural disasters

October 2020, Hurricane Zeta hit the Mexican Yucatan peninsula, high winds, and heavy rain head towards Cancun and the surrounding area. State governor of Quintana Roo Carlos Joaquín told citizens and tourists that: "nobody should be on the streets ... you shouldn't go out anymore" until the hurricane passes (Alcocer, 2020). The region was just recovering from

Hurricane Delta which hit 3 weeks earlier. Cancun is one of the most visited tourist centers of Mexico, and while these visitors will leave their vacation safely with crazy stories about the wild hurricanes, but others cannot leave. Hurricanes are not a tourist attraction for them, but a crippling natural disaster that puts their home and their lives at risk. Extreme storms, wildfires, rising sea levels all are becoming greater and greater threats to rural populations. Even with the global pandemic of 2020, natural disasters are continuing to wreak havoc in Latin America. In the Amazon, forest fires have not stopped, in fact, 1 million hectares of forest were burned. Last year had the highest number of wildfires than in the last thirteen years (Gonzaga, 2020). In both Yucatan and the Amazon, the people who will truly see the full extent of these disasters are the people who live there. While the whole range of natural disasters affects Mexico and Brazil, hurricanes and wildfires are the two main risk factors for Yucatan and the Amazon. Figure 7 tracks modern and early Pliocene changes, or current cyclone paths which can Yucatan.

Figure 7



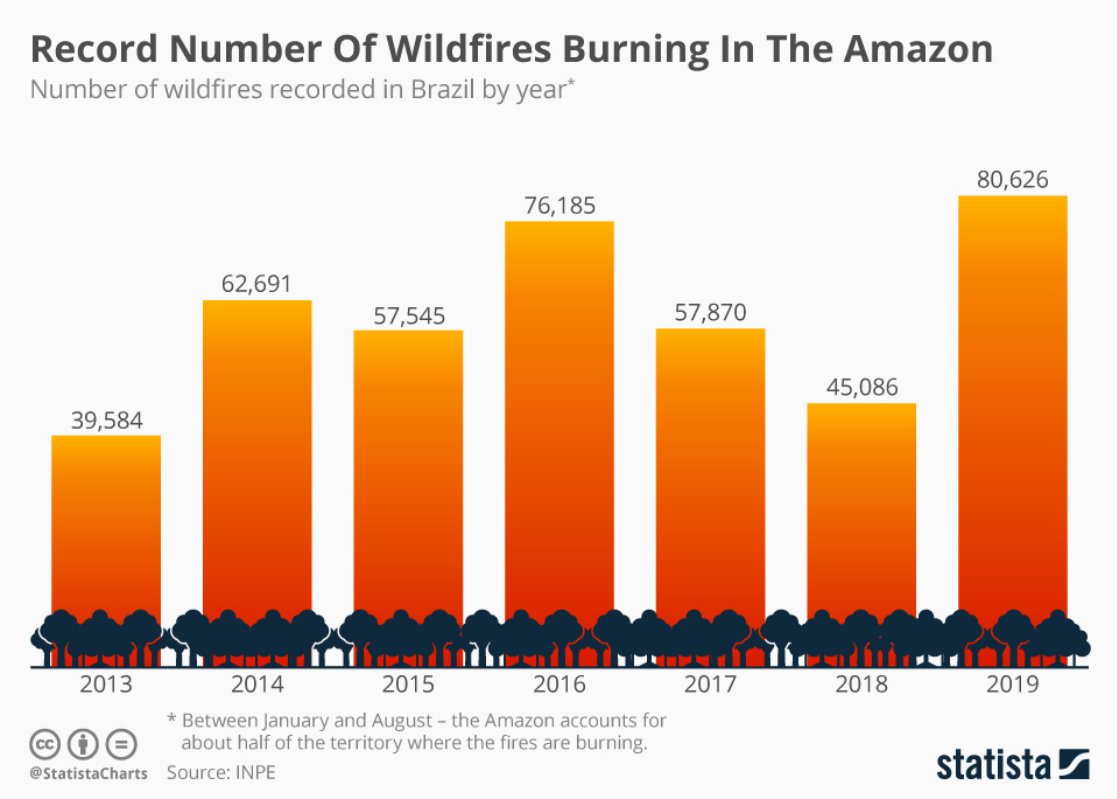
Note. Cyclone patterns in current times compared to early Pliocene from Ministry of Environment and Natural Resources. (2016). Mexico's Climate Change Mid-Century Strategy. https://unfccc.int/files/focus/long-term_strategies/application/pdf/mexico_mcs_final_cop22nov16_red.pdf

