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Chair of Demography and Social Challenges

The Combined Effects of Global Warming, Demographic Changes, and Economic Vulnerability on Developing Countries: Insights from the Guatemalan Case Study

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Introduction

The issue of both climate change and demographical dynamics is particularly crucial in today's context, especially when concerning the economic development of emerging countries. Specifically, the term "climate change" encompasses the profound and enduring alterations in the Earth's temperature and atmospheric conditions over extended periods. While natural phenomena such as variations in solar activity and significant volcanic eruptions have historically played a role in these shifts, there is widespread scientific consensus that since the 19th century, human activities have become the predominant catalyst for climate change.[1] This transformation has been primarily instigated by the combustion of fossil fuels, including coal, oil, and natural gas.

More importantly, changes to worldwide temperatures over recent decades have begun to exert their influence on ecosystems: This impact is evident through occurrences such as the diminishing of glaciers and ice sheets, shifts in the geographic range of plant and animal species, and the heightened occurrence and severity of heat waves.[2] These changes inflict irreparable damage to global ecosystems and high economic and social costs on human communities.

Whilst being a phenomenon affecting virtually all regions of the Earth, the effects of global warming are not being equally felt across the world. Geographical differences indeed do play a role in making different countries more susceptible to different variations in the global weather, with certain regions experiencing, for instance, increases in their annual rainfall levels whilst other regions experience prolonged droughts and desertification.

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[1] Lynas, M., Houlton, B.Z., & Perry, S. (2021). Greater than 99% consensus on human caused climate change in the peer-reviewed scientific literature. *Environmental Research Letters 16*(11), 114005. Doi: https://doi.org/10.1088/1748-9326/ac2966.

[2] Arias, P.A., Bellouin, N., Coppola, E., Jones, R.G., Krinner, G., Marotzke, J., Naik, V., Palmer, M.D., Plattner, G.K., Rogelj, J., Rojas, M., Sillman, J., Storelvmo, T., Thorne, P.W., Trewin, B. (2021). Technical Summary. In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Doi: 10.1017/9781009157896.002.

Besides purely geographical differences, global warming has been shown to function as an amplifier of economic and social inequalities, both among countries[3] and within them.[4] Indeed, developed countries, due to their technological advancements and relative macroeconomic stability, seem to be better positioned to adapt to the challenges of a changing climate, whilst developing countries, suffering from low levels of institutional transparency, macroeconomic instability, and low technological progress are projected to be more vulnerable to the effects of climate change.

Similarly, the most vulnerable social groups – including gender, sexual, and ethnic minorities, lower social classes, and rural populations – are likely to suffer more from the effects of climate change, due to their economic, social, and political marginalization exposing them to higher degrees of vulnerability to natural disasters and climate-related macroeconomic shocks.

In addition to geographical and economic features, the demographic composition of societies also impacts the degree of vulnerability to climate change and its effects. Besides demographic variables such as gender and ethnicity, the age structure of a country may also play a role in determining the climate-related challenges it faces. Countries with youthful populations and significant macroeconomic vulnerabilities (e.g., high youth unemployment rates[5]), may experience different challenges than countries with more mature population structures, especially as climate change impacts their economic stability and further disrupts employment opportunities.

Given this general framework, the following questions arise. What is the relationship between climate change, demography, and economics in a developing country? How does this relationship impact phenomena such as food insecurity and

[3] Roberts, J. T. (2001). Global inequality and climate change. *Society & Natural Resources*, *14*(6), 501-509. Doi: https://doi.org/10.1080/08941920118490.
[4] Islam, N., & Winkel, J. (2017). *Climate change and social inequality. DESA Working Paper No. 152 ST/ESA/2017/DWP/152*. Retrieved at: https://abrohilo.org/wp-content/uploads/attachments/wp152_2017.pdf
[5] Yifu Lin, J. (2012). Youth Bulge: A Demographic Dividend or a Demographic Bomb in Developing Countries? *World Bank Blogs*. Retrieved at: https://blogs.worldbank.org/developmenttalk/youth-bulge-a-demographic-dividend-or-a-demographic-bomb-in-developing-countries.

migration? Which elements make a country more vulnerable to global warming than others?

Thus, as stated in the overture of this introduction section, climate change and demographic shifts pose significant challenges to the development of emerging countries. Briefly, on one hand, previous literature importantly demonstrated while climate change may disrupt agricultural production, exacerbating food insecurity and limiting economic growth in these nations, where agriculture often plays a pivotal role. Moreover, extreme weather events, such as droughts and floods, can lead to crop failures and infrastructure damage, impeding progress. On the other hand, demographic changes, including rapid population growth, may strain resources and public services, potentially leading to unemployment and social instability: To foster sustainable development in emerging countries, it is imperative to address these interconnected issues by implementing adaptive strategies, investing in infrastructure resilience, and promoting education and family planning to manage demographic transitions effectively.

Therefore, in light of these considerations, this thesis aims to research the pragmatic effects of global warming on the status of food security and inequality in developing countries, by focusing on an interesting case study that is Guatemala. Indeed, Guatemala is a country located in Central America and characterized by a high vulnerability to climate change, the presence of a demographically significant indigenous population, a relatively low median age, and a developing economy.

Guatemala may be an interesting case study for examining the interplay of climate change and demographic dynamics in emerging countries' development for several reasons. Firstly, it is particularly vulnerable to climate change due to its geographical location, with a susceptibility to hurricanes, droughts, and irregular rainfall patterns. These environmental challenges may directly impact agriculture, a vital sector in Guatemala's economy. Secondly, Guatemala has a rapidly growing population with a large youth demographic, presenting both opportunities and challenges for economic development. Furthermore, the country's ability to harness the potential of its youthful workforce while adapting to climate-related disruptions will offer insights into the broader issues faced by emerging nations. Thus, studying

Guatemala's experiences may provide valuable insights on how to address the complex relationship between climate change and demographic dynamics in fostering sustainable development.

Based on the reasoning above, this thesis will explore the nexus existing between geographical factors (i.e., global warming, soil quality, water scarcity, extreme weather events), demographic factors (i.e., age structure, ethnic composition, gender), and economic factors (for instance, GDP, income distribution, levels of agricultural output), to see how the three elements interplay in shaping the levels of food and social insecurity in the country, as well as in influencing the migration patterns in the country. By combining quantitative data deriving by secondary data for each variable, this research will investigate the quantitative and qualitative effects of the nexus among the three elements, to see whether a correlation does exist and what impact it has on issues such as migration and inequality.

For the purpose of this research project, global warming will be calculated as the variation in the average temperature in the country in a 20-year period, as well as changes in the frequency and intensity of extreme weather events (e.g., tropical cyclones and drought) in the last two decades. The relevant quantitative data will be collected from the World Bank, the Intergovernmental Panel on Climate Change, and the World Meteorological Organization.

The economic variables used in this analysis will be the Gross Domestic Product of the country, its unemployment rate, and the share of the agricultural sector over the total GDP. Indeed, the agricultural sector is particularly susceptible to variations in the local weather, such as changes in rainfall patterns. The data will be collected from institutions' databases such as the World Bank and the International Labour Organization.

With respect to the demographic elements, the present thesis will look at gender and ethnic variables as measures of social inequality and marginalization, as well as at the percentage of rural population over the total population. Gender and ethnic minorities, alongside the rural population (mainly of Indigenous background), are expected to suffer more from the effects of climate change. Moreover, the

demographic variable of age will be given particular emphasis within this thesis project, in particular with respect to the vulnerability associated with a youthful population in developing countries. The relevant demographic data will be collected from international organizations' databases, such as the World Bank, as well as official statistics.

The thesis will address these questions, by following the following structure: The First chapter of this thesis provides a broad introduction to the demographic and economic outlook of Guatemala and will better explain the concept of climate change and its connection to issues such as food security, and shedding light on the main data and concepts that will be used in the subsequent chapters.

The Second chapter sheds light on the relationship existing between climate change and food security in the country, whilst also providing relevant statistics on how this correlation impacts gender and ethnic minorities. To detail, the chapter begins by providing an overview of how climate has changed in the nation in the past decades, in terms of annual mean temperature, extreme weather events, and changes to precipitation patterns. Then, it sheds light on how these changes may impact the country's agricultural sector, and, in turn, the rates of food security of its population. It will then measure the impact of demographic variables – namely gender, ethnicity, and urbanization – on access to food and water security.

Then, the Third chapter specifically looks at the role played by the age structure of the country in its vulnerability rates to climate change: Firstly, it provides the main theoretical and empirical theories in demographic and security literature regarding the relationships existing between the youthful population, unemployment, and violence in developing countries. Then the presence of a youthful population in an economic context characterized by unemployment, together with how such a protentional opportunity may play a role in fuelling the high rates of social violence in the country is analysed, also by considering the migration flows of Guatemalans towards the United States of America.

The Fourth chapter explores the "replicability" of the findings of the previous chapters, by comparing the demographic, geographical, and economic features of

Guatemala with two other countries, namely El Salvador and Honduras. These two countries have been chosen because of their similarities with Guatemala, forming together a region collectively known as the "Northern Triangle of Central America" (NTCA), which has become a central point of interest for academic literature due to its shared vulnerability to climate change (and particularly drought), its rates of violence and criminality, and its status as a global hub of emigration. Moreover, this chapter also offers a comparison of these three countries to shed light on the combined effects of Demography, Climate Change, and Economics on Guatemala, alongside countries with similar structures.

Finally, the last section of this thesis briefly draws the conclusions and explains their relevance as well as their connection to previous literature and the potential elements that should be analysed by future studies.

Chapter 1: The Demographic and Economic Outlook of Guatemala

1.1 The Linkage Between Food Security and Climate Change

The Rome Declaration on World Food Security, adopted during the 1996 World Food Summit, defines food security as existing when "all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life". This definition identifies four dimensions of food security, which must be met simultaneously in order to ensure its achievement. Namely, these four dimensions include the physical *availability* of food (specifically, the level of food production, the net trade, and the stock access of food), the economic and physical *access* to food (i.e., ensuring that individuals are able to obtain and afford food, free from income constraints and other barriers), the *utilization* of food (how the body processes and exploits the macro- and micro-nutrients in the consumed aliments, determining the nutritional status of the individual), and the *stability* of all of the previous dimensions over time.[6] The fourth dimension captures the concept of vulnerability, i.e., the persistence of all other indicators through time. As such, it is a measurement of susceptibility to risks and threats to food security and of the ability to overcome them.[7]

Despite ground-breaking changes in the systems of food production and distribution – such as technological advancements and the globalization of supply chains – have ushered in the emergence of an interconnected global economy capable of creating more resistant and nutritious aliments and trading them around every corner of the globe, food insecurity remains a significant international challenge.[8] Indeed,

[6] The World Bank (2022). *What is Food Security?* Retrieved at: https://www.worldbank.org/en/topic/agriculture/brief/food-security-update/what-is-food-security.
[7] Mahadevan, R., & Hoang, V. (2016). Is There a Link Between Poverty and Food Security? *Social Indicators Research*, *128*(1), 179–199. Retrieved at: https://www.jstor.org/stable/48715535.
[8] FAO, IFAD, UNICEF, WFP, & WHO (2022). *The State of Food Security and Nutrition in the World 2022*. *Repurposing food and agricultural policies to make healthy diets more affordable*. Rome, FAO. https://doi.org/10.4060/cc0639en.

pursuant to estimations provided by the Food and Agriculture Organization of the United Nations, between 702 and 828 million people were affected by hunger in 2021. Hunger and malnutrition are global phenomena; Nevertheless, there still remain stark inequalities in the figures of malnourishment, both among and within countries. Specifically, lower-income nations and their most vulnerable social groups are more threatened to suffer from food insecurity than their higher-income counterparts.[9] Citizens with lower levels of personal wealth, unstable incomes, and reduced means to access basic social services remain at a higher risk to suffer from malnutrition than more privileged social groups; These unequal patterns of food security are exacerbated in lower-income countries with low responsiveness from political institutions and weak state apparatus.[10]

Estimates collected by the Food and Agriculture Organization of the United Nations show that countries in Africa, Asia, and Latin America have higher percentages of citizens suffering from undernourishment than countries in North America and Europe. Indeed, as of 2021, food insecurity affected 20.2% of citizens in Africa, 9.1% of citizens in Asia (with stark variations among different regions of the continent, with less than 2.5% of Eastern Asians suffering from malnutrition vis-à-vis around 16.9% of Southern Asians), and 8.6% of Latin Americans, whilst less than 2.5 percent of Europeans and North Americans experienced undernourishment. Moreover, the percentage of citizens suffering from food insecurity at the global level increased from 7.8 percent in 2016 to 9.8 percent in 2021; the increase in the rate of malnutrition in the period 2016-2021 affected all of the African macro-regions, Southern Asia, and all of Latin America and the Caribbean (see Figure 1 below).

[9] FAO et al. (2022). *The State of Food Security and Nutrition in the World 2022.*
[10] Subramaniam, Y., Masron, T.A., & Subramaniam, T. (2022). Institutional Quality and Food Security. *The Singapore Economic Review 67*(6), 2099-2127. Doi: https://doi.org/10.1142/S0217590820500046.

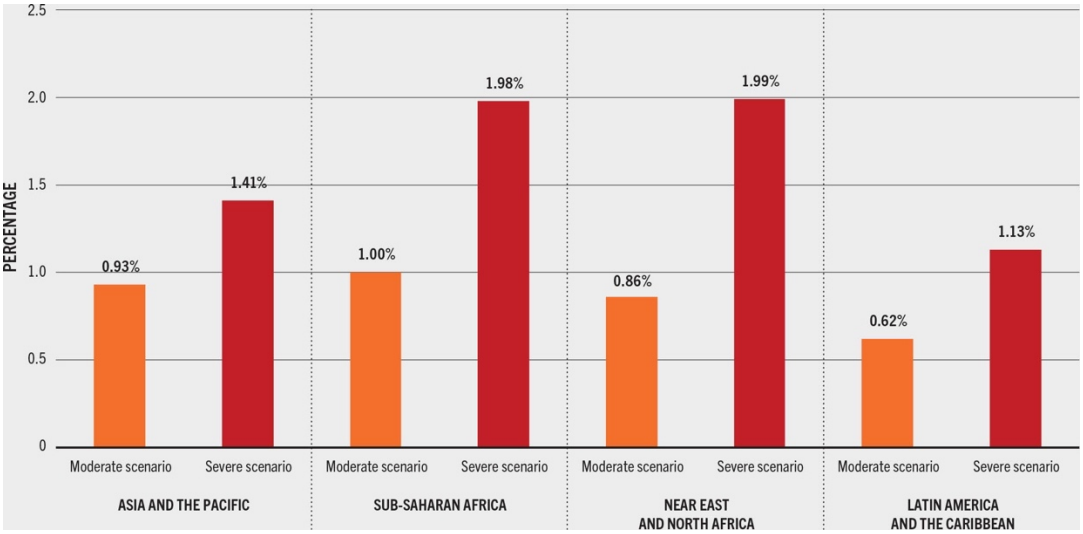

Figure 1: Estimated Increase in The Number of Undernourished People in 2022 by Region; *Source*: FAO, 2022[11]

Alongside traditional threats to food security – such as natural disasters, poverty, and blocks in the supply chain – a new emerging factor has the potential of further threatening the status of food security at the global level: Climate change.[12] Climate change broadly refers to the long-term alterations of global temperatures and weather events. Such alterations can be natural, but climate scientists collecting and researching data since the middle twentieth century identified a general trend of increase in global temperatures happening at a faster rate than previous changes.[13] As of 2021, the scientific community largely agrees in considering the current warming of global temperatures as having mainly been driven by human activities – and particularly by the burning of fossil fuels since the beginning of the Industrial

[11] Note: The percent change in the number of undernourished people is calculate as the difference between the moderate and severe scenario results and the projected number of undernourished people in a baseline scenario for 2022 based on FAO estimates. Source: FAO (2022), Retrieved at: https://www.fao.org/3/cc0639en/online/sofi-2022/food-security-nutrition-indicators.html#fig3a.
[12] Gregory, P.J., Ingram, J.S.I., & Brklacich, M. (2005, Oct 24). Climate Change and Food Security. *Philosophical Transaction of the Royal Society B. Biological Sciences, 360*(1463). Retrieved at: https://royalsocietypublishing.org/doi/abs/10.1098/rstb.2005.1745.
[13] Allen, M.R., Dube, O.P., Solecki, W., Aragón-Durand, F., Cramer, W., Humphreys, S., Kainuma, M., Kala, J., Mahowald, N., Mulugetta, Y., Perez, R., Wairiu, M., & Zickfeld, K. (2018). Framing and Context. In: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Retrieved at: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_Chapter1_High_Res.pdf

Revolution.[14] The United Nations lists among the main drivers of global warming a variety of human activities, including: the production of energy (specifically electricity and heat) through fossil fuels – powerful contributors to the emission of greenhouse gases which capture the heat of the Sun inside the Earth's atmosphere; The manufacturing of goods – including clothing, plastic items, infrastructures, and other man-made items created through mechanical and industrial processes employing large quantities of energy and fossil fuels; deforestation, i.e., the destruction of forest habitats with the purpose of creating pastures and farms, producing paper, as well as for the extraction of timber and other natural resources;[15] Transportation, as the majority of means of transportation, such as planes, ships, and most cars, require the combustion of petroleum-based products to function, resulting in large-scale emissions of greenhouse gases, particularly carbon-dioxide; Food production, which significantly contributes to global warming through emissions of methane, carbon-dioxide, and other greenhouse gases, as well as worsening the status of environmental degradation through processes such as deforestation, use of fertilizers and pesticides, and water consumption.[16]