Due to the location of Yucatan, it usually does not get hit the hardest by hurricanes, compared to states in the US and Caribbean islands. Therefore, death tolls are usually kept to the minimum. Last year, hurricane Delta saw no death trolls nor injuries directly following, but there was some major damage done to the infrastructure (*WFP LATIN AMERICA & CARIBBEAN REGION COVID-19 Logistics Situation Update #12*, 2020). Similarly, hurricane Zeta also had no casualties. However, even if causalities are kept at the minimum, one should not dismiss the consequences these natural disasters can have on one's mental health. Following these two hurricanes, thousands were left homeless. While a statistic is difficult to find, due to the isolation of people in rural Yucatan to researchers, social workers, and medics, it fair to say that the prevalence of serious mental illness could mirror that following Hurricane Katrina, from 11 percent to 14 percent. According to IHME, the mental disorders DALY increased from 1,357.98 DALYs to 1,813.21 DALYs from 1990 to 2019, and self-harm and interpersonal violence increased from 527.26 DALYs to 759.31 DALYs in those same years.

Opposite to hurricanes but equally as devastating are the prominent wildfires in the Amazon Basin. In the last 35 years, half a million square kilometers of the rainforest have been cut down to make way for agriculture, at the speed for the forest loss has only increased since the election of President Bolsaro in 2019. In his first year, there was an increase of 85 percent of forest lost. As seen in figure 8, there was a drastic increase in wildfires following Bolsaro's inauguration in 2018. And unlike hurricanes, a lot of wildfires are deliberately set by people

looking to clear the land to make it suitable for agriculture and real estate development. Again, due to geographical difficulties and the lack of access to reliable healthcare, there is not reliable data about related death and illness. Millions of people live in the Amazon, and there is very limited access to health facilities, so a precise number is difficult to find. The closes estimated can be based on the number of people exposed to toxic haze, over three million, and 90 municipalities (*"The Air Is Unbearable,"* 2020). Interestingly though, the DALY of chronic respiratory diseases decreased from 663.61 DALYs to 612.67 DALYs in 1990 and 2019. However, like in Yucatan, there has been an increase of mental disorders, from 1,639.81 DALYs to 2,059.95 DALYs and self-harm and interpersonal violence shifted from 1,755.18 DALYs to 2,258.2 DALYs. While these are not necessarily direct indicators of how natural disasters are affecting health, they should still be considered.

Figure 8



Note. Graph of wildfires in the Amazon from 2013 to 2019 from McCarthy, N. (2019, August 26). Infographic: Record Number Of Wildfires Burning In The Amazon. Statista Infographics. https://www.statista.com/chart/19089/number-of-wildfires-recorded-in-brazils-amazon-rainforest/