The rise of global temperatures in the past decades is already affecting ecosystems; examples include the shrinking of glaciers and ice sheets, changes in the geographical distribution of plant and animal species, and more frequent and intense heat waves.[17] Global warming is already showing its impacts. The Intergovernmental Panel on Climate Change (IPCC)[18] has pointed out to the fact that the published evidence and scientific literature imply that the costs and damages caused by global

[14] Lynas, M., Houlton, B.Z., & Perry, S. (2021). Greater than 99% consensus on human caused climate change in the peer-reviewed scientific literature. *Environmental Research Letters 16*(11), 114005. Doi: https://doi.org/10.1088/1748-9326/ac2966.
[15] Archana, K. (2013). Impact of Deforestation on Climate. *IOSR Journal of Environmental Science, Toxicology, and Food Technology 4*, 24-28. Doi: https://doi.org/10.9790/2402-0422428.
[16] Driga, A.M., & Drigas, A.S. (2019). Climate Change 101: How Everyday Activities Contribute to the Ever-Growing Issue. *International Journal of Recent Contributions from Engineering, Science & IT (iJES) 7*(1), 22-31. Doi: https://doi.org/10.3991/ijes.v7i1.10031.
[17] Shaftel, H., Callery, S., Jackson, R., & Bailey, D. (2023). The Effects of Climate Change. *Global Climate Change: Vital Signs of the Planet*. Retrieved at: https://climate.nasa.gov/effects/.
[18] The IPCC is the United Nations' body tasked with assessing the science behind climate change. Created in 1988 by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO), its purpose is to provide governments with the scientific information needed to develop effective climate policies. Its reports also serve as a base for carrying out international climate change negotiations.

warming are likely to be significant and increase in frequency and intensity over time. In particular, some of the most relevant impacts of climate change as identified by the IPCC include – but are not limited to: Increases in the average global temperatures; increased rates of drought and desertification; disruptions in the frequency and intensity of precipitation; reductions in the snow cover extent; increases in the proportion of intense tropical cyclones; rise in the sea levels with loss of coastal areas.[19] Current insights suggest that the world is on track to likely hit a global warming of +1.5°C above the pre-industrial levels somewhere between 2030 and 2052 at the current pace.[20] More recent statistics and data seem to suggest that the +1.5°C threshold could be hit as soon as the early 2030s.[21] When this happens, the changes to the climate system are likely to be relevant and potentially disruptive across the planet: estimates suggest that with a median temperature +1.5°C degrees warmer than the pre-industrial average, phenomena like droughts that used to occur once in a decade will happen with a frequency ×2.0 higher (with a minimum range of ×1.0 and maximum range of ×5.1), whilst the proportion of intense tropical cyclones will increase by +10%.[22]

Climate change and food security are deeply interconnected issues. Food security is sustained by food systems, i.e., dynamic schemes of production, processing,

[19] Arias, P.A., Bellouin, N., Coppola, E., Jones, R.G., Krinner, G., Marotzke, J., Naik, V., Palmer, M.D., Plattner, G.K., Rogelj, J., Rojas, M., Sillman, J., Storelvmo, T., Thorne, P.W., Trewin, B. (2021). Technical Summary. In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Doi: 10.1017/9781009157896.002.

[20] IPCC, 2018: Summary for Policymakers. In: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 3-24, doi:10.1017/9781009157940.001.

[21] Diffenbaugh, N.S., & Barnes, E.A. (2023Data-Driven Predictions of the Time Remaining Under Critical Global Warming Thresholds are Reaches. *Proceedings of the National Academy of Sciences (PNAS) 120* (6). Doi: https://doi.org/10.1073/pnas.2207183120.

[22] The afore-mentioned phenomena are already taking place. The IPCC has drawn estimates on how much the climate system will react to temperature changes. The data suggests that progressively higher levels of global warming will result in greater changes to the Earth ecosystem. The temperature increase is calculated using as a start point pre-Industrial levels. As of 2021, the median temperature of Earth stood at +1.1°C above the pre-industrial average. At this rate of global warming, a drought that used to happen once in a decade now happens ×1.7 times more; what used to be the wettest day in a decade now happens ×1.3 times more; the snow cover extent changed by -1%.

distribution, preparation, and consumption of food resulting from an interplay between environmental and human factors.[23] Food systems sustain food security since they comprise the *availability* (in terms of production, distribution, and exchange), *access* (in terms of affordability, allocation, and preference), and *utilization* (in terms of safety, nutritional value) of food. As such, changes and disruptions in the health of food systems are reflected in the status of food security. Global warming and changes in the Earth temperatures may affect the stability of food systems in a variety of ways. As farming and agriculture strongly depend on geographical features, such as weather predictability and soil quality, changes in these elements threaten the stability of food production.[24] Environmental degradation, drought and desertification, changes in the availability of water resources, floodings, loss of biodiversity, and tropical cyclones directly threaten the status of food security at the global level, with the risk of aggravating the rates of malnourishment around the world.[25]

Moreover, despite climate change and food insecurity being global phenomena, the negative results of the interplay between the two are likely to be more harshly felt in lower-income countries. Increases in climate change vulnerability are positively associated with rising income inequalities. Whilst climate change seems to have no statistically-relevant effects on income distribution in advanced economies, the coefficient on vulnerability to climate change has been found to be highly-statistically significant in developing countries – due to weaker capabilities of mitigation and adaptation to climate change.[26] As climate change affects the production and availability of cereals, vegetables, and other staples, the price of food is expected to increase as a result of a potential overall decline in global food

[23] Gregory, P.J., Ingram, J.S.I., & Brklacich, M. (2005). Climate Change and Food Security. *Philosophical Transaction of the Royal Society B. Biological Sciences, 360*(1463). Retrieved at: https://royalsocietypublishing.org/doi/abs/10.1098/rstb.2005.1745.

[24]Mbow,C.,C.Rosenzweig,L.G.Barioni,T.G.Benton,M.Herrero,M.Krishnapillai,E.Liwenga,P.Pradhan, M.G.Rivera-Ferre, T. Sapkota, F.N. Tubiello, Y. Xu, (2019): Food Security. In: *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*. Retrieved at: https://www.ipcc.ch/site/assets/uploads/2019/11/08_Chapter-5.pdf.

[25] Muluneh, M.G. (2021). Impact of Climate Change on Biodiversity and Food Security: A Global Perspective – A Review Article. *Agriculture & Food Security 10*(36). Doi: https://doi.org/10.1186/s40066-021-00318-5.

[26] Cevik, S., & Jalles, J. T. (2023). For whom the bell tolls: Climate change and income inequality. *Energy Policy*, *174*. Doi: https://doi.org/10.1016/j.enpol.2023.113475.

production[27]. FAO estimates suggest that the countries which will face greater challenges to their agricultural outputs due to global warming are located in the tropical and subtropical regions of the world, areas in which hunger and malnutrition are already prevalent.[28]

The threats posed by climate change on food and social security are not only positively associated with income distribution variables; they also have differential effects on different demographic cohorts. Gender and ethnic inequalities are likely to be reflected in different rates of vulnerability to the effects of climate change. Global warming acts as a threat multiplier.[29] It magnifies existing patterns of inequalities, with minority groups being disproportionately affected by its consequences. A report by the UN Women[30] found that women are more likely to be impacted by all the challenges underlined in the United Nations' Sustainable Development Goals (SDGs). As global warming increases the likelihood of natural disasters and extreme weather events, gender and social minorities are more likely to disproportionately suffer from these threats.[31] A positive correlation has also been shown to exist between natural disasters and gender-based violence.[32] Globally, women make up 43% of agricultural workforce.[33] Figures on female employment in agriculture vary greatly between high-income countries and developing countries, with the latter having higher percentages

[27] Von Witzke, H. (2008). Agriculture, World Food Security, Bioenergy and Climate Change: Some Inconvenient Facts. Quarterly Journal of International Agriculture 47(1), 1-4. Retrieved at: https://www.agrar.hu-berlin.de/de/institut/departments/daoe/ihe/Veroeff/hvw.pdf.
[28] Alexandratos, N., & Bruinsma, J. (2012). *World Agriculture Towards 2030/2050: The 2012 Revision* (ESA Working Paper no. 12-03). FAO. https://www.fao.org/3/ap106e/ap106e.pdf.
[29] Economist Impact (2023). *Gender Inequality and Climate Change are not Separate Challenges*. Retrieved at: https://impact.economist.com/sustainability/social-sustainability/gender-inequality-and-climate-change-are-not-separate-challenges.
[30] Acronym for United Nations Entity for Gender Equality and the Empowerment of Women, the UN agency tasked with tackling gender inequality and working towards the achievement of women empowerment. The afore-mentioned report is titled "*Women and Sustainable Development Goals*". https://sustainabledevelopment.un.org/content/documents/2322UN%20Women%20Analysis%20on%20Women%20and%20SDGs.pdf.
[31] Gloor, J.L., Mestre, E.B., Post, C., & Ruigrok, W. (2022). We Can't Fight Climate Change Without Fighting for Gender Equity. *Harvard Business Review*. Retrieved at: https://hbr.org/2022/07/we-cant-fight-climate-change-without-fighting-for-gender-equity.
[32] Sloand, E., Killion, C., Gary, F.A., Dennis, B., Glass, N., Hassan, M., Campbell, D.W., & Callwood, G.B. (2015). Barriers and Facilitators to Engaging Communities in Gender-Based Violence Prevention following a Natural Disaster. *J Health Care Poor Underserved 26*(4), 1377-1390. Doi: 10.1353/hpu.2015.0133.
[33] IFAD (2022). *These Numbers Prove That Rural Women Are Crucial for a Better Future. But They're Not Getting What They Need to Succeed*. Retrieved at: https://www.ifad.org/en/web/latest/-/these-numbers-prove-that-rural-women-are-crucial-for-a-better-future.

of female employment in agriculture[34]. The potentially disruptive effects of global warming on agricultural production are therefore expected to have a high impact on female employment and food security.

Other vulnerable demographic categories experiencing higher rates of vulnerability to climate change are ethnic minorities and indigenous groups. In particular, indigenous peoples are expected to suffer more immediate and serious threats to their survival due to climate change in light of their special cultural relationship and economic dependence upon the local environment and its resources.[35] Indigenous people already suffer from higher levels of food insecurity; they are among the most marginalized groups in societies, with rare access to decision-making processes and low levels of economic and political participation.[36] Globally, indigenous groups tend to derive their economic subsistence from agriculture, fishing, and livestock. The food systems supporting their communities often depend on traditional agricultural practices, seasonality, predictable weather patterns, access to water, and soil quality. Changes in these elements due to global warming are expected to disproportionally affect indigenous peoples and their rates of malnourishment, magnifying the already-prevalent levels of social exclusion and food insecurity.

[34] According to estimates collected by the International Labor Union and the World Bank, the percentage of female employment in agriculture in 2019 stood at 3% in the European Union and 1% in the US and Canada, whilst standing at 53% in Sub-Saharian Africa and 57% in South Asia. Latin America and the Caribbean presented high cross-country fluctuations, with higher income economies in the region such as Chile and Uruguay standing at 5% and 4%, respectively, and lower-income countries such as Peru and Bolivia standing at 26% and 30%, respectively. Source: The World Bank: https://data.worldbank.org/indicator/SL.AGR.EMPL.FE.ZS?locations=EU-XU-ZJ-ZG-8S.

[35] United Nations Department of Economic and Social Affairs (2021). *World Social Report 2021: Reconsidering Rural Development*. Retrieved at: https://www.un.org/development/desa/dspd/wp-content/uploads/sites/22/2021/05/OVERVIEW_WSR2021.pdf.

[36] UNHCR (2020). *Indigenous People's Knowledge and Climate Adaptation*. Retrieved at: https://www.unhcr.org/media/indigenous-peoples-knowledge-and-climate-adaptation.

1.2 Demographic Assessment of Guatemala: Population, Age Structure, Ethnic Composition

As of 2023, the United Nations estimated a total population in Guatemala of around 18,857,293 people. Considering Mexico as part of North America, this data makes Guatemala the most populous country in Central America and the Caribbean, and the eleventh most populous country in the Americas. Guatemala's population has been growing steadily since the mid-1980s, when the annual population growth percentage of the country reached a 2.8 percent increase rate. With a negative net migration and a fertility rate of 2.9 per woman in 2020, the Country's annual population growth rate from 2019 to 2020 was 1.90 percent.[37] This collocates Guatemala above the world average annual growth rate of 1.1 percent in the same period (World Bank, 2022). The nation is set to reach a population of over 20 million in 2027 and 30 million in 2066 (Fig. 2).

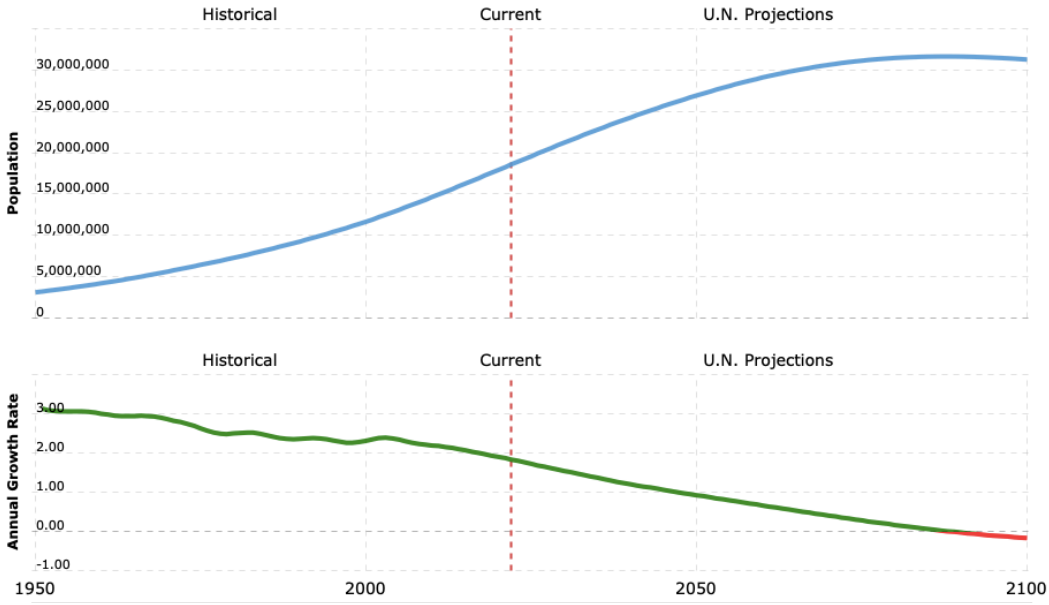

Figure 2: Guatemala's total population and annual growth rate in the period 1950-2100; Source: UN Department of Economic and Social Affairs, 2019.

[37] World Population Review (2023). *Guatemala Population 2023*. Retrieved at: https://worldpopulationreview.com/countries/guatemala-population.

The country's population is still very young, with roughly half of Guatemalan citizens below the age of 19. The median age in the country stood at 21.7 years in 2020.[38] With roughly 33 percent of the total population having an age between 0-year-old and 14-year-old, as of 2021 Guatemala was the country with the youngest population in all of Latin America and the Caribbean (The World Bank, 2022)[39]. In 2020, the country had a crude birth rate of 22 per 1,000 people, and a crude death rate of 5 per 1,000 people (The World Bank, 2022).[40] Such insights are shown in the Figure 3 below. In light of this data, Guatemala appears to be in the process of leaving behind the second stage and entering the third stage of the demographic transition model.

[38] O'Neill, A. (2023). *Median Age of the Population in Guatemala 2020*. Statista. Retrieved at: https://www.statista.com/statistics/441803/average-age-of-the-population-in-guatemala/.

[39] The percentage of population aged 0-14 over the total population in Latin America and the Caribbean was estimated to be at 24% in 2021. Guatemala presented the youngest population in the continent, with 33% of its population having an age comprised between 0-year-old and 14-year-old, shortly followed by Haiti (32% of total population ages 0-14). Source: The World Bank: https://data.worldbank.org/indicator/SP.POP.0014.TO.ZS?locations=ZJ&most_recent_value_desc=true.

[40] The World Health Organization defines the crude birth rate as "*the ratio between the number of live births in a population during a given year and the total mid-year population for the same year, usually multiplied by 1,000*", whilst the crude death rate is calculated as "*the number of deaths over a given period divided by the person-years lived by the population over that period. It is expressed as number of deaths per 1,000 population*". https://www.who.int/data/gho/indicator-metadata-registry/imr-details/3198.