Infectious Diseases

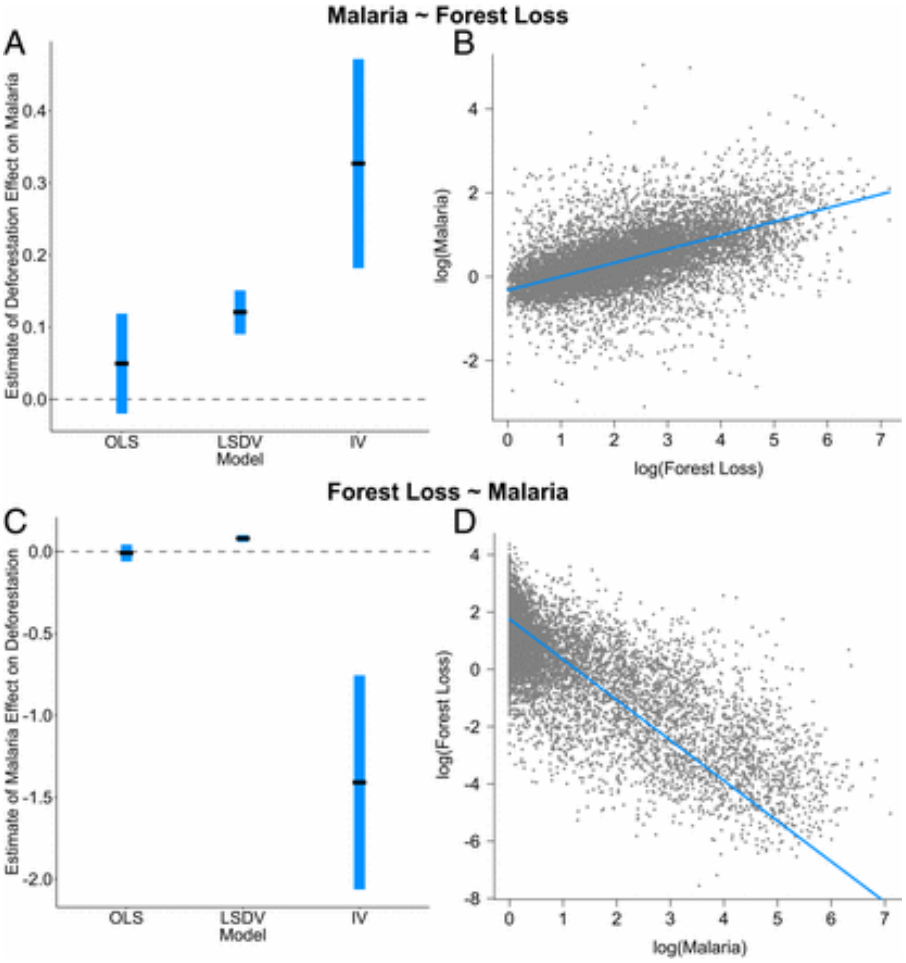
Amid the 2019 Covid pandemic, it easy to forget that is not the only pandemic. For millions living in rural Latin America, this is just another disease that is pledging their population. Infectious diseases can infect anyone regardless of location, but rural populations, in general, are more vulnerable due to their proximity to rivers, forests, and live stoke. Malaria, Dengue, Zika, and Changa are the most infectious vector-borne disease in Latin America. While the incidents of certain diseases like Malaria and Dengue have decreased overall in Latin America, other diseases have not followed. In Yucatan, an increase in flooding as a result of hurricanes has also created a breeding ground for insects and infectious diseases. In the Amazon, deforestation has caused a "spillover" effect in which diseases can jump from one species to domesticated animals to humans are a lot easier. Deforestation is creating more breeding grounds for insects like mosquitos to prosper and carry with them infectious diseases. In fact, land-use changes are the main contributors to the rise of infectious diseases.

In the Yucatan peninsula, Triatoma dimidiate, the main vector species of Chagas disease is the main infectious disease in the region. Accord the world 6 to 7 million, mostly in Latin America, are estimated to be infected with the parasite Trypanosoma cruzi which causes Chaga disease (*Chagas Disease,* 2020). Even though the overall DALY of infectious disease in Yucatan

are not the highest, and they have decreased from 172.19 DALYs 1990 to 140.97 DALYs 2019 (*GBD Compare | IHME Viz Hub*, 2020), the rate of infection should not be dismissed since it is a prominent disease connected to climate change. In one study, researchers found a prevalence of 17.3 percent of T.cruzi (Zavala-Velázquez, 2003). Even those the case numbers of infectious disease in Yucatan are not particularly high right now, if natural disasters continue to create suitable areas of reproductions for inserts, these numbers can easily increase in the near future.

In the Amazon, the infectious disease that is the greatest threat to human health is Malaria. Malaria is usually carried by mosquitos who thrive in swamp humid areas making the amazon rainforest their perfect environment. There is no current vaccination for Malaria, and while there are drugs and treatments for it, western healthcare is not something that most rural communities have access to. Erin Mordecai, Ph.D., a researcher for Standard explained that: "For every square kilometer of forest lost we can expect about six new cases of malaria," (Ohayon, 2019). Figure 9 demonstrates how the rates of malaria increase alongside deforestation. New cases are rising and will continue to rise alongside deforestation, but the DALY score for neglected tropical diseases and malaria has dropped significantly since 1990 from 1,591.05 DALYs to 186.82 DALYs in 2019 (*GBD Compare | IHME Viz Hub*, 2020). This is a positive result, but if deforestation continues at its same rate, it is unknown if infectious diseases will continue to drop.

Figure 9



Note. Graph comparing forest loss to cases of malaria in the Amazon from MacDonald, A. J., & Mordecai, E. A. (2019). Amazon deforestation drives malaria transmission, and the malaria burden reduces forest clearing. Proceedings of the National Academy of Sciences, 116(44), 22212–22218. https://doi.org/10.1073/pnas.1905315116

Air pollution

While air pollution has been a great risk factor for the urban population due to industrialization and population density, it is also affecting rural populations, just in different

ways. Most rural communities are affected by air pollution due to the lack of proper venation in their homes, but that is not necessarily related to climate change. Indoor air pollution is common in rural areas of Mexico, where 91 percent of all rural inhabitants in 1990 use wood or charcoal for cooking (Maldonado et al., 2011). However, wildfires are. Even in Yucutan, wildfires are have been burning more often and more intensely leaving the local only ash to breathe in. As stated in the previous section about natural disasters the air quality in the Amazon is caused by over 2,195 hospitalizations due to respiratory illnesses in 2019, with over half being infants under a year old and those over the age of 60 (*"The Air Is Unbearable,"* 2020). Air pollution blurred the lines between air pollution and natural disasters, but it is not surprising because all these different risk factors work together to jeopardize human health.

Conclusion

Despite being in two drastically different areas, and having different traditions and cultural practices, the people living in Yucatan and the Amazon regions are both seeing the effects of climate change. Overall, they are seeing the worse effects from natural disasters, have they causing harm to their health as well as pushing them further into poverty and dislocating them. In general, people in rural settings are seeing minimal effects of air pollutions when compared to urban centers, but they are still seeing some effects. Infectious diseases and extreme heat are still a problem for the two regions.

As two vastly different regions with different cultural practices, something both Yucatan and the Amazon share in common is the protentional damage climate change could enact. In fact, the harms of climate change spread across all rural regions in the world. At this point, it not a

question of if climate change is having an impact on a population, but how is climate change having an impact on a population. Poor people in rural areas have the added disadvantage that they do not have access to a lot of the same resources available to poor people in urban areas. Hospitals, doctors, supermarkets are not as wildly available in certain rural regions limiting the type of aid available to them. Typically, rural communities are also more culturally connected and dependent on natural resources, so climate change is altering livelihoods and social structures.

Now that the urban and rural contexts have been extanmented individually, the next step is to compare the two. The two previous chapters compared two regions each to demonstrate the general trends, but to answer what group is seeing the worse health outcome, it necessary to compare the two sections overall.

Chapter VI:

Comparing the Urban and Rural Contexts

The world is changing, summers are getting warmer, the water is getting dirtier, trees are disappearing. Optimists call for a collaborative effort across all borders to stop climate change, for world unification for the common problem. Climate change is altering everyone's life to an extent, but some are already seeing the worse predictions. Latin America is amongst one of the regions most vulnerable to climate change, and within Latin America, poor people are likely to see the worse of it. Despite any and all regional differences, poor people throughout Latin America are already seeing similar climate change-related problems. Latin America proportionately has not contributed to climate change, in terms of CO2 emission per capita, when compared to countries in the global North, but they one of the most vulnerable to climate change. Even if the effects present themselves differently, even if the external stressor causing the effects may differ, the end result stays more or less the same. Extreme heat, natural disasters, infectious diseases, and air pollution are all risen, and so have the related health problems. Air pollution in urban centers may be a result of transportation and factories while air pollution in the rural areas is a result of wildfires, but ultimately, they affect the citizens the same way. Climate change impacting millions of poor people in Latin America, both physically and mentally. But who is seeing the worse health outcome? Has the process of urbanization created an epicenter of climate change-related disease for poor people, or are poor people in rural centers are a greater disadvantage due to the lack of resources?

Extreme Heat

Extreme heat can have both minor and severe symptoms, ranging all the way from a minor headache all the way to death. The main ways that preventing people's bodies during extremely hot weather: high humidity and personal factors. In humid climates, sweat is not evaporated as quickly and the body is not able to release heat fast enough to keep cool. Mexico City, Sao Paulo, Yucatan, and the Amazon are humid regions, so that just added another risk factor for the people in those regions. Personal factors like age, obesity, and underlying conditions. Therefore, the more extreme outcomes do not occur randomly, they target vulnerable populations. This, of course, includes the elderly and young children, but poverty and location can be a risk factors. Since poor people are less likely to have the essential resources to cool down, and people they are more likely to work in physically demanding jobs, they are placed at a higher risk.