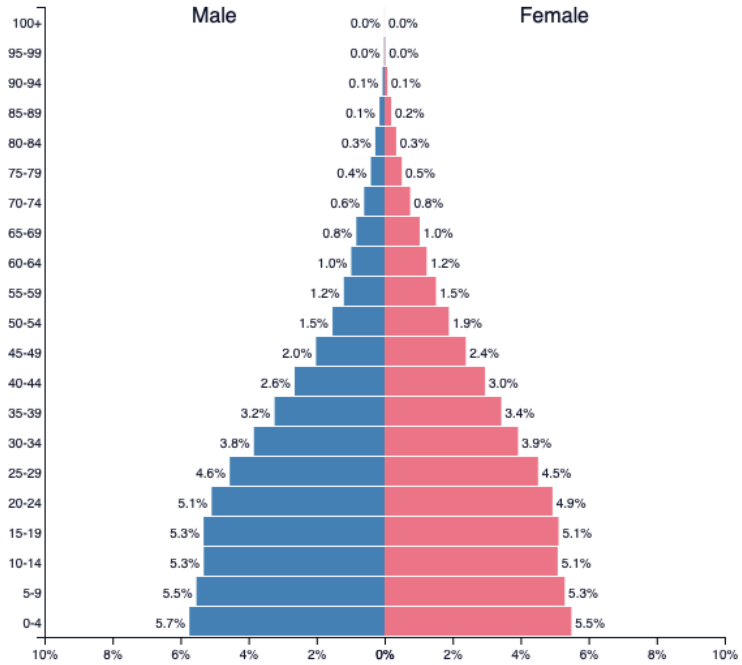

Figure 3: Guatemala's population pyramid in 2022; *Source*: PopulationPyramid.net, 2022.

The Demographic Transition Model (DTM) is a framework used to represent the transition from traditional societies with minimal levels of economic development, technological advancement, and education, characterized by high birth rates and high death rates, to industrialized societies characterized by low birth rates, low death rates, and high levels of economic development, technological advancement, and education. The DTM was firstly developed based on the interpretations given in 1929 by Warren Thompson, an American demographer, on demographic history. The original model – built on data gathered by Thompson on various countries – identified three main groups according to their patterns of population growth. The nations falling into the first of these groups exhibited a shift from very high rates of natural increase to very low rates of increase, and were characterized by high levels of industrialization and economic development; the countries falling into the second group showed evidence of a decline in both birth rates and death rates, but Thompson suggested that the death rate would continue declining as rapidly or more rapidly than the birth rate in the

medium term; the third group, namely largely-traditional societies outside of Europe and North America, saw little evidence of control over either deaths or births.[41]

The findings of Thompson (1929) were expanded fourteen years later by Frank Notestein, who defined the pattern of the first group identified by Thompson as "incipient decline", the second one as "transitional growth", and the third one as "high growth potential". Thus, the first model of the demographic transition was roughly divided into three stages. The first one, the high growth potential, was characterized as having both high death rates, high birth rates, and a stationary population. During the second stage, the transitional growth, the death rate falls more rapidly than the birth rate, resulting in a rapid expansion of the population. In the third stage, the incipient decline, both death rates and birth rates are low, resulting in a slowdown of the population growth. The key finding from the DTM entails the existence of a negative correlation between fertility and economic and social development.[42]

Today, the standard DTM assumes the presence of five stages[43], as shown in Figure 4 below. Under this model, the demographic transition represents the framework explaining why rapid population growth constitutes a temporary phenomenon. The first stage, the pre-industrial stage, is characterized by both high birth rates and high death rates, and therefore there is little to no population growth. The second stage sees improvements in public health as societies begin to modernize, and as a consequence, death rates begin to rapidly fall, whilst birth rates, at least in an initial moment, remain high. The third stage sees falling birth rates whilst mortality keeps slowly decreasing, and therefore the rapid increase in population begins to slow down. The fourth stage sees both low death rates and low birth rates, with the population stabilizing. The fifth stage is a phenomenon which has been identified so

[41] Thompson, W.S. (1929). *Population*. The American Journal of Sociology 34(6), 959-975. Retrieved at: https://u.demog.berkeley.edu/~jrw/Biblio/Eprints/%20T-V/thompson.1929.AJS.population.pdf.
[42] Myrskylä, M., Kohler, H.P., & Billari, F.C. (2009, Aug 6). Advances in development reverse fertility rates. *Nature 460*, 741-743. Doi: https://doi.org/10.1038/nature08230.
[43] Roser, M. (2023). *Demographic transition: Why is rapid population growth a temporary phenomenon?* Published online at OurWorldInData.org. Retrieved at: https://ourworldindata.org/demographic-transition.

far in very few societies, and therefore there is still little evidence on how the fertility rate of those countries will change in the medium/long term.

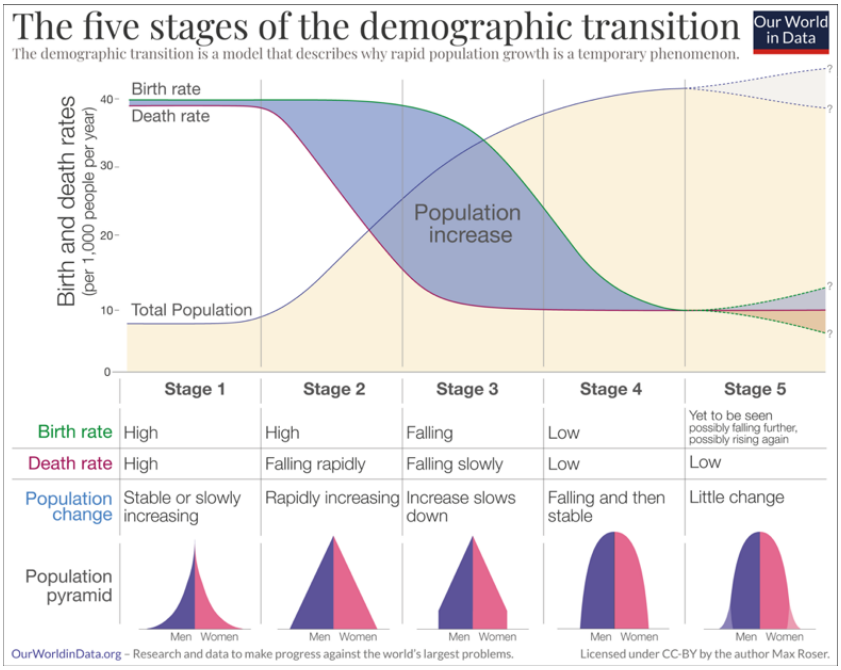

Figure 4: Graphic Representation of the DTM with Respective Population Pyramids; *Source*: OurWorldinData.org (2017).

Guatemala appears to be entering the third stage of the demographic transition model. Indeed, its crude death rates have been declining sharply in the last decades, falling from a mortality rate of 19 in 1960 to an estimated mortality rate of 5 in 2020. As concerns the birth rate in the country, it has also been falling consistently and incrementally, passing from a value of 48 in 1960 to a value of 39 in 1990, and reaching an all-time low in 2020 with a crude birth rate of 22; whilst the 30-year period 1960-1990 saw a decrease of 9 points in the crude birth rate of the country, the 30-year period from 1990 to 2020 saw a 17-point decrease, signifying a faster pace in the last years in the decline of the crude birth rate in the nation. As shown in Figure 5, the fall in the death rate in the country has been slowing down in the last years, whilst the birth rates have begun to decline more rapidly.

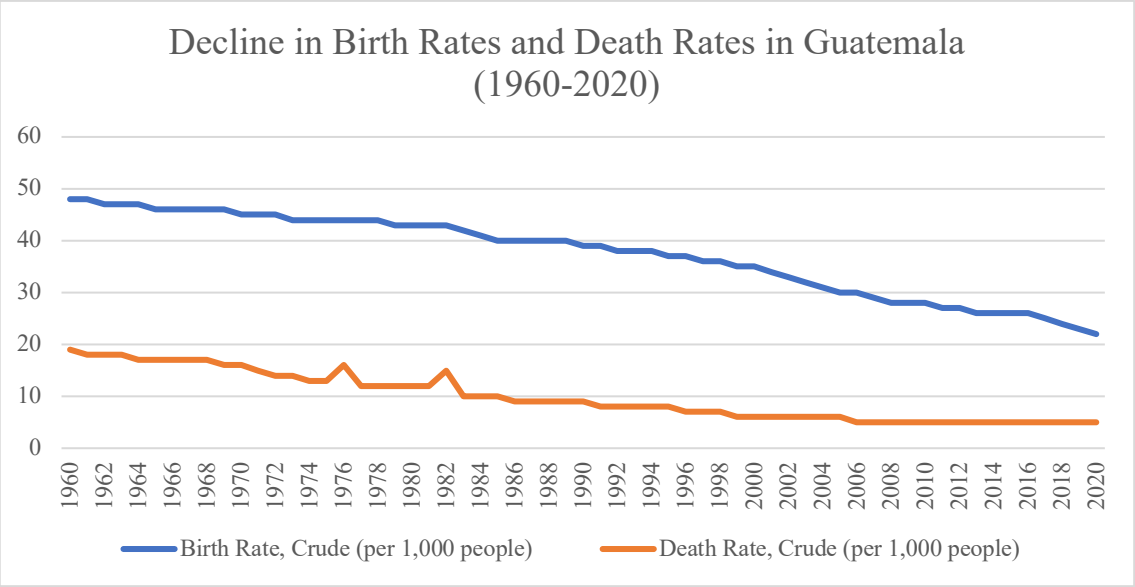

Figure 5: Decline in Death and Birth Rates in Guatemala, 1960-2020; *Source*: World Bank (2020) [44]

The country is set to enter the demographic window in the following years. Within the demographic evolution of a nation, the demographic window is a period of time in which the percentage of working-age population (defined as people over the age of 15 and below the age of 65) constitutes a significant proportion of the total population. During this window, the dependency ratio[45] of a nation shrinks, resulting in a potential boost for economic and social development, higher levels of savings, and stronger investments in human capital, as a rapid growth of the labor force occurs whilst the relative proportion of children decreases.[46] As concerns the precise quantitative boundaries of the demographic window, the United Nations Commission on Population and Development defines it as the period in which the proportion of old people (individuals aged 65-year-old or more) is below 15 percent of the total population, whilst the proportion of children (individuals aged 0 to 14) falls below 30 percent of the total population. By using these parameters, Guatemala is still to enter

[44] Graph drawn based on data collected from The World Bank Databases. For Crude Birth Rates: https://data.worldbank.org/indicator/SP.DYN.CBRT.IN?locations=GT. For Crude Death Rates: https://data.worldbank.org/indicator/SP.DYN.CDRT.IN?locations=GT.

[45] The ratio of children (individuals aged 0-14) plus elderly (individuals aged 65+) to working-age adults.

[46] Crenshaw, E.M., Ameen, A.Z., & Christenson, M. (1997). Population Dynamics and Economic Development: Age-Specific Population Growth Rates and Economic Growth in Developing Countries, 1965 to 1990. *American Sociological Review 62*(6), 974. Doi: https://doi.org/10.2307/2657351.

the demographic window; indeed, whilst the proportion of elderly in the country stands at 5 percent of the total population, the proportion of children below the age of 15 stands at 33 percent of the total population, slightly above the 30 percent threshold conventionally considered to mark the beginning of the demographic window.

With respect to the ethnic composition of the Guatemalan population, the country can be roughly divided into a non-indigenous majority and various indigenous Maya denominations constituting a significant minority, as can be seen in Figure 6. The "non-indigenous" majority – called *Ladino* in official Guatemalan statistics – is also known as "*mestizo*". This term refers to individuals of mixed ancestry – the descendants of European settlers and colonizers and indigenous Maya groups. The percentage of *Ladinos* in Guatemalan society, whilst still constituting a majority, appears to be relatively shrinking; it was estimated at roughly 60 percent in 2002[47], but a 2018 national census by the Instituto Nacional de Estadistica Guatemala[48] found *Ladinos* constituting 56.01 percent of the country's population. The remaining percentage of the population is mainly composed by indigenous Maya people, themselves divided into different groups and cultures. There are high discrepancies in terms of living conditions between the *Ladino* majority and the Maya people, with the former exhibiting higher levels of economic and political influence over Guatemalan society and institutions, as well as higher rates of urbanization and literacy.[49]

[47] Anderson, T.P., Horst, O.H., Griffith, W.J., & Stansifer, C.L. (2023). *Guatemala*. Encyclopædia Britannica. Retrieved at: https://www.britannica.com/place/Guatemala.
[48] Data retrived from: https://www.ine.gob.gt/sistema/uploads/2021/11/19/202111192139096rGNQ5SfAlepmPGfYTovW9MF6X2turyT.pdf.
[49] Anderson et al., 2023

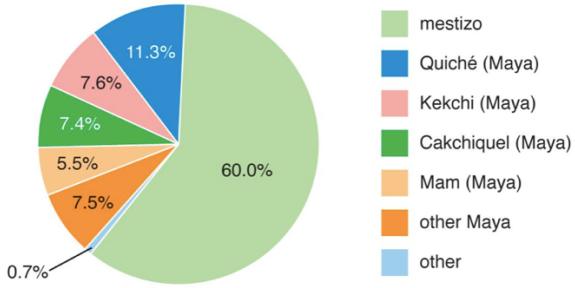

Figure 6: Ethnic Composition of Guatemalan Society; *Source*: Encyclopædia Britannica (2002)

1.3 Urbanization, Geography, and Weather Conditions in Guatemala

Geologically positioned at the convergence between the North American Plate, the Caribbean Plate, and the Cocos Plate – one of the most seismically and volcanically active regions in the world – Guatemala has historically been prone to natural hazards such as earthquakes and volcanic eruptions; moreover, bordering the Pacific Ocean to the west and the Caribbean Sea to the east in a tropical area has made it vulnerable to hurricanes, mudslides, and floods. Deforestation, overexploitation of its natural resources (especially carried out by foreign multinational companies, such as the United Fruit Company during much of the 20th century), and unsustainable slash-and-burn agricultural practices, have impoverished the country's water, timber, and raw materials' supplies. Guatemala can be approximately divided into three different geographical regions; the northernmost part of the country is occupied by the Petén, a sparsely populated area constituted by lowlands covered in tropical forests; the Pacific lowlands, in the western region of the nation; and the Guatemalan highlands, stretching across the central part of the country. The majority of the population resides in this latter region, where the biggest cities are located. The volcanic belt in the south of the country presents highly fertile soils. However, the whole region, and particularly the northern part of the volcanic belt and the Sierra region, are suffering from high levels of soil erosion – largely caused by human practices such as deforestation; heavy rainfall, predicted to be exacerbated by climate change, further threatens to aggravate the widespread soil erosion in the country.[50]

The environmental situation in Guatemala has been dramatically worsening in the last decades. The demographic growth, the rapid urbanization of the country, alongside an upsurge in productivity and demand have increased the pressure on the environment and the exploitation of natural resources.[51] One of the key environmental problems regards the loss of forest areas. Global Forest Watch estimated a loss of -

[50] Stansifer, C.L. , Anderson, T.P. , Horst, O.H. and Griffith, W.J. (2023). *Guatemala*. Encyclopedia Britannica, https://www.britannica.com/place/Guatemala.
[51] Universidad Rafael Landívar & Instituto de Incidencia Ambiental (2006). *Perfil Ambiental de Guatemala: Tendencias y Reflexiones Sobre la Gestión Ambiental*. Retrieved at: https://www.url.edu.gt/publicacionesurl/FileCS.ashx?Id=41022.

1.63Mha[52] in Guatemala's tree cover for the period 2000-2020; that equals a loss of -21 percent of the nation's total tree cover over a twenty-year period, and a total of 755Mtn of CO_2e emissions. Around 34% of the country's total tree loss in the period 2002-2021 was represented by humid primary forest[53], whose total area shrank by 21 percent over this time span. The region most affected by deforestation was the Perén tropical lowlands.[54] The main drive behind this process is to be attributed to the conversion of primary tropical forests into unsustainable agricultural and production systems, often the result of high levels of rural unemployment leading rural workers to reconvert forest areas into land used for grazing and agriculture.

The issue of deforestation is also deeply linked to the rapid demographic growth of Guatemala's population and to its urban transition, as an increasing percentage of forested area is being transformed into spaces for urban expansion of pre-existing cities or the creation of new settlements.[55] As primary forests play a key role in preventing and mitigating natural hazards such as floodings, their disappearance and reconversion into land used for urban development on unsuitable territory – with extremely high numbers of population density – aggravates the threat of natural disasters. The correlation between environmental degradation, demographic expansion and urban transition, and natural hazards in the country is likely to be further exacerbated by climate change, as global warming increases the frequency and intensity of tropical cyclones in the Caribbean region.[56]

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[52] Million hectares.

[53] Primary forests are defined by the European Commission as forests of native species "*where there is no clearly visible indication of human activity and the ecological processes are not significantly disturbed*". In light of their diverse tree-related structures, primary forests are among the most important ecosystems at the global level, preserving biodiversity, purifying water, controlling floodings, and have proven to be more effective at climate change mitigation than newly planted forests (McGarvey et al., 2015).

[54] Global Forest Watch (2023). *Guatemala*. Retrieved at: https://www.globalforestwatch.org.

[55] The World Bank (2006). *Republic of Guatemala: Country Environmental Analysis Addressing the Environmental Aspects of Trade and Infrastructure Expansion* (Report No. 36459-GT). Environmentally and Socially Sustainable Development Department Latin America and the Caribbean Region. https://documents1.worldbank.org/curated/en/356941468033564451/pdf/36459.pdf.

[56] Angeles, M.E., Gonzales, J.E., Erickson III, D.J., & Hernández, J.L. (2006, Oct 25). Prediction of future climate change in the Caribbean region using global general circulation models. *International Journal of Climatology 27*(5), 555-569. Doi: https://doi.org/10.1002/joc.1416.

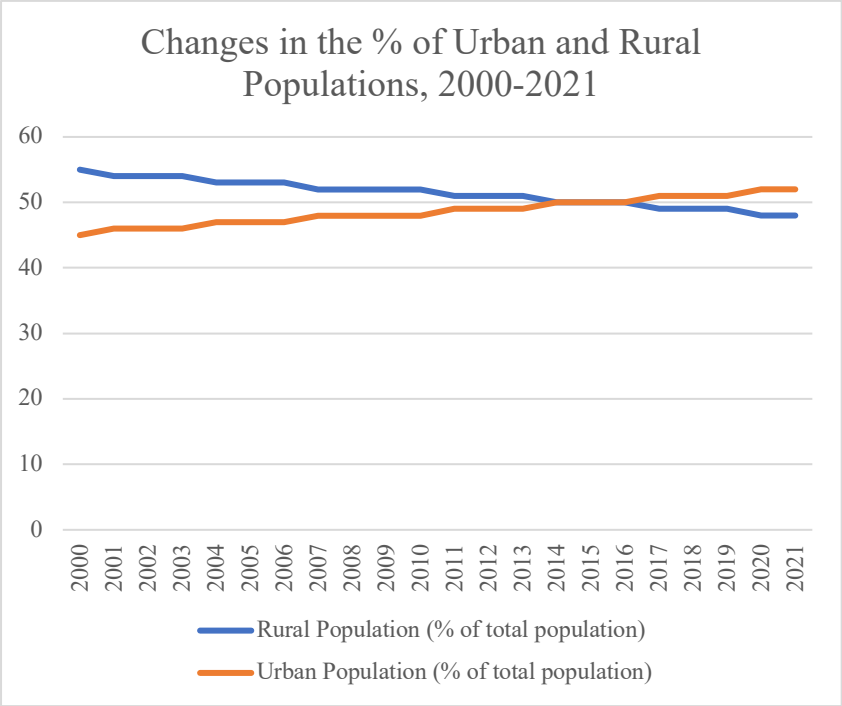

Figure 7: Changes in the Percentage of Rural and Urban Populations in Guatemala, 2000-2021; Source: World Banks (2021)[57]

As shown in Figure 7, Guatemala population is rapidly urbanizing. The percentage of urban dwellers in the country outnumbered the proportion of rural population in 2017 and has kept growing since then. The nation is currently in the midst of a rural-urban transition, fueled by high rates of internal migration. To accommodate the growing need for housing, municipalities are expanding urban land on hazard-prone territory.[58] Changes in the climate patterns are already threatening to exacerbate sociological and ecological vulnerabilities in the country.[59] Moreover, the urban expansion of

[57] Graph drawn based on data collected from The World Bank's databases.
[58] Di Villarosa, F. (2021). *Urban Planning and Housing in Guatemala: Links with Migration and Local Development*. Retrieved at: https://www.thedialogue.org/wp-content/uploads/2021/02/Report-LAV02-Guatemala_English-2.pdf.
[59] ECLAC (Economic Commission for Latin America and the Caribbean), CAC (Central American Agricultural Council), COMISCA (Council of Ministers of Health of Central America), CCAD (Central American Commission for Environment and Development), COSEFIN (Council of Ministers of Finance/Treasury of Central America and Dominic Republic), SIECA (Secretariat of Central American Economic Integration), SICA (Central American Integration System), UKAID (United Kingdom Department of International Development) and DANIDA (Danish International Development Agency**),** (2015), *Climate Change in Central America: Potential Impacts and Public Policy Options*, (LC/MEX/L.1196/Rev.1), Mexico City, Mexico. Retrieved at:

Guatemala City and of other urban centers on territories prone to high levels of seismic activity – and at the expense of areas of extreme ecological value, is resulting in a serious negative impact of urbanization on the access to natural resources, environmental services, and on the risk levels to which citizens are subject.[60]

The demographic growth of the country and its urban transition are taking place in a context still characterized by high rates of crime, poverty, inequality, and instability. The structural fragility of the country has made it particularly vulnerable to the adverse effects of climate change. Guatemala has constantly struggled with natural hazards, including earthquakes and volcanic eruptions, but also hurricanes, floodings and mudslides. Climate change is set to further exacerbate the intensity and the frequency of these events.[61] The higher unpredictability of rainfall and extreme heat events are causing a drought crisis in the Central and Eastern regions of the Country, where the risk of drought is considered to be high/extremely high, fueling a water scarcity crisis, as shown in Figure 8 below. These regions, forming part of the Central American "dry corridor"[62], are suffering from extreme poverty rates, resulting in high levels of migration towards the US.[63]

https://repositorio.cepal.org/bitstream/handle/11362/39150/S1800827_en.pdf?sequence=7&isAllowed=y

[60] Lungo, M. (2004). Expansión urbana y regulación de la tierra en Centroamérica: antiguos problemas, nuevos desafíos. In CLACSO, Consejo Latinoamericano de Ciencias Sociales (Ed.). *El rostro urbano de América Latina. O rostro urbano da América Latina*. Buenos Aires. Retrieved at: http://bibliotecavirtual.clacso.org.ar/clacso/gt/20100930021252/12p5art2.pdf.

[61] Stansifer, C.L. , Anderson, T.P. , Horst, O.H. and Griffith, W.J. (2023). *Guatemala*. Encyclopedia Britannica, https://www.britannica.com/place/Guatemala.

[62] The Dry Corridor is defined by the World Food Program USA as "*a strip of land across El Salvador, Guatemala, Honduras and Nicaragua that is vulnerable to extreme climate events like long periods of drought, putting livelihoods at risk*". Source: https://www.wfpusa.org/countries/dry-corridor/#:~:text=The%20Dry%20Corridor%20is%20a,drought%2C%20putting%20livelihoods%20at%20risk.

[63] Strochlic, N. (2021). A Hunger Crisis Forces Guatemalans to Choose: Migration or Death. *National Geographic*. Retrieved at: https://www.nationalgeographic.com/culture/article/a-hunger-crisis-forces-guatemalans-to-choose-migration-or-death.

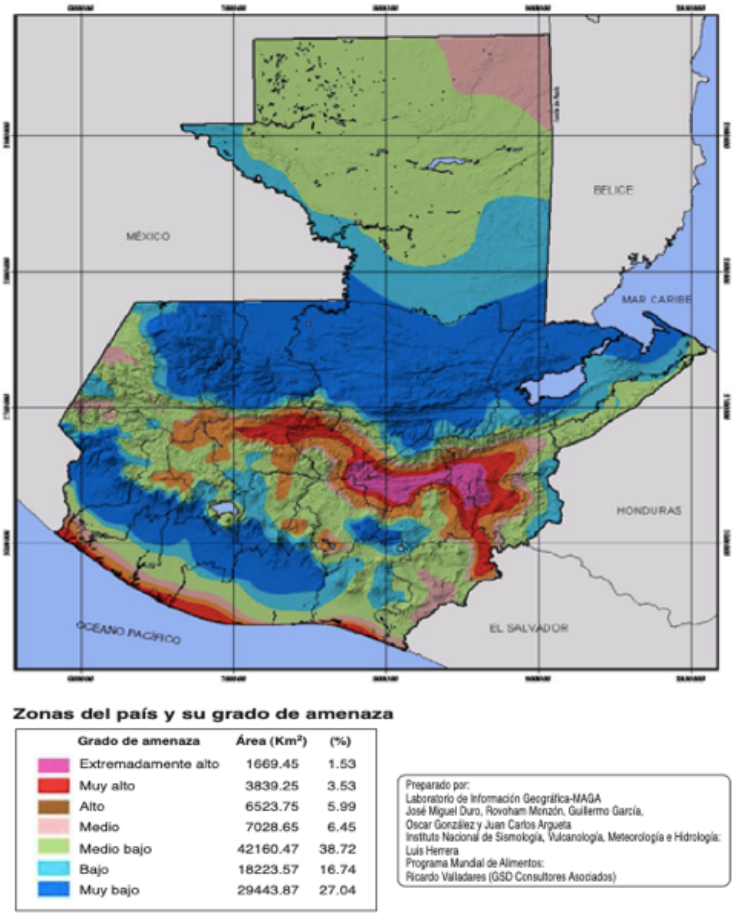

Figure 8: Drought Risk in Guatemala; *Source*: Guatemala Ministry of Agriculture, Livestock and Food, Laboratory of Geographical Information (2002)

The availability of freshwater has become a major concern in recent years. The growth in demand for water, coupled with pollution, is expected to cause a serious decline in water availability by 2025. This problem has already manifested itself in some watersheds, where shortages are becoming increasingly common. The root cause of this issue is pollution, which stems from both municipal and industrial sources. Direct and indirect liquid effluents are the primary culprits, but the problem is compounded by the presence of municipal and illegal garbage dumps that further pollute the water. Moreover, the legal framework concerning water, alongside the rights and obligations associated with it, is further complicating the issue. The absence of a comprehensive

water legislation has led to ill-defined water rights that are managed by various political and administrative divisions.[64]

Water pollution is particularly alarming for the status of public health in the country; the World Bank estimated that in the year 2000 acute diarrheal illness – caused by water-borne diseases and pollution – was the second leading cause of both morbidity (45.1 per 1,000) and mortality (3.6 per 10,000), exceeded only by respiratory infection or pneumonia. Water pollution also has on concerning effects on newborn mortality. Indeed, diarrheal disease was responsible for 43 percent of newborn mortality.[65] This equated to an average of five fatalities per day among Guatemalan children under the age of one. The economic expenses of diarrheal infections are likewise large, with World Bank estimating their cost at 1.6 percent of the country's GDP. In this context, the incidence of drought – set to be exacerbated in frequency and intensity by global warming – could further aggravate the status of water risk and the threats associated with it in the country.

Access to safe and clean water is already a pressing issue in Guatemala City, and the scarcity of this resource is set to be additionally aggravated by growing demand in the city – as its population expands as a result of demographic growth and the urban transition; moreover, the urbanization process in taking place in a disorderly manner, leading to a greater level of degradation of the water basins in the city and its surroundings.[66] The issue of water scarcity, made more extreme by the impact of climate change and more erratic precipitations, is also a threat for agricultural production in the country, with the potential of leading, in turn, to higher rates of food insecurity and unemployment.[67]

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[64] The World Bank (2006), *Report No. 36459-GT.*
[65] The World Bank (2006), *Report No. 36459-GT*
[66] Instituto de Agricultura, Recursos Naturales y Ambiente de la Universidad Rafael Landívar, & The Nature Conservancy (2013). *Bases técnicas para la gestión del agua con visión de largo plazo en la zona metropolitana de Guatemala*. Guatemala City. Retrieved at: https://www.url.edu.gt/publicacionesurl/FileCS.ashx?Id=40197.
[67] Lampe, K., & Zedek, R. (2020). *Urban Water Scarcity and Contamination in The Guatemala City Metropolitan Region: A Management Proposal*. Urban Water Atlas. Retrieved at: https://www.urbanwateratlas.com/2020/05/08/managing-urban-water-scarcity-and-contamination-in-the-guatemala-city-metropolitan-region/.

The worsening of the environmental situation in Guatemala is leading to heavy economic damages. World Bank estimates suggest that land degradation in the country had an annual cost of around 0.55 percent of Guatemalan GDP.[68] The level of land degradation was estimated to highly affect roughly 37 percent of the country's total area in 2006, with the most affected region being the western highlands[69]. The same estimates also pointed out to the fact that 56 percent of the land exhibited a high level of degradation in the upper watershed, further aggravating the status of water scarcity and pollution in an area of key importance for the country's hydric reserves – roughly corresponding to 14.2 percent of the country's area. The interplay between deforestation and land degradation in the region of the upper watershed is a serious concern for the status of water security in the country, as the area is located at the convergence between Guatemala's three most important water drainages, at the source of 70 percent of the nation's rivers. The World Bank pointed out that the interplay between land degradation and population growth could have dramatic consequences in terms of unemployment rates and social conflict.[70]

[68] The World Bank (2006), *Report No. 36459-GT*
[69] As it will be explored in Chapter 2, the Western Highland also present a higher percentage of indigenous population, magnifying the adverse effects resulting from the interplay between ethnic inequality and environmental degradation.
[70] The World Bank (2006), *Report No. 36459-GT*

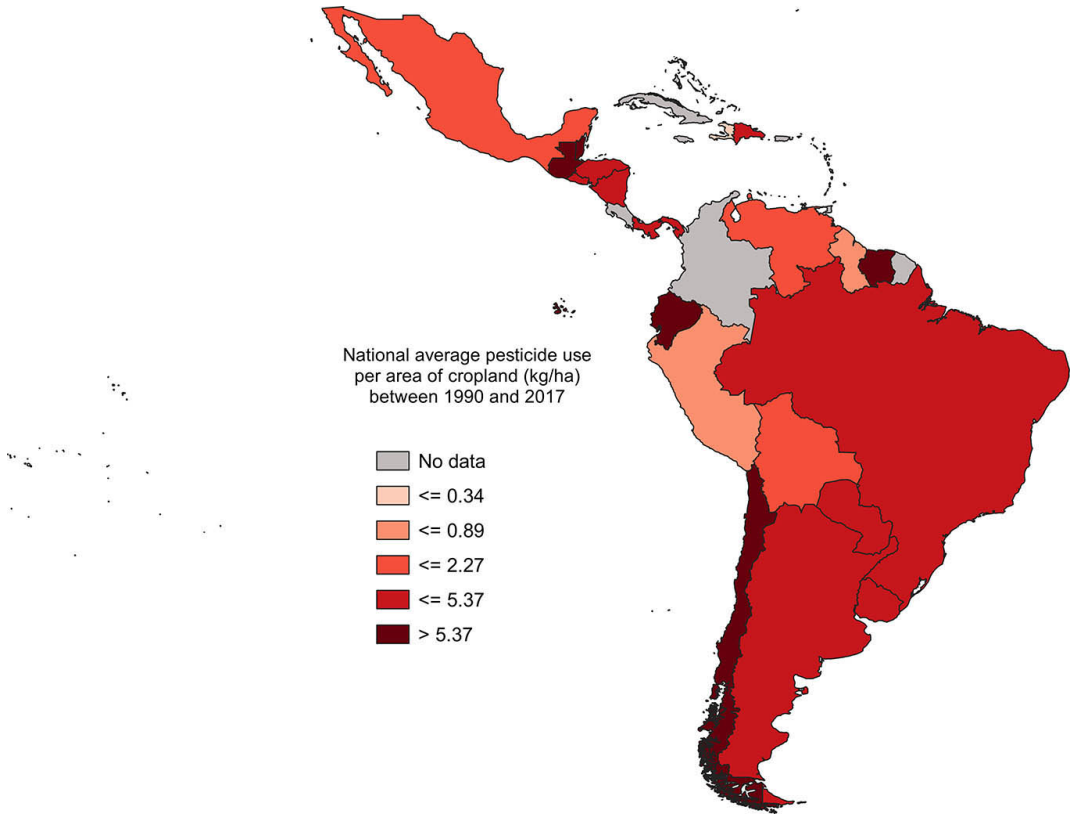

Figure 9: National Average Pesticide Use per area of Cropland (kg/ha) between 1990 and 2017; Source: FAO & UNEP (2021).

A major issue contributing to the level of soil degradation in the country is the widespread use of pesticides. As can be seen in Figure 9, Guatemala presented one of the highest levels of national average pesticide use per area of cropland between 1990 and 2017, with an average of over 5.37 kg/ha. Guatemala was the country with the highest national average in Central America alongside Belize. The widespread use of pesticides for agricultural production causes enormous environmental damages to the soil quality, especially in an already-threatened area already suffering from drought and deforestation.[71] In a context of growing population – and therefore growing necessity for food – the risk is that an increase in the use of pesticide to fulfil a short-term increase in the demand for food will cause long-term damages to the quality of

[71] FAO & UNEP (2021). *Global Assessment of Soil Pollution: Report*. Rome. Doi: https://doi.org/10.4060/cb4894en.

the food systems in the country, paradoxically leading to further food insecurity due to widespread soil degradation.

1.4 The Economy of Guatemala

Guatemala presented the highest GDP (PPP)[72] in continental Central America (excluding Mexico), with a value in 2021 of $167.79 billion. However, the country was only fourth in the region in terms of GDP per capita, with a value of $5,025.5 in 2021, lagging behind Panama ($14,617.6), Costa Rica ($12,472.4), and Belize ($6,228.3). As of 2023, Guatemala was described as a developing country by the International Monetary Fund and by the United Nations.