The Center for Disease Control and Prevention (CDC) published a guide for how to stay cool in unsafe hot weather. It suggests that everyone, but especially those over 65 years, young children, and people with chronic or mental illness to drink enough water, turn on the air conditioning, do not cook with a stove or oven, and stay indoors as much as possible. However, for poor people, there are impossible demands (CDC, 2020). Over 50 percent of Mexicans face water scarcity. Aging water pipes in Mexico lose up 35 percent due to poor distribution and contamination (*7 Facts about Access to Clean Water in Mexico*, 2020). In rural Mexico, the pipelines are not any better; they have also riddled with pollutants and the water is often undrinkable. While Brazil is home to 20 percent of the world's water reserve, but the poorest often do not have access to any of it. In the *Favela do Moinho* in the center of Sao Paulo, 2,500 residents are forced to share one single PVC pipe for water. It fails to reach everyone, the taps

often run dry by 2 pm (Rigby, 2015). The little water they do have is often contaminated, since there a lack of effective wastewater treatment. In the Amazon, locals rely on the Amazon River but recently the lack of regulations has contaminated the water. In all the regions, non-profits have set up to address water scarcity problems: Amazon Watch, The Water Project, Water, and several other works with locals for protentional solutions.

As for staying indoor to avoid extreme heat, the two main problems are that access of air-condition units among poor people and the type of work available. In both Mexico and Brazil as of 2016, only 16 percent of all households have an air-conditioning unit (Holst, 2020). In rural parts of Mexico, 34.73 percent of workers participate in agricultural actives, 7.07 in the building industry, so at least 40 percent work outdoors. In the urban areas, 0.75 work in agriculture, 5.49 work in the building industry, and 24.94 encompassed other services in 2002 (van Gameren & Hinojosa, 2004). This includes informal work, such as street vendors. Statistics comparing rural versus urban employment is not available for Brazil, but in 2020 9.12 percent of Brazilians work in agriculture (*Agricultural Sector's Employment Share in Brazil 2020*, 2020) and 41.4 percent working in informal jobs (Nitahara, 2019).

All diseases related to extreme heat such as cardiovascular disease, strokes, skin disorders, and chronic respiratory are all maintained in the same range; no disease has seen a drastic spike from 1990 to 2019. The largest spike was with cardiovascular diseases in Mexico City jumping from 2423.53 DALYs per 100,000 to 3,619.36 DALY. But, every other disease in Mexico City, Sao Paulo, Yucatan, and the Amazon have just seen a gradual but consistent rise. For extreme heat, there is no clear answer as to what population is seeing the worse health outcome since the issues that poor people face are the same in the two regions.

Natural Disasters

The climate change so does precipitation patterns, temperatures rise, weather becomes more intense. The two great oceans are warming, and sea levels are rising, and natural disasters are becoming the norm. For natural disasters, illness can be both direct and indirect. A direct negative health outcome following a natural disaster would include physical harm, injury, or death. Often, when discussing natural disasters, the tragedy is often measured by how much physical damage occurs, as well as how many victims there are. Little attention is rarely given following the disaster; the long-term psychological damage survivors often experience. As climate change continues to worsen, it will lead to an increase in intense and frequent natural disasters. The natural disaster also contributes to the spread of infectious diseases following events like floods and wildfires but will be covered in the next section.

Since a lot of the illnesses caused by natural disasters overlap with other categories, the purpose of this section will only focus on the increase of mental health. However, unlike other diseases such as diabetes where there is a clear diagnosis, tracking mental health usually requires patients to seek help. Due to mental health stigma, especially in Latin America, one should consider that the numbers are likely higher. Depression, anxiety and other mental illnesses are often not reported or diagnosed. Even then, there has been an increase in mental illness in more urban and rural areas. In urban centers, depression increased from 667 to 693 DALYs per 100,000 and anxiety increase from 547 to 740 DALYs in Sao Paulo, and in Mexico, it increased depression from 414 to 565 DALYs and 289 to 363 DALYs. In rural Brazil, mental health disorders increased from 1639 to 2059 DALYs and 1357 to 1813 DALYs in Yucatan. Mental health disorders increased from around 20 to 33 percent in both areas.