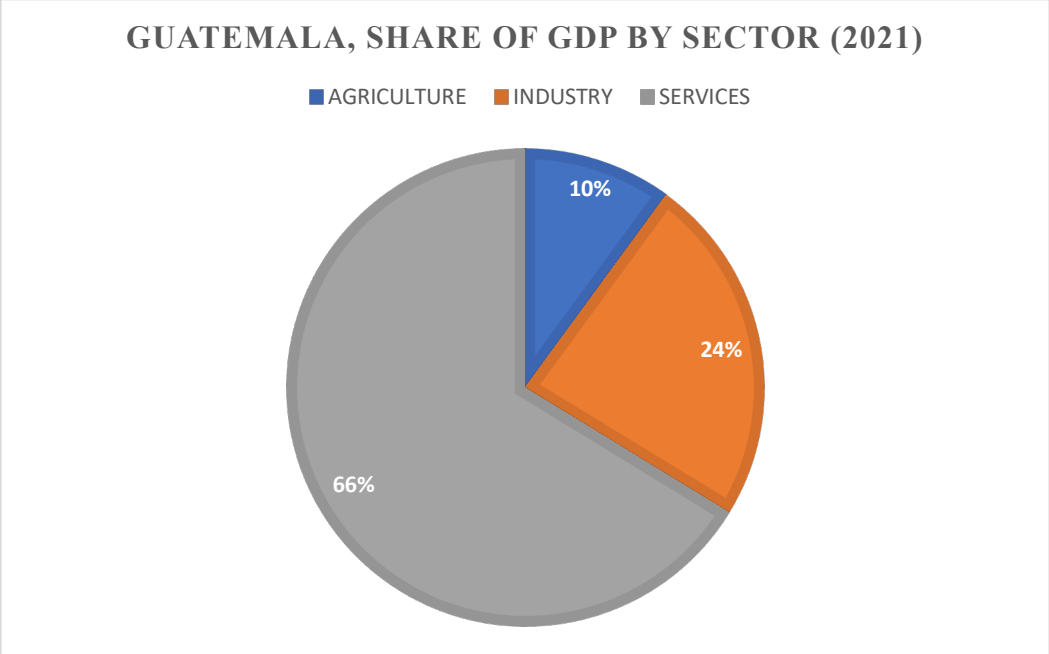

Figure 10: Guatemala, GDP Sector Composition in 2021; Source: The World Bank, (2023)

The economy of the country is still largely dependent upon agriculture. As shown in Figure 10, drawn using data Retrieved at: the World Bank statistics, the sector of agriculture, forestry, and fishing contributed to 9.4 percent of the Gross Domestic Product of the country in 2021. This value was above the regional average, as in the same year the sector of agriculture, forestry, and fishing contributed to 6.9 percent of

[72] Calculated as Gross Domestic Product based on purchasing power parity in current international US dollars.

the overall GDP of Latin America and the Caribbean. In continental Latin America[73], only Nicaragua (15.5 percent), Bolivia (12.9 percent), Honduras (11.0 percent), and Paraguay (9.9 percent) had higher rates of economic dependency on agriculture for their gross domestic output. In 2019, World Bank data indicated that employment in agriculture in the country represented 31.3 percent of total employment. According to the United States Department of Agriculture, in 2015 the agricultural sector contributed to approximately 41 percent of total exports. The major agricultural exports of the country included bananas, coffee, sugar cane, and cardamom. As can be seen in Table 1, these goods play a crucial role in the foreign exports of the country.

Table 1: Percentage of Exports over Total Production in the Agricultural Sector for Selected Crops in Guatemala; Source: Solomons *et al.*, (2015).[74]

Most Important Agricultural Products of Guatemala Destined for Foreign Markets (2015)			
Crop	**Production (MT)**	**Exports (MT)**	**Share of Exports over Total Production (%)**
Bananas	3.248.215	1.968.939	60,62
Coffee	251.660	219.624	87,27
Sugar Cane	27.546.560	1.799.341	6,53
Cardamom	36.344	34.226	94,17

Whilst the nation is self-sufficient for some food commodities, it has to rely on imports for other goods, and especially animal products and most staple crops. In particular, the country does not produce enough items to meet the demand of the most consumed dietary items in Guatemalan society, namely maize and black beans. One of the main reasons damaging the production of maize and black beans is represented by irregularities in the raining seasons and weather patterns, which have become increasingly unstable and unpredictable in the last years.[75] More in general, most of the agricultural sector in Guatemala is constituted by dryland agriculture, a practice

[73] Including only romance-speaking countries, thereby excluding Guyana and Suriname.
[74] Table drawn using data collected from Solomons et al. (2020). *Food and Nutrition Security in Guatemala*. Retrieved at: https://ianas.org/wp-content/uploads/2020/07/Guatemala-1.pdf.
[75] Solomons, N.W., Castellanos, E.J., Cifuentes Velázquez, F.R., Conde, S.M., Orozco Figueroa, M.N., Pennington, P.M., Schuster, J.C., & Zambrano Ruano, G.G. (2020). *Food and Nutrition Security in Guatemala*. Retrieved at: https://ianas.org/wp-content/uploads/2020/07/Guatemala-1.pdf.

which heavily relies on rainfall. Therefore, potential changes in the levels and frequency of rainfall, in the form of droughts or tropical cyclones, threaten to further disrupt the agricultural sector, with far-reaching consequences for employment and economic growth in the country.

The socio-economic conditions in Guatemala appear to be particularly uneven, with a Gini index of 48.3 recorded in 2014 (The World Bank, 2014). The Gini index is a tool used to gauge the degree of inequality in the distribution of income (or, in certain instances, consumption expenditure) among individuals or households within an economy. It is determined by analyzing the deviation of this distribution from a state of absolute equality. By plotting the cumulative percentages of total income received against the cumulative number of recipients, starting from the least affluent individual or household, a Lorenz curve is formed. The Gini index quantifies the extent of inequality by measuring the area between the Lorenz curve and an imaginary line that represents complete equality. This area is expressed as a percentage of the maximum area beneath the line. Hence, a Gini index of 0 signifies a situation of perfect equality, while an index of 100 indicates absolute inequality. In the period 2014-2019, inequality in Guatemala was estimated to have increased from a Gini of 0.483 to 0.541, remaining high by global standards.

Guatemala was classified as the 50th most unequal country out of 169 nations in the World Inequality Ranking by Country 2022. The World Bank classified it as one of the countries with the highest poverty and inequality rates in the Latin American and Caribbean region (LAC). According to the World Bank, one of the key factors behind these values was considered to be the existence of a large and underserved population mainly composed by rural and indigenous individuals who are often unemployed or employed in the informal sector. Data collected in 2019 suggested that about 54 percent of the country's population was below the poverty line. This means that more than half of the country's population were living on less that $2.15 (using 2017 prices) a day. The World Bank listed among the main reasons contributing to poverty a weak and inefficient state apparatus, low levels of education, lack of job opportunities, as well as the incidence and frequency of natural disasters in the country.

Guatemala presented a Human Capital Index of 0.46 in 2020. The Human Capital Index (HCI) is a measurement developed by the World Bank to quantify how countries fare in mobilizing their human capital, i.e., the economic and professional potential of their citizens. As such, the Human Capital Index is a measurement of how much human capital nations lose due to lack of education and health. The Index is built following three pillars, namely **survival** (the percentage of children who survive past the age of five), **education** (measured in terms of quantity, i.e., the expected years of schooling attained by the average citizen by the age of eighteen, and quality, i.e., how students fare in terms of harmonized test scores), and **health** (measured as the rates of adult survival, namely the percentage of 15-year-olds who survive until the age of 60, combined with the rates of healthy growth among children, by taking into account the levels of stunting among children under the age of five). Guatemala's Human Capital Index score of 0.46 indicates that a kid born in the country in 2020 would be expected to reach only 46 percent of what its lifetime productivity would have been if they had enjoyed full health and a complete education. The indicators for human capital were particularly low among indigenous citizens. The HCI score of Guatemala in 2020 was below both the world average (0.563) and the regional average for Latin America and the Caribbean (0.557)[76]. Based on World Bank classifications for the year 2020, Guatemala ranked 124th at the global level out of 173 countries/regions, and 25th out of 26 countries in the Latin America and Caribbean region.

The incidence of natural disasters has been considered one of the main challenged to the social and economic development of the country. Extreme weather events such as floodings, hurricanes, and drought have reversed some of the recent achievements in human capital.[77] These events have posed significant challenges to the economics of the nation, by damaging infrastructures, reducing agricultural output, intensifying the levels and status of food security, increasing the prevalence of disease, and severely disrupting the provision of essential goods and services. Considering the relatively high dependency of Guatemalan economics on agriculture – both in terms

[76] Note: no data recorded for Venezuela, Bolivia, Cuba, Suriname, Belize, the Bahamas, and Barbados.
[77] The World Bank (2023). *The World Bank in Guatemala*. Retrieved at: https://www.worldbank.org/en/country/guatemala/overview.

of exports and internal consumption and employment – losses in the agricultural sector due to adverse weather events have further exacerbated the financial hardships and the status of food security in the country, and particularly among those populations who already suffer from higher rates of vulnerability to economic and food insecurity and who tend to have higher rates of employment in the agricultural sector: rural and indigenous communities. Recent estimates suggest that the impact of the Eta and Iota hurricanes, which devastated the country in 2020, caused infrastructure-related losses amounting to nearly 0.56 percent of the country's Gross Domestic Product (GDP).

In terms of GDP growth, Guatemala witnessed a substantial recovery in 2021, with an 8 percent economic growth. In 2022, the country's GDP grew by roughly 4 percent, which World Bank estimated suggest was mainly driven by private and public consumption as well as by investments. The growth rate is expected to be approximately 3.2 percent in the year 2023. The economic stability experienced by the country in recent years has not translated into growth acceleration to close the income gap with developed nations, with levels of poverty and inequality remaining high, and indigenous communities continuing to suffer from significant disadvantages. The country is a developing economy with an enormous potential in terms of natural resources; moreover, as it approaches the beginning of the demographic window of opportunity in the following decades, Guatemala could potentially reap the benefits of a low dependency ratio. However, the nation faces significant endogenous and exogenous challenges to its social and economic development. Low levels of investments on human capital, widespread unemployment, and high rates of inequality represent significant threats to the economic growth of the country. Within this context, the effects of climate change – including damages to the agricultural output and infrastructures, public health threats, food and water insecurity – could potentially aggravate the current economic and social vulnerabilities of the country, leaving thousands more people unemployed and malnourished.

Chapter 2: The Impact of a Changing Climate on Agriculture and Food Security

2.1 Figures of Climate Change in Guatemala

Climate change affects populations and environments through diverse and multi-layered factors. With respect to the agricultural sector, some of the most relevant elements include changes in the annual mean temperatures, disruptions to the precipitation patterns, and extreme weather events. All these dynamics have the potential to damage crops and limit the availability of water, in turn leading to higher unemployment rates in the agricultural sector and among rural populations, as well as directly threatening the life and health of those communities.

The recorded impacts of global warming on Guatemala, whilst being difficult to comprehensively assess and measure, are already showing their effects, and are already being felt across the region. One of the ways in which climate change has been affecting the area include the recorded increase in the average temperatures in the country. As shown in Figure 11, the mean-temperature in Guatemala has been rising in the past decades. Whilst in 1901 the recorded annual mean temperature in the country was documented to be 22.98 °C, in 2021 the annual mean temperature had reached 24.09 °C. This shows a +1.11 °C increase in slightly more than a century, as can be graphically observed in Figure 11.[78]

[78] The World Bank (2021). *Guatemala: Current Climate*. Climate Change Knowledge Portal for Development Practitioners and Policy Makers. Retrieved at: https://climateknowledgeportal.worldbank.org/country/guatemala/climate-data-historical.

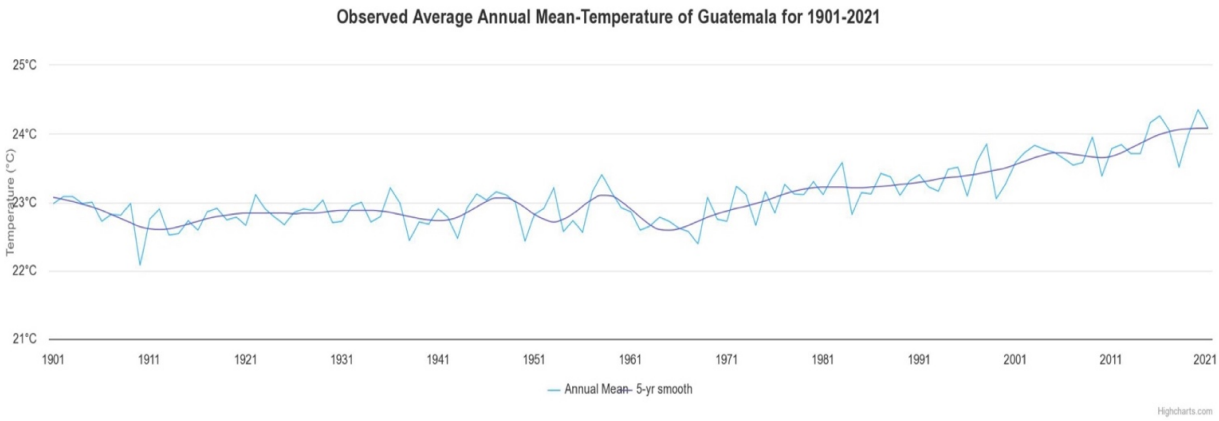

Figure 11: Variations in the Annual Mean-Temperature in Guatemala, 1901-2021. Source: The World Bank (2021)

Variations in the annual mean temperatures constitute a direct threat for agricultural output, as they can lead to changes in the growth patterns of crops. Moreover, changes in temperatures have also been linked to variations in the seasonal precipitation patterns. The weather of Guatemala is not marked by the normal seasons which characterize the Northern Hemisphere, but by a rainy season (running from May to October) and by a dry season (running from November to April).[79]

The increase in the country's annual temperatures is beginning to affect the regularities in these weather patterns. Indeed, as can be seen in Figure 12, the predictability of precipitation patterns in the past three decades seems to be showing some anomalies in comparison to the thirty-year period 1961-1990. The months of December, January and February, as well as June, July, and August are receiving on average less precipitation than what they used to receive in the previous three decades, whilst March, April, May, September, October, and November seem to be getting wetter than what they used to be.

[79] The World Bank (2021). *Guatemala: Current Climate*.

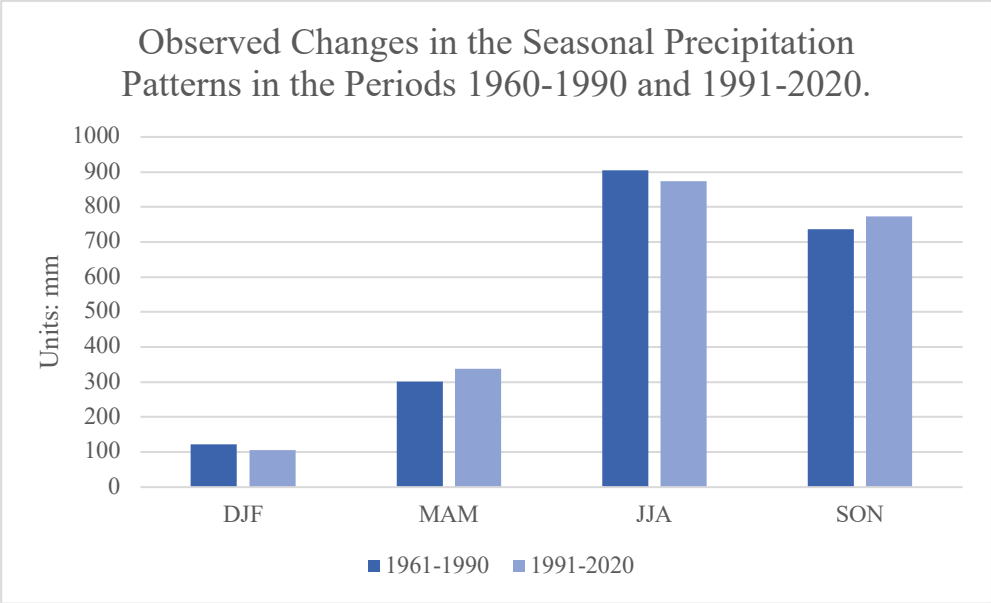

Figure 12: Observed Changes in the Seasonal Precipitation Patterns in the Periods 1960-1990 and 1991-2020; *Source*: The World Bank (2021).[80]

Changes in temperatures and in precipitation patterns can threaten the macroeconomic stability of the agricultural sector. The impacts of climate change on food systems can manifest in various aspects, encompassing direct consequences on crop production (such as alterations in precipitation patterns resulting in droughts or floods, or shifts in temperature influencing the duration of growing seasons) as well as influencing markets, food prices, and the infrastructure of supply chains.[81]

Another important threat deeply interconnected with climate change is represented by extreme weather events. Due to its geographical characteristics, the territory of Guatemala has historically been prone to natural disasters; 40.8 percent of Guatemalans live in areas at risk of five or more natural hazards simultaneously, and

[80] Note: DJF stands for December-January-February; MAM stands for March-April-May; JJA stands for June-July-August; SON stands for September-October-November. Figure drawn by author based on data Retrieved at: The World Bank (2021), *Guatemala: Current Climate*. Retrieved at: https://climateknowledgeportal.worldbank.org/country/guatemala/climate-data-historical.
[81] Gregory, P.J., Ingram, J.S.I., & Brklacich, M. (2005). Climate Change and Food Security. *Philosophical Transaction of the Royal Society B. Biological Sciences, 360*(1463). Retrieved at: https://royalsocietypublishing.org/doi/abs/10.1098/rstb.2005.1745.

the country ranks in the top five countries in the world most affected by hurricanes, floods, and earthquakes.[82]

Hurricanes and tropical storms constitute serious natural hazards. They often result in floodings which can destroy vital infrastructure, damage agricultural output, cause loss of life and property, and inflict immeasurable economic costs. The converge of four factors is essential in determining the formation and the strength of hurricanes, namely: warm ocean waters, abundance of moisture in the air, low vertical wind shear, and a pre-existing disturbance.[83] The precise impact of climate change on the frequency and intensity of tropical storms and hurricanes has not been fully assessed by the scientific literature yet. Indeed, multiple factors contribute to influencing variations and shifts in hurricanes' patterns, including environmental variabilities and phenomena such as natural large-scale changes in climate patterns caused by *El Niño* and *La Niña*[84].

Nevertheless, there is growing scientific consensus on the theory that anthropogenic warming does seem to have an impact on the intensity and frequency of tropical storms and cyclones. Global warming is leading to increases in the temperature of ocean waters and in the levels of humidity in the air. According to a recent study, it has been indicated that the recent rise in the proportion of North Atlantic hurricanes experiencing rapid intensification exceeds what could be solely attributed to natural variations.[85] Hurricanes are indeed subject to several influences connected to anthropogenic warming. In the period 1979-2017, the number of major hurricanes has increased, whilst the number of low-intensity hurricanes has decreased; this change has been partly attributed to warmer sea surface temperatures, which

[82] The World Bank (2021). *Guatemala: Vulnerability*. Climate Change Knowledge Portal for Development Practitioners and Policy Makers. Retrieved at: https://climateknowledgeportal.worldbank.org/country/guatemala/vulnerability.
[83] Colbert, A. (2022, June 1). A Force of Nature: Hurricanes in a Changing Climate. *NASA Global Climate Change: Vital Signs of the Planet*. Retrieved at: https://climate.nasa.gov/news/3184/a-force-of-nature-hurricanes-in-a-changing-climate/.
[84] *El Niño* and *La Niña* are components of a climate phenomenon known as the El Niño Southern Oscillation (ENSO). ENSO is a recurring pattern of ocean temperature changes (warmer, colder, or average) along the equatorial region in the tropical Pacific Ocean. These temperature variations have significant impacts on global weather patterns.
[85] Bhatia, K.T., Vecchi, G.A., Knutson, T.R., Murakami, H., Kossin, J., Dixon, K.W., & Whitlock, C.E. (2019). Recent Increases in Tropical Cyclones Intensification Rates. *Nature Communications 10*(635). Doi: https://doi.org/10.1038/s41467-019-08471-z.

intensify the speeds of the tropical storm winds.[86] Moreover, warmer sea temperatures seem to be positively correlated with the intensity of tropical cyclone-related precipitations, fueling greater risks of floodings.[87] In addition, rising sea levels significantly increase the risk of coastal flooding, with estimates indicating that the likelihood of such flooding occurring is up to three times higher due to sea level rise.[88]

With respect to Guatemala, Figure 13 shows how the intensity of various weather-related natural disasters – measured as number of people affected – has worsened in the last years. The data, collected from World Bank databases, points out to a strong incidence in the occurrence of storms and droughts in the country in the past years. In particular, 2020 appears to be the worst year in terms of total number of people affected by weather-related natural disasters, with almost 3,000,000 individuals being exposed to the devastating effects of tropical storms.

[86] Kossin, J.P., Knapp, K.R., Olander, T.L., Velden, C.S. (2020). Global Increase in Major Tropical Cyclone Exceedance Probability Over the Past Four Decades. *Proceedings of the National Academy of Sciences (PNAS) 117*(22), 11975-11980. Doi: https://doi.org/10.1073/pnas.1920849117.
[87] Center for Climate and Energy Solutions (2022). *Hurricanes and Climate Change*. Retrieved at: https://www.c2es.org/content/hurricanes-and-climate-change/.
[88] Lin, N., Kopp, R.E., Horton, B.P., Donnelly, J.P. (2016). Hurricane Sandy's Flood Frequency Increasing from Year 1800 to 2100. *Proceedings of the National Academy of Sciences (PNAS) 113*(43), 12071-12075. Doi: https://doi.org/10.1073/pnas.1604386113.

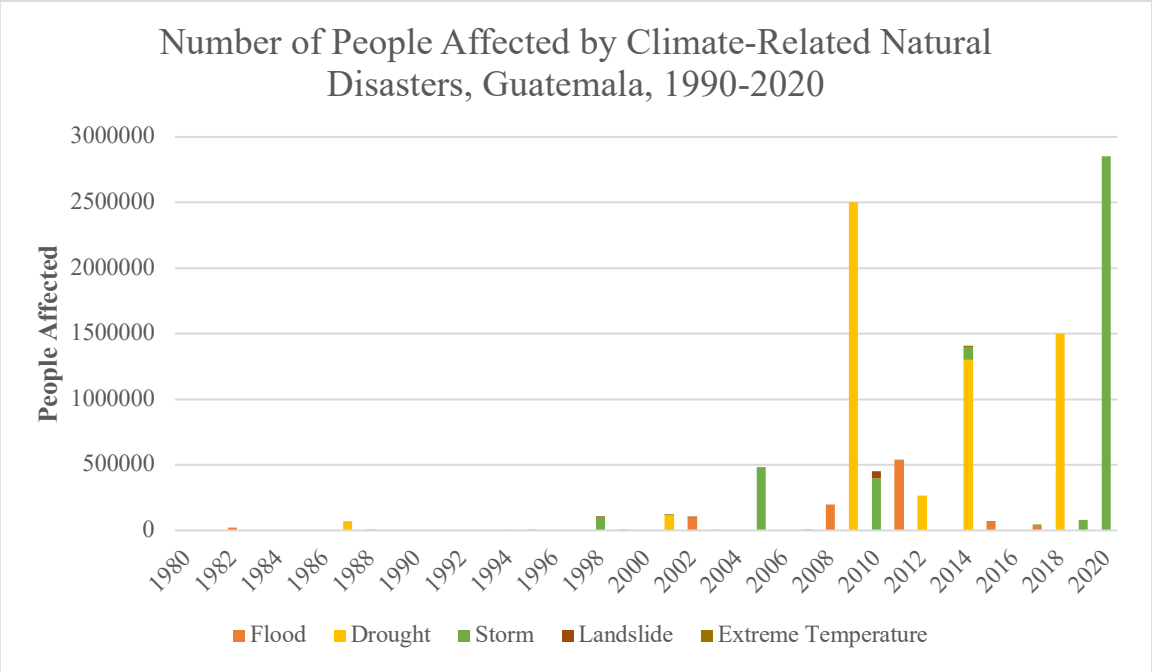

Figure 13: Number of People Affected by Climate-Related Natural Disasters, Guatemala, 1990-2020. *Source*: The World Bank (2021)[89]

For the year 2020, Figure 13 shows a spike in the number of people affected by tropical storms. The event in question regards the impact of Hurricane Eta and Hurricane Iota. The storms represented, respectively, the third and second most intense November Atlantic hurricanes on record. The two storms ravaged the country between November 3rd and November 17th, 2020. The situation was worsened by the fact that Iota occurred two weeks after Eta, while the country was still struggling with the consequences of the previous storm. Eta and Iota had dramatic effects, both in terms of human casualties (60 deaths, 30 people injured, and over 100 missing) and economic losses, estimated at around 763,791,000.00 USD (6,000,000,000 GTQ). The storms resulted in mudslides and floodings which destroyed infrastructures and seriously damaged the agricultural output of the country, causing immeasurable losses to rural households.[90]

[89] Figure drawn based on data collected from The World Bank (2021). *Guatemala: Vulnerability*. Climate Change Knowledge Portal for Development Practitioners and Policy Makers. Retrieved at: https://climateknowledgeportal.worldbank.org/country/guatemala/vulnerability

[90] International Federation of Red Cross and Red Crescent Societies (2022, Dec 5). *Final Report Central America: Hurricanes Eta – Iota* (Report No. MDR43007). https://reliefweb.int/report/guatemala/central-america-hurricanes-eta-iota-final-report-mdr43007.

Another major kind of natural hazards which has become particularly worrisome in Guatemala in the past years is drought. The phenomenon is particularly evident in the areas of the country forming part of the Central American Dry Corridor, more specifically the region ranging from the departments of Santa Rosa and Jutiapa in the south to the departments of Izabal and Baja Verapaz in the north. As can be noted in Figure 13, the decade 2009-2019 saw a rise in the incidence of drought in the country with unprecedented levels in comparison to the previous three decades. The regions forming part of the Guatemalan Dry Corridor present also the highest incidence of poverty in the country.[91]

[91] The World Bank (2021), *Guatemala: Vulnerability*.

2.2 Agriculture and Climate Extremes in Guatemala

As explained in the previous chapter, agriculture contributes to a significant share of the Gross Domestic Product of the country, above the regional average. According to International Labour Organization statistics, in 2022 the agricultural sector represented 27.1 percent of the total employment. More specifically, it represented 37.2 percent of total male employment in the country and 10 percent of the total female employment. Despite the relative share of agriculture over the total Gross Domestic Product of the country has been decreasing in the last decades, the sector remains of pivotal importance for the economic growth of Guatemala, as well as for sustaining thousands of households and individuals who depend upon it for their survival. In particular, agriculture employs more than 70 percent of the rural population in Guatemala, meaning that non-urban communities tend to be at higher risk of suffering from the more immediate effects of disruptions to the agricultural sector.[92]

There still persist important ethnic disparities in the number of individuals employed in agriculture in Guatemala. Indeed, whilst in 2019 roughly 30 percent of the country's workforce was employed in the agricultural sector, the number rose to 46.3 percent for indigenous workers.[93] Moreover, indigenous communities in Guatemala tend to me more concentrated in rural areas than their *mestizo* counterparts: in 2013 the national percentage of Guatemalans living in rural areas was around 51 percent, but the value rose to 75 percent for the indigenous population.[94] Rural populations, in light of their strong dependency upon the agricultural sector for their economic well-being, their health, and their survival, are experiencing more directly the consequences of climate change.

One of the most important agricultural products exported by Guatemala is coffee. Between 2017 and 2019, Guatemala ranked 10th globally in the International

[92] Alvarez Ruiz, L., & Miller, H. (2022). Rural, Poor, and Pressured by Climate Change: Migration and Financial Inclusion in Guatemala's Western Highlands. *Center for Financial Inclusion*. Retrieved at: https://www.centerforfinancialinclusion.org/rural-poor-and-pressured-by-climate-change-migration-and-financial-inclusion-in-guatemalas-western-highlands.
[93] International Labour Organization (2021). *Employment and Migration Guatemala 2021*. Retrieved at: https://www.ilo.org/wcmsp5/groups/public/---americas/---ro-lima/---sro-san_jose/documents/publication/wcms_831273.pdf.
[94] Minority Rights Group International (2013). *State of the World's Minorities and Indigenous Peoples 2013 – Guatemala*. Retrieved at: https://www.refworld.org/docid/526fb749b.html.

Coffee Organization list of the major coffee-exporting countries.[95] The production of coffee for export in Guatemala dates back to the 1850s. Today, coffee constitutes the second-most important agricultural export in the country after sugar, with a total production in 2015 of 251.660 MT of coffee, of which 87 percent (219.624 MT) were destined for exports. Every year, revenues from exports of coffee contribute hundreds of millions of dollars to Guatemala's economy; moreover, the coffee sector employs more than 125,000 families in Guatemala.[96]

Nevertheless, the country's coffee production is being directly challenged by extreme weather events. Indeed, coffee is deeply susceptible to changes in the precipitations' patterns and in the mean temperatures. Annual mean temperatures above 23°C have the potential to hinder the development and ripening of coffee cherries, and constant exposure to daily temperatures of 30°C or higher can result in a reduction of the crops' growth and in the yellowing or loss of their leaves.[97]

[95] International Coffee Organization (2021). *Exports of All Forms of Coffee by Exporting Countries to All Destinations*. Accessed from https://ico.org/trade_statistics.asp?section=Statistics.
[96] World Coffee Research (2023). Focus Country: Guatemala. https://worldcoffeeresearch.org/focus-countries/guatemala.
[97] Haggar, J., & Schepp, K. (2012). *Coffee and Climate Change: Impact and Options for Adaptation in Brazil, Guatemala, Tanzania and Vietnam*. Climate Change, Agriculture and Natural Resources Working Paper Series No. 4. London: Natural Resources Institute, University of Greenwhich,. Retrieved at: http://www.academia.edu/2050482/Coffee_and_Climate_Change_Impacts_and_Options_for_Adaptation_in_Brazil_Guatemala_Tanzania_and_Vietnam.

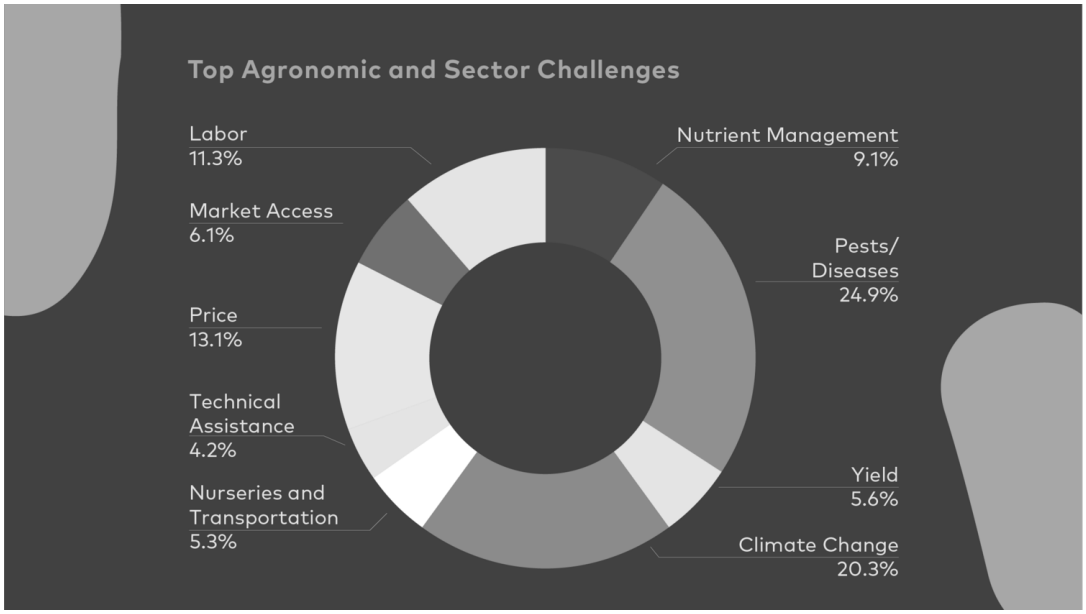

Figure 14: Results from the data analysis show the top nine agronomic and sector challenges, ranked by the number of mentions by interviewees. *Source*: Antoshak & Smith (2020).

Figure 14 shows the results of a study carried out by the University of California, Davis Coffee Center on the main challenges faced by coffee farmers in Guatemala. The research project, carried out in 2019, involved a series of open- ended questions submitted to local coffee farmers to identify their needs and issues with respect to the production of coffee. As can be seen in Figure 14, climate change was documented as the second most commonly mentioned challenge by coffee producers in the country.[98] In particular, climate change was identified by the farmers as changes in the intensity, timing, and quantity of precipitations on the coffee farms. Reported variations included less predictable and reliable rainfall and less, but more intense, rainstorms. Rain strongly influences the moment of coffee harvest, as it determines when the plants blossom and when the cherries develop, how many times each coffee plant must be harvested, and when cherries can be reaped and dried.[99]

[98] Antoshak, L., & Smith, E. (2020). *Trouble Brewing: Climate Change, Labor Migration, and Implications for the Sustainability of the Coffee Industry*. Specialty Coffee Association 13. Retrieved at: https://sca.coffee/sca-news/25/issue-13/trouble-brewing-climate-change-labor-migration-and-implications-for-the-sustainability-of-the-coffee-industry.
[99] Antoshak, L., & Smith, E. (2020). *Trouble Brewing: Climate Change, Labor Migration, and Implications for the Sustainability of the Coffee Industry*

Moreover, reductions in precipitations in the region are expected to make the dry season even drier. This is likely to result in a further deterioration of the growing conditions for coffee.[100] During the dry season, coffee plants already face challenges such as increased water stress and higher susceptibility to pests and diseases. A lack of rainfall exacerbates these issues and can result in reduced yields and lower-quality coffee beans. This is particularly true for the higher-value Arabica species, which constitutes around 96.27 percent of the total coffee production in the country, and which is more susceptible to climate change than other coffee species.[101]

Figure 14 shows that the only challenge to coffee production which was mentioned more times than climate change was represented by pests and diseases. In particular, one of the major issues affecting coffee production in Guatemala is constituted by a disease known as Coffee Leaf Rust (CLR). The CLR is a fungus that targets coffee crops and reduces the number of cherries produced, before leading to the death of the tree in around two years. An outbreak of the disease in Guatemala in 2012 led to a decline of 25 percent in coffee exports in 2013/2014 from the peak year, and the coffee sector has been marked by a series of difficulties every year since.[102] Coffee Leaf Rust, which firstly emerged in the country in the 1970s, used to only affect farms at lower altitudes. However, due to warming temperatures, the 2012 outbreak saw for the first time CLR affecting coffee plantations at higher altitudes.[103]

There is growing scientific consensus on the positive correlation between global warming and the incidence of pests. Changing rainfall patterns create environmental conditions which extend the area of land and the amount of time in which pests and diseases can thrive.[104] An example is the afore-mentioned shift in the altitudes in which CLR is able to spread. Moreover, as the application of fertilizers depends upon precipitation patterns, climate change is making it harder to efficiently

[100] Lynch, C. (2019). The Impact of Warming Coffee: The Climate Change-Coffee-Migration Nexus in the Northern Triangle of Central America. *Independent Study Project (ISP) Collection 3008*. Retrieved at: https://core.ac.uk/download/pdf/232741188.pdf.
[101] Davis, M. (2021). The Global Challenge of Adapting Coffee to a Changing Climate. *Stockholm Environment Institute (SEI)*. https://www.sei.org/featured/global-challenge-adapting-coffee-changing-climate/.
[102] Hochachka, G. (2023). Climate Change and the Transformative Potential of Value Chains. *Ecological Economics 206*, 107747. Doi: https://doi.org/10.1016/j.ecolecon.2023.107747.
[103] Hochachka, G. (2023). Climate Change and the Transformative Potential of Value Chains.
[104] Antoshak, L., & Smith, E. (2020).

plan the application of fertilizers to maximize the yield and quality of coffee. Indeed, in order to allow the coffee trees to be able to absorb all the necessary nutrients, fertilizers must be applied in conjunction with rain. Shifts in the predictability, intensity, and frequency of precipitation challenge the farmers' ability to make an efficient planning in the application of fertilizers.[105]

In addition to pests and diseases, another major challenge to coffee production in the country was represented by the occurrence of Hurricane Eta and Hurricane Iota. The storms coincided with the beginning of the coffee harvest season, and affected more than 10,500 hectares in over 21 municipalities. Besides destroying farms and coffee trees, the storms translated into higher production costs for coffee farmers, as they needed to invest more in fertilizers and pesticides to tackle outbreaks in CLR and other fungal diseases which thrive in high humidity. The increase in the costs of production for coffee in the country where not matched by an equal increase in the international price of coffee on the stock exchanges, leading to additional economic losses and costs for producers in Guatemala.[106]

Extreme weather events do not only damage crops destined for foreign markets, but also items mainly reserved for domestic consumption, and which constitute the staples of the Guatemalan diet. An example is constituted by beans, which form the main source of protein in Guatemalan dietary habits. The production of commercial black beans is concentrated in the Eastern region of the country, which was severely affected by Hurricane Eta and Hurricane Iota. The storms destroyed approximately 24,000 hectares of beans out of 150,000 planted, resulting in a total loss of 18,617 MT of black beans. These statistics, which are to be considered as an underestimation of the actual damage, amounted to 16 percent of the total annual production of black beans in the country.[107]

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[105] Antoshak, L., & Smith, E. (2020).
[106] Hochachka, G. (2023).
[107] Tay, K. (2020). *Preliminary Assessment of Eta and Iota Tropical Depressions Impact on Guatemalan Agriculture* (Report No. GT2020-0022). United States Department of Agriculture Foreign Agricultural Sector & Global Agricultural Information Network. Retrieved at: https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Preliminary%20Assessment%20of%20Eta%20and%20Iota%20Tropical%20Depressions%20Impact%20on%20Guatemalan%20Agriculture_Guatemala%20City_Guatemala_12-07-2020.