The best methods to address this would be through therapy or counseling, but these mental health services are not yet available to people in rural areas. Recently, Mexico began implementing mental health services into their primary health care, but they are still largely unavailable for those in the countryside. In Brazil, there is an extreme lack of mental health professional, in the southern region where most of the major cities are located, including Sao Paulo, there are roughly 5 psychiatrists per 100,000 and in the Northeast, there is less than 1 psychiatrist per 100,000. Sao Paulo is considered to be the best place for psychological help, having 1.75 times more psychiatrists than the national average but comparatively, it is still low (Mateus et al., 2008). In western countries, online therapy has recently emerged to fill in the gap between urban and rural centers, but online therapy has not been commonly adopted in Latin America. Even then, it would require a regular internet connection and computer which is still a problem for poor people.

While mental illness has steadily increased in both urban and rural sections, overall rural areas are facing the worse health comes due to natural disasters. Geographically, there are more often exposed to natural disasters, as well as the increase of hurricanes and wildfires than their urban counterparts, but there is also a large gap between people in aid and resources available. For an individual seeking aid following a natural disaster, their best option is to go to an urban center for help.

Infectious Diseases

As mentioned in the previous section, natural disasters and infectious diseases spread hand in hand. Most climate change related issues in terms of health are not just a result of one

category but overlap with several. Flooding following a natural disaster and disturbing wild animals and insects following wildfires are all linked to the spread of infectious disease. Wildfires as a result of agriculture and the lack of regulation are some of the few instances where natural disasters are the direct factor. Still, the reason why wildfires spread quickly is fundamentally connected to the decrease in precipitation. Vector-borne and waterborne disease are stereotypically thought of as an example of infectious diseases that affect people in rural locations, but other diseases like HVI and COVID-19 both example of infectious diseases which have spread all other the world.

When it comes to infectious diseases like Malaria, Zika, Lime diseases, these diseases predominately attack people in rural areas. They are geographically closer to animals that spread it, and they are not “urban buffer” between residents and the wild. However, when highly infectious diseases hit, like COVID-19, cities are more vulnerable because of the overpopulation and how closely people live with one another. Rural areas are more isolated from outside communities allowing them to more easily control the spread of the infectious. If a rural community is less reliant, as in their ability to feed and care for themselves without outside aid, they less vulnerable to catching a disease like COVID-19. However, if they depend on imports and outside help, their vulnerability increase. In urban areas, on the contrary, it much more difficult to prevent the spread amongst in populations for several million people. People in urban areas are more likely to live in small and overpopulated areas. Poor people living in the informal settlement are the most vulnerable due to the small living condition and how many resources they have to share with their neighbors.

Regardless of all overpopulation in urban centers, they are still a better place to get sick. Mexico City has 3.9 physicians per 1,000 people compared to only 1.2 to 2.2 physicians per

1,000 in rural areas (OECD, 2016). Sao Paulo also has the highest number of physicians per person of all of Brazil but it still falls short of Mexico. There are approximately 1.02 physicians per 1,000 in Sao and a minuscule rate of 0.001 doctors per 1,000 people (*Number of Doctors by State in Brazil 2018*, 2018). As of 2018, there are only 4,844 doctors for a population of 3.874 million people. In terms of prevention, people in rural areas are more likely to catch a vector-borne disease but less likely to catch a highly infectious global disease while people in urban areas are more likely to catch the ladder. Nevertheless, if someone in an urban area catches an illness like COVID-19, they are more likely to get adequate help than someone living in a rural area.

The people living in the rural areas of the Amazon are at a greater risk of catching infectious diseases than people in Yucatan, but both groups of people face a similar struggle in terms of treatment. The low rates of doctors and hospitals in isolated areas contribute to the poor health outcomes due to infectious diseases.

Air Pollution

The Industrial Revolution created the blueprint for modern society, gone are the days where culture was based on agriculture and handicrafts, the Industrial Revolution created large-scale industries, machines, power sources. Through that, factories were created, new forms of transportation were invented, things became easier and cheaper to make. Nonetheless, there are always consequences, and they have been primarily on the planet as well as human health. Starting in the twentieth century, air quality has drastically dropped in most urban areas. Through wind or factories outside of major cities, they have also spread in more rural areas. While

urbanization is the main contributor to air pollution, wildfires also contribute to the decrease in quality. The air quality in both Mexico City and Sao Paulo reached extreme contamination levels around the 1980s, but through effective public health policy and monetization of air quality, cities have been able to improve it and deem it safe. There are still days in the two cities where it is unsafe to spend an extended period outside, and poor people who work outdoor, this is problematic. For rural communities, their air quality overall is better, and are not exposed to as many harmful pollutants. Following a wildfire, the quality of air will of course decrease, but wildfires are not an everyday occurrence.