Other affected crops include corn, the main staple in Guatemala and produced in every department of the country. Estimates assessing the impact of Eta and Iota on small production corn plots in the areas affected by the storms pointed out to the destruction of 22,941 hectares over a total affected area of 29,930 hectares, impacting over 50,000 families who depended on this crop.[108] The storms also strongly disrupted the production of rice, caused by the flooding of the Polochic Valley, resulting in the loss of 420 hectares of rice in the area; the losses amounted to 8.9 percent of the total production of rice for the year 2021, equivalent to 1,656 MT.[109] The storms affected nearly every crop produced in the country, with immeasurable losses in the production of items destined for domestic consumption and for exports.

A study carried out by the United Nations University Institute for Environment and Human Security in 2014 aimed to understand the views and opinions of four communities residing in the area of Cabricán, Western Guatemala, with respect to variations in the precipitation patterns and intensity. The research team employed four research methods in measuring these variables: a household survey; participatory research approach (PRA) workshops and focus group discussions; expert interviews at the local and national levels; and rapid rural appraisal techniques.[110]

The results showed that 74 percent of respondents agreed that there had been changes in the climate of the region. Most respondents cited increases in the intensity of rainfall as the most relevant one and the one of primary concern. 68 percent of respondents reported an increased frequency of extreme weather events, with 50 percent agreeing with the fact that drought had become more common than three decades ago, and 39 percent reporting a higher incidence of floods. A majority of respondents reported changes in three main aspects related to the weather in the past two decades, namely: a reduction in the duration of the rainy season, an increase in the intensity of rain, and an increase in the duration of drought.

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[108] Tay, K. (2020).
[109] Tay, K. (2020).
[110] Ruano, S., & Milan, A. (2014). *Climate Change, Rainfall Patterns, Livelihoods and Migration in Cabricán, Guatemala* (Report No.14). Bonn: United Nations University Institute for Environment and Human Security (UNU-EHS). Retrieved at: https://collections.unu.edu/eserv/UNU:1852/pdf11648.pdf.

The study also found that in the region the main economic activity was constituted by subsistence farming. Due to a lack of sources of water, all farming systems were reported to be rain-fed and therefore entirely dependent upon weather conditions (especially rainfall). Increases in the intensity of rain were cited by participants as being particularly damaging for maize production, as well as for other crops and for livestock. Moreover, respondents reported that increases in moisture had resulted in the proliferation of diseases – particularly fungi – which had impacted the production of beans and lima beans, and made it impossible for many families to grow wheat and potatoes.

2.3 The Status of Food and Water Insecurity in Guatemala

One of the most dramatic effects associated with natural disasters and with decreases in the agricultural output of Guatemala is the worsening of the status of food security in the country. The levels of malnutrition in Guatemala appear to be extremely worrying, and, as it will be explained in Chapter 3 of this project, the issue is forcing thousands of individuals to abandon the country and migrate due to hunger. The prevalence of poverty, further accentuated by the loss of agricultural products upon which thousands of households depend for their economic survival, puts additional pressure on individuals, as almost half of the population can not afford the cost of the basic food basket.[111]

Drought and extreme weather events are causing crop failures and widespread disruption in the agricultural production, generating a food crisis particularly severe in the central and western highlands of the Country. Over 50 percent of the Guatemalan population suffers from food and nutrition insecurity as measured by the 8-point Latin American and Caribbean Household Food Security Scale (ELCSA); the incidence of food insecurity is higher in rural areas and among the poorest groups in the Country.

The effects of climate change on the status of food and water security in Guatemala are not going to equally affect all demographic groups in the Country: indigenous Maya, rural populations are already suffering from some of the highest rates of chronic child malnutrition in the world.[112] The poorest and the most vulnerable in Guatemala often rely on being hired as unskilled laborers for agricultural activities as their main sources of income; in particular, a high percentage of them have traditionally relied on working in coffee picking. However, the production of coffee in the Country has become increasingly disrupted due to the effects of climate change. Coffee producers are facing higher production costs due to climate extremes and pests associated with climate vulnerability, thus reducing the demand for labor and, in turn,

[111] World Food Program (2023). *Guatemala*. https://www.wfp.org/countries/guatemala.
[112] Webb, M.F., Chary, A.N., De Vries, T.T., Davis, S., Dykstra, M., Flood, D., Rhodes, H.M., & Rohloff, P. (2016). Exploring Mechanisms of Food insecurity in Indigenous Agricultural Communities in Guatemala: A Mixed Methods Study. *BMC Nutrition 2*(55). Retrieved at: https://bmcnutr.biomedcentral.com/articles/10.1186/s40795-016-0091-5.

leaving those unskilled workers without any source of income, aggravating the status of food insecurity among the most vulnerable.[113]

Data from the Government of the Republic of Guatemala estimates that in 2020 rates of chronic malnutrition were significantly higher among rural children (53 percent compared with 34.6 percent among urban children) and among Maya children (58 percent compared with 34.2 percent among mestizo children); these estimates suggest that the indigenous and non-urban populations are already bearing the higher costs of the climate and food crisis, due to the high inequality of Guatemalan society and their almost-exclusive dependence on the agricultural sector – the most affected by climate change.[114]

As can be seen in Figure 15, Guatemala presents the highest stunting rate in Latin America. According to the World Health Organization definition, stunting refers to a condition characterized by inadequate height-for-age measurements. It arises due to persistent or repeated malnourishment, often linked to economic disadvantage, inadequate maternal well-being and nourishment, frequent illnesses, and suboptimal early-life feeding practices and caregiving. This phenomenon obstructs children from attaining their full physical and cognitive capacities.[115] Despite progress has been made in the country since 1990, the issue remains widespread, affecting almost 46.5 percent of children.

[113] Pons, D. (2021). *Climate Extremes, Food Insecurity, and Migration in Central America*. Retrieved at: https://reliefweb.int/report/guatemala/climate-extremes-food-insecurity-and-migration-central-america-complicated-nexus.
[114] Marroquín, L. (2021). *Centavitos Against Food Insecurity: Structural Violence, Charity, and Technical Fixes in Guatemala*. Retrieved at: https://blog.castac.org/2021/06/centavitos-against-food-insecurity-structural-violence-charity-and-technical-fixes-in-guatemala/.
[115] World Health Organization. *Malnutrition*. https://www.who.int/health-topics/malnutrition#tab=tab_1.

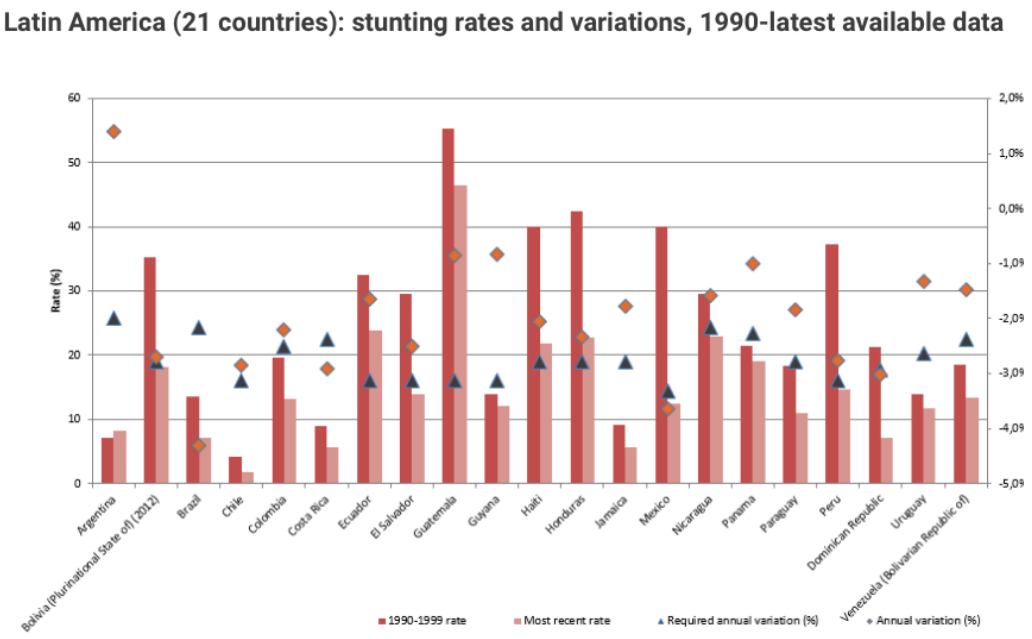

Figure 15: Stunting Rates and Variations in Latin America, 1990-latest available data. *Source*: Economic Commission for Latin America and the Caribbean, (2022).

The 46.5 percent stunting rate for children under 5 refers to the national average; however, some departments present rates as high as 70 percent, with peaks of 90 percent of children suffering from stunting in the hardest-hit municipalities.[116] A region of particular concern in represented by the Western Highlands. The 2014 United Nations University Institute for Environment and Human Security report on Cabricán, mentioned in the previous subchapter, also dealt with the prevalence of food insecurity in the region. In the Western Highlands, where the main source of food production tends to be rain-fed subsistence agriculture, the relationship between food security and weather variabilities tends to be particularly evident. As a consequence, food insecurity is prevalent in the area, with roughly 80 percent of respondents in the study reporting suffering from food shortages at least one time in the previous decade. In the area, malnourishment was estimated to affect 70 percent of children, above the national average of 45.6 percent.[117]

[116] World Food Program (2023). *Guatemala*. https://www.wfp.org/countries/guatemala.
[117] Ruano, S., & Milan, A. (2014). *Climate Change, Rainfall Patterns, Livelihoods and Migration in Cabricán, Guatemala* (Report No.14). Bonn: United Nations University Institute for Environment and

One of the most important factors cited by respondents as a cause of food insecurity relates to the production of maize – the main staple in the Guatemalan diet. When its production is damaged by diseases or natural disasters, the market price for maize tends to sharply increase, with catastrophic consequences in a region where 83 percent of respondents declared earning less than US$1 per capita per day. In addition, food insecurity disproportionately affects landless families. Indeed, their economic survival depends on working as unskilled laborers in exchange for cash, but periods of food shortages tend to coincide with periods of general decreases in the demand for labor.[118]

Drought remains one of the most severe threats to food security in the country, and particularly in those regions forming part of the Dry Corridor. The occurrence of dry spells throughout the past two decades has had enormous impacts on the production of food in the country, in turn aggravating the status of food insecurity. The prolonged drought hitting the country in 2009 was reported by the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) to have caused damages to crops amounting to 34,000 tons of food, triggering a famine in the North and North-East of the country. In the provinces constituting part of the Central American Dry Corridor, the Guatemalan Ministry of Agriculture reported that the 2009 drought had resulted in over 120,000 rural families losing 90 percent of their food crops. Most of these rural families were composed of subsistence farmers with a lack of income to buy food from other sources.[119]

In 2015, the Food and Agriculture Organization of the United Nations reported that nearly 1 million people in Guatemala were facing food insecurity as a consequence of prolonged droughts caused by reductions in precipitation. The report cited a particularly worrying situation, especially in the indigenous communities of rural Guatemala, where drought-related damages to the harvest of beans and maize were forcing families to drastically reduce their daily caloric intake, with staggering rates

Human Security (UNU-EHS). Retrieved at:
https://collections.unu.edu/eserv/UNU:1852/pdf11648.pdf.
[118] Ruano, S., & Milan, A. (2014).
[119] Reliefweb (2009). *Drought Decreases 34,000 tons of Food in Guatemala: Gov't*.
https://reliefweb.int/report/guatemala/drought-decreases-34000-tons-food-guatemala-govt.

of child malnutrition emerging as a direct consequence. The same year, the World Food Program estimated that some families had lost between 50 to 100 percent of their maize harvest.[120]

A major issue interconnected to food security and climate change dynamics relates to the status of water security in the country. The availability of water in Guatemala is threatened by growing demand due to demographic growth and by pollution, as well as changes in the precipitations patterns. The primary factors driving the need for water include agricultural activities, energy generation, industrial processes, and human consumption. As global water demand continues to rise, it is highly probable that the accessibility of freshwater in numerous areas will decline as a consequence of climate variations. The impact of worldwide climate change is projected to amplify existing and forthcoming pressures on water supplies, stemming from population expansion and land utilization, ultimately intensifying the occurrence and intensity of both droughts and floods. Climate change is expected to influence the availability of water resources by altering the distribution of rainfall, soil moisture levels, melting of glaciers and ice/snow, as well as the flow of rivers and groundwater.[121]

In a recent study[122] analyzing the potential impact of global warming on water security and the agricultural sector in Guatemala, the researchers conducted an assessment of the consequences associated with droughts on economic growth, household income, and food security. The findings revealed that agriculture, due to its reliance on water resources, would be the most affected economic sector, suffering some of the most adverse impacts. Remarkably, the research indicates a significant surge in prices of agricultural and food items associated with an increase in droughts. Furthermore, with the decline in domestic food production, there would be a

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[120] Moloney, A. (2015). *Nearly 1 Million People Face Food Emergency in Drought-Hit Guatemala: UN*. Reuters. Retrieved at: https://www.reuters.com/article/us-guatemala-food-crisis-idUSKCN0QJ1QY20150814.

[121] United Nations World Water Assessment Programme (2016). *The United Nations World Water Development Report 2016: Water and Jobs*. Paris: UNESCO. Retrieved at: https://unesdoc.unesco.org/ark:/48223/pf0000244189.

[122] Vargas, R., Cabrera, M., Cicowiez, M., Escobar, P., Hernández, V., Cabrera, J., & Guzmán, V. (2018). Climate Risk and Food Availability in Guatemala. *Environment and Development Economics 23*(5) *Special Issue Natural Resources and Economic Development*, 558-579. Doi: https://doi.org/10.1017/S1355770X18000335.

corresponding rise in imports of food products. As a result, increases in the frequency and duration of drought scenarios would pose substantial threats to the status of food security in the country.

The study also estimated a potential reduction in the GDP of the country of almost 1.2 percent as a direct consequence of reductions in the availability of water due to climate change. The study also highlighted the importance of improving and strengthening the legal framework governing the status of water resources in Guatemala. The issue is, at the present moment, regulated by Guatemala's National Irrigation Policy, which, however, appears to be incomplete due to the absence of a water-distribution system aimed at prioritizing strategic economic activities and guaranteeing food security. Improving the effectiveness of legal and institutional guarantees in the country is of the utmost importance in light of the natural and demographic risks that the nation is set to experience in relation to the management and availability of its natural resources such as agricultural land and water.

The issue of water scarcity is made even more dramatic by the demographic growth of the country, with the potential of creating a sharp increase in the demand for water (either for direct consumption, or for sustaining agricultural production and in turn food systems). If changes in the climate of the country continue to make rainfall more unpredictable and droughts more common, and if adequate sustainable policies aimed at better management of agricultural land and water are not designed and adopted, the status of food security could become even worse.

2.4 Unequal Patterns in the Access to Goods and Services

Despite the effects of climate change and natural disasters represent a global threat with negative repercussions potentially affecting societies in their entirety, demographic groups with higher degrees of social and economic exclusion appear to be more at risk of suffering the most dramatic consequences of global warming. This statement seems to be true both among countries and within them, with developing countries such as Guatemala facing higher risks than their more economically and socially stable counterparts, and poorer and most vulnerable groups inside the Guatemalan society appearing to be more at risk than more affluent social groups.