Almost all diseases related to air pollution have increased in both urban and rural areas. Mexico City saw an increase in chronic respiratory disease from 648.76 to 833.14 DALYs per 100,000. Diabetes type 2 increased 1,660.6 to 3,009.13 DALYs. Chronic obstructive pulmonary diseases increased from 413.54 to 603.71 DALYS. Sao Paulo saw an increase in diabetes type 2 from 754.31 to 978.63 DALYs. Lung cancer rose from 323.72 to 424.51 DALYs per 100,000. Yucatan, on the other hand, saw an increase in Diabetes type 2 from 1,071.93 to1,918.96DALYs, ischemic heart disease 1,178.37 to 1,861.84 DALYs, lower respiratory infectious 1,490.36 to 595.23 DALYs and chronic respiratory disease 604.2 to 670.06 DALYs. The Amazon similarly saw an increase from 385.94 to 773.61 DALYs for Diabetes type 2. However, all other diseases decreased. For instance, Ischemic heart disease went from 779.34 to 771.23 DALYs, chronic respiratory disease decreased from 663.61 to 612.67 DALYs, and lower respiratory infectious dropped1,587.3 to 781.27 DALYs.

For air pollution, it seems that people in urban areas are at a higher risk for contracting air pollution-related diseases. Even with all the available resources, the air quality in urban areas is significantly worse than in rural areas. On average, the days air pollution is considered dangerous

is more often in urban centers than rural areas. Unlike extreme heat, there is little an individual can do to avoid breathing in contaminated air apart from staying home. Even then, indoor air is not completely free from harmful chemicals.

Conclusion

The climate change related problems individuals face in rural and urban areas are more or less the same; the main difference is how exactly they harm the individuals. In rural areas, the main sources of air pollution are wildfires while in urban centers the main sources come from factories, cars, and other industries. But, even if the source changes, the overall source stays the same, climate change. When answering the question of which group suffers the worse overall health outcome as a result of climate change the answer is not as simple. It is easier to answer in terms of individual categories. Extreme heat is about the same for urban and rural poor, natural disasters are more intense for rural areas, infectious diseases are more prevalent and dangerous in rural areas, and air pollution is more dangerous in urban areas. Overall, there is an argument that rural poor has the worse climate change related health outcomes. Nevertheless, urban poor should not be dismissed in the conversation since they are also experiencing some serious consequences.

Chapter VII:

Conclusion

The World Health Organization predicts that at our current rate, climate change will result in 250,000 deaths each year between 2030 and 2050. In less than ten years, the WHO predicts that a quarter-million people will die every year. Then again, looking at the way's climate change is affecting people nowadays, it is not too hard to believe. This thesis aims to answer the key question: do poor people in urban or rural areas experience a greater burden of illness. Just like every other disease, illness as a result of climate change has many different risk factors, making some more vulnerable than others. But if factors such as gender, age, social class are taken out of the picture, and we only focus on how geography contributes to poor health, we may have a better understanding. As an understudied region, Latin America serves to give a new perspective as to how other areas are facing the effects of climate change. The effects of climate change may be irreversible, so it is important to understand how and who is the most affected in order to better help them. As for who is experiencing a worse health outcome, overall, it is poor in rural areas.

The conclusion of how is experiencing a greater health burden is not as simple as comparing the prevalence of diseases in one area to another. There are a lot of unspoken factors which contribute to why people in one area are more likely to suffer than another. What is considered poor in a rural area differs from what is considered poor in an urban area. The number of doctors, hospitals, ICU beds, non-profit widely differs from the two areas. Not only are people in rural areas at a greater overall risk for contracting a climate change related illness, but they less likely to have the resources available to help them. Natural disasters and infectious diseases are more ramped and more intense in rural communities, and there are not enough

recourses available. In more cases, people suffer from illness would have to travel to an urban center to receive the necessary care. The effects of extreme heat are similar in the two regions, there not a clear answer as to what area in specific seeing the worse health outcome. The only area where urban areas see a clear worst outcome is in terms of air pollution. Even with all the existing resources, there is still little poor people can do to avoid air contamination. Poor people in rural and urban regions do not have the luxuries often required of them to avoid getting sick; actives like staying indoors and drinking plenty of water are not always an option, not when you need to go outside to work and pay your bills.

Chapter VIII:

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