In this sense, ethnic, geographical, and gender dynamics seem to be reflected in different risk levels with respect to the economic and nutritional threats associated with global warming. In particular, higher levels of poverty and lack of access to goods and services remain at higher risk of suffering from the adverse effects of climate change.

As explained in Chapter One of this thesis project, global warming acts as a magnifier of inequalities, in turn resulting in higher rates of disparities and disproportionately affecting groups that already are at risk. Within the socio-economic context of Guatemala – characterized by high rates of social inequality, disadvantaged groups, including indigenous and rural people, are therefore expected to be at higher risk to suffer from the threats associated with climate change than Ladinos and urban populations. This is particularly relevant in connection to the access to goods and services in the country. Indeed, issues of water scarcity and food insecurity are already affecting disproportionately those communities.

A report by Minority Rights Group International [123], published in 2013, highlighted the existing patterns of ethnic inequality in the country with respect to access to goods and services. According to the report, in 2012 most indigenous groups were suffering from extremely high levels of water insecurity, lacking access to clean drinking water, electricity, paved road, and vital infrastructures, as well as adequate sewage systems. This put those populations at higher risk of contracting diseases due

[123] Minority Rights Group International (2013). *State of the World's Minorities and Indigenous Peoples 2013 – Guatemala*. Retrieved at: https://www.refworld.org/docid/526fb749b.html.

to pollution and the proliferation of viruses and bacteria in the water and sewage systems.

The report estimated that less than 6 percent of indigenous communities had access to drinkable water. Moreover, according to ECLAC around 68.4 percent of mostly non-indigenous urban households had access to sewerage connections in 2010, whilst the percentage fell to 15.4 percent for mostly indigenous rural households. Additionally, the report cited statistics pointing out to around 79 percent of Indigenous people still using outdoor toilets.

This data was correlated with higher levels in the incidence of diarrhea and other intestinal illnesses among indigenous people in comparison to Ladino populations. These statistics seem to be correlated with the poor quality of water supply and sanitation in Maya communities vis-à-vis non-indigenous communities. Unsafe water is also associated with bacteria-borne diseases.

Within indigenous and rural communities, the issue of water scarcity also appears to have differential impacts based on gender variables. Indeed, in traditional Maya communities in Guatemala, women are often tasked with collecting water for their families. The lack of adequate sources of safe water often forces women to walk long distances to gather water. This has severe implications for female health, as carrying heavy weights of water has dire effects on women's muscular-skeletal systems.

In indigenous rural communities, the report also found women to be at a higher risk of contracting respiratory diseases than their male counterparts. A reason for this is associated with the lack of goods and services in Maya non-urban communities, and in particular the lack of electricity and gas. As a result, women often have to rely on firewood for cooking and heating in enclosed spaces, inhaling large quantities of smoke as a result. Moreover, similarly to water, carrying large amounts of wood represented a risk for the muscular-skeletal systems of indigenous people.

Indeed, most houses in indigenous rural communities lack adequate ventilation systems. With respect to access to electricity, the report found extremely high levels of inequality between rural and urban households; in 2010, 94 percent of all urban

households had access to electricity, but in rural communities, the number fell to 4 percent.[124]

Ethnic variabilities are also associated with income distribution inequalities in the country. In turn, different income levels are also associated with different health and security levels. There still persist important ethnic inequalities in the job sector in Guatemala. The report by Minority Rights Group International found half of the Maya population – accounting for around 5 million citizens – was still employed in low-wage agricultural jobs.

Employment in agriculture – and particularly subsistence agriculture – is not only associated with lower salaries, but also with overall poor working conditions. During the seasons of coffee and cane harvest, agricultural workers tend to live in shacks with very high population density, facilitating the spread of communicable diseases – such as tuberculosis.

Another issue identified by the report regards access to land. Maya people and communities have historically suffered from a pattern of land dispossession, often for the agricultural industry. This practice has resulted in further income inequalities between indigenous people and the rest of Guatemalan society. This issue is interconnected with gender inequalities, as disparities in the access to land are magnified by gender variables.

Indeed, indigenous female-headed households are particularly subject to limited access to land in Guatemala. In turn, this has resulted in prevailing issues of chronic malnutrition among Maya children and women, further exacerbated by the droughts and floods which devastated the agricultural production in the country in recent years. In the period 2008-2009, 58.6 percent of indigenous Maya children below the age of 5 suffered from chronic malnutrition, whilst the percentage fell to 30.6 percent among

[124] Minority Rights Group International (2013, September 24). *State of the World's Minorities and Indigenous Peoples 2013 – Guatemala*. Retrieved at: https://www.refworld.org/docid/526fb749b.html.

non-Maya children, indicating a pattern of ethnic inequalities in the vulnerability to food insecurity.[125]

Income inequalities and ethnic inequalities appear to be deeply interconnected in Guatemala. Indigenous communities in Guatemala present some of the highest rates of poverty, malnutrition, and maternal-child mortality in the entire Latin American macroregion.[126] Moreover, as a consequence of the extreme weather events which affected the country – and particularly its rural areas – in the last two decades, rural poverty increased from 74.5 to 76.1 percent in the period 2000-2014, whilst extreme rural poverty increased from 23.8 percent to 35.3 percent. When only considering indigenous Maya communities in the country, the poverty rate rose to 80 percent.

A survey conducted in 2013 by the Farmers Development Committee (CODECA) found that the overwhelming majority of rural workers in Guatemala identified as Maya indigenous (69 percent) and suffered from social exclusion and discrimination. 25 percent of rural workers were women and 11 percent were children. The same study found that 90 percent of rural workers earned a salary below the national minimum wage, and that rate climbed to 97 percent for female rural workers. The findings from the UN Special Rapporteur on the right to food, in collaboration with the Office of the High Commissioner for Human Rights and the Human Rights Committee, identified a clear pattern of inequality in the access to land in Guatemala. According to their research, a significant disparity exists in the distribution of arable lands within the nation. It was revealed that a mere 2 percent of the national population controls a staggering 80 percent of these lands. Remarkably, despite representing the majority of the rural population, indigenous peoples only have access to a mere 2.5 percent of the land.[127]

The Western Highlands are among the regions with the highest levels of vulnerability to food insecurity in the country. The area is characterized by higher

[125] Minority Rights Group International (2013, September 24). *State of the World's Minorities and Indigenous Peoples 2013 – Guatemala*. Retrieved at: https://www.refworld.org/docid/526fb749b.html.
[126] De La Peña, I., & Hennings, E. (2022). *Guatemala*. IFAD. Retrieved at: https://www.ifad.org/en/web/operations/w/country/guatemala.
[127] CETIM (2013, Nov 11). *The Situation of Farm Workers in Guatemala*. Retrieved at: https://www.cetim.ch/the-situation-of-farm-workers-in-guatemala/.

percentages of Maya populations, living in rural communities and with high levels of social and economic exclusion. Economic activity in the area tends to be mainly concentrated around subsistence farming and the production of coffee and maize. This makes the region particularly vulnerable to climate change and the threat of extreme weather events on agricultural production.[128] This can be observed in Figure 16 below.

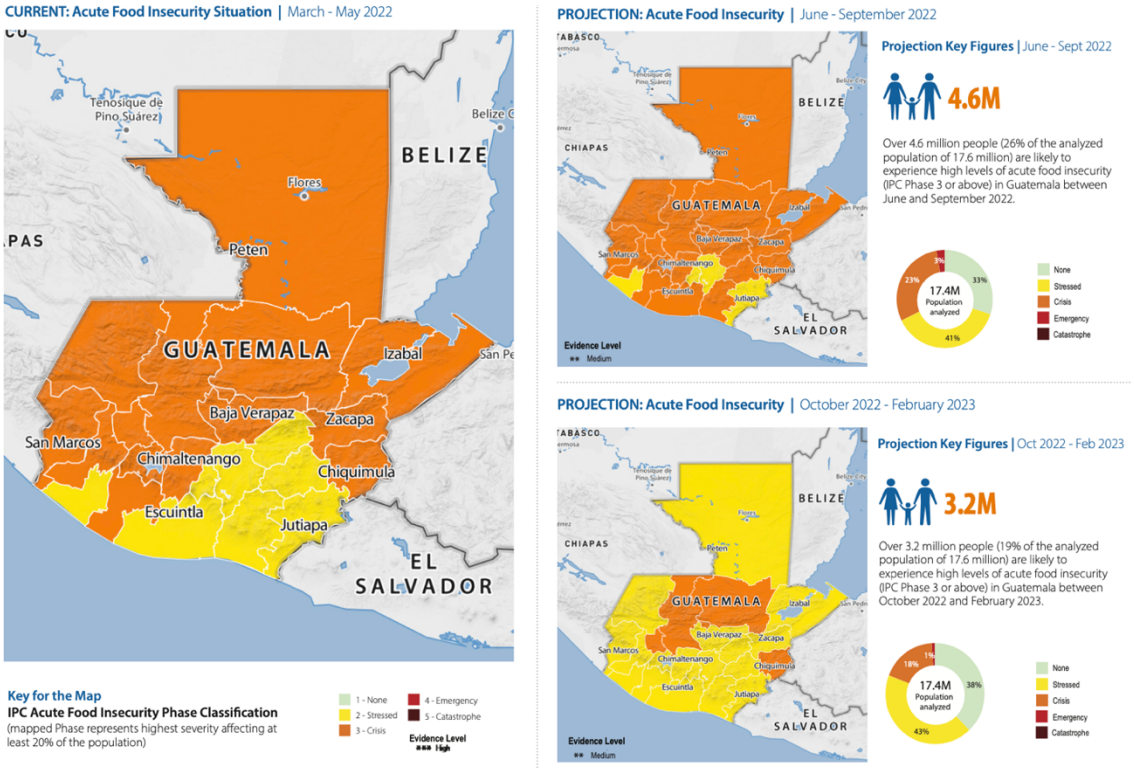

Figure 16: Status of Acute Food Insecurity in Guatemala March 2022 – February 2023. *Source*: Integrated Food Security Phase Classification (2022)[129]

As will be explored in Chapter 3, one of the consequences of the interplay between climate change, rural poverty, and food insecurity is migration. This phenomenon is becoming particularly relevant in the regions of the Guatemalan Dry Corridor, where the consequences of this nexus on the economic survival of the local population are magnified. This is resulting in higher levels of migration – especially towards the US

[128] Lopez-Ridaura, S., Barba-Escoto, L., Reyna, C., Hellin, J., Gerard, B., & van Wijk, M. (2019). Food Security and Agriculture in the Western Highlands of Guatemala. *Food Security 11,* 817-833. Doi: https://doi.org/10.1007/s12571-019-00940-z.
[129] Integrated Food Security Phase Classification (2022). *Guatemala Acute Food Insecurity Situation March to May 2022 and Projections for June - September 2022 and October 2022 - February 2023*. Retrieved at: https://www.ipcinfo.org/ipc-country-analysis/details-map/en/c/1155665/.

– with important gender and geographical differences in the number of people who decide to move. Rural people and men are more likely to move than urban dwellers and women.

The rates of food insecurity, water scarcity, and lack of access to goods and services are characterized by stark demographic inequalities, dependent upon gender variables, ethnic variables, and geographical variables. With global warming and extreme weather events set to exacerbate the rates of food and water insecurity, it is likely that this will be reflected in a worsening of the inequality levels within Guatemalan society. Indigenous people, due to their higher levels of poverty and their higher dependency upon agriculture for their economic sustenance, are at higher risk of suffering from these consequences. This is already evident from the higher levels of poverty and malnutrition among indigenous and rural populations compared to Ladino and urban populations.

Gender variables appear to also have an influence. The status of women and children's health in the country is particularly worrying, and this seems to be correlated with lower access of women to land. At the same time, most Guatemalan migrants are men, partly due to the idea of males as breadwinners inside traditional family structures. Demographic variabilities thus appear to be statistically relevant when assessing the impact of food insecurity and, in turn, the effects of climate change and global warming on the latter.

Chapter 3: The Security Implications of the Youth Bulge-Extreme Weather Nexus

3.1 The Interplay Between Age Structure and Global Warming in Developing Countries

So far, this analysis has focused on the interplay between climate change, economics, and two demographic variables, namely gender and ethnicity. However, a third demographic variable is deeply interconnected with the threats associated with climate change and economic instability: the role of age. The age structure of a society provides countries with both challenges and opportunities. The distribution of different age groups within a population plays a crucial role in shaping the economic production and the political stability of nations. A country's age structure directly influences patterns of consumption, productivity, as well as the size of the labor force. In turn, it can play an important role in impacting levels of economic growth, as well as social and political stability and conflict.

These assumptions lie at the core of the age-structural theory of state behavior. Pursuant to this theoretical framework, the probabilities of realizing certain social, economic, and political conditions shift as the population moves through the age-structural transition.[130] Whilst it should be noted that *demography is not destiny*, meaning that it should not be assumed that certain demographic conditions will always yield the same results, it should be acknowledged that the demographic structure of a country – when associated with other factors, such as geography or institutional quality and political representation – can result in opportunities or threats for countries and societies.

Within the framework of the age-structural theory of state behavior, one of the most widely discussed issues has been the relationship between the human population's age structure and the potential for violence, instability, and unrest. In

[130] Cincotta, R. (2017). The Age-Structural Theory of State Behavior. *Oxford Research Encyclopedia of Politics*. Doi: 10.1093/acrefore/9780190228637.013.327.

other words, the presence of a particular demographic condition – the "youth bulge" – has been linked to higher risks of political and social violence and unrest. Pursuant to this hypothesis, countries with a high percentage of young adults in their adult population are therefore expected to suffer from higher levels of threats of violence or conflict.[131]

The term "youth bulge" refers to a demographic phenomenon characterized by a significant proportion of young people within a population. It occurs when there is a higher concentration of individuals in the younger age groups, typically between the ages of 15 and 24. The phenomenon of a "youth bulge" often arises when the proportion of the youth population is significantly larger than other age groups, creating a bulge-like shape when represented graphically.

Under the demographic transition theory, a youth bulge represents a normal phenomenon in the age transition of societies, the product of the rapid decrease in mortality rates whilst fertility rates remain high. Therefore, the presence of a youth bulge *per se* is not necessarily associated with a negative outcome. Youth bulges can actually have positive effects on societies, as the presence of a youthful population can foster economic growth and innovation; moreover, as societies progress through the age transition, the youth bulge can result in a demographic dividend arising from declining age-dependency ratios.

Indeed, as young adults enter the working age, the nation's dependency ratio, namely the ratio of the non-working age population to the working age population, will shrink. This can turn into positive gains for societies, resulting in higher levels of average per-capita income. However, for this to be achieved, the additional working-age individuals – those young adults associated with a youth bulge – must be fully employed in productive activities.[132] In this case, the youth bulge will result in a demographic dividend, fostering the economic growth and development of a country.

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[131] Mesquida, C.G., & Wiener, N.I. (1999). Male Age Composition and Severity of Conflicts. *Politics and the Life Sciences 18*(2), 181-189. Retrieved at: https://www.jstor.org/stable/4236494.
[132] Yifu Lin, J. (2012). Youth Bulge: A Demographic Dividend or a Demographic Bomb in Developing Countries? *World Bank Blogs*. Retrieved at: https://blogs.worldbank.org/developmenttalk/youth-bulge-a-demographic-dividend-or-a-demographic-bomb-in-developing-countries.

However, if the increase in the number of young adults is not met by an equal increase in the employment rate – meaning that if large percentages of the new working-age population individuals are not able to find employment in productive activities – then the presence of a youth bulge could potentially turn into a source of instability.

Youth bulges alongside high unemployment rates and unfavorable macroeconomic landscapes have been proposed – at least partially – as explanatory variables in a multitude of revolutions and cases of civic unrest. For instance, the presence of high numbers of young people lacking access to employment opportunities and political participation has been associated with increased instability in the Arab world – eventually precipitating the Arab Spring of 2011.[133]

Several factors can potentially play a role in determining whether a youth bulge will result in a demographic dividend or a demographic bomb. Youth bulges are likely to sharply increase the supply of labor, and when this increase is not met by a sufficient rise in the number of available jobs – resulting in large percentages of unemployment – economic grievances will arise, generating tensions and potentially leading to conflict.

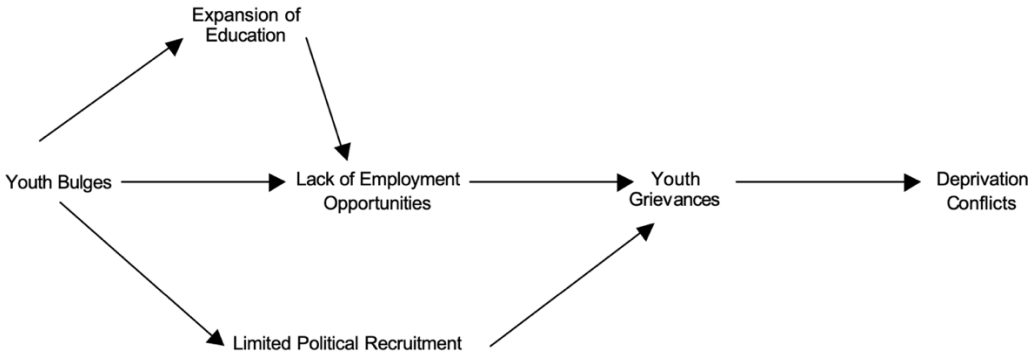

Figure 17: Youth Bulges as a Source of Armed Conflict. Source: Urdal, (2004).

Figure 17 shows how certain factors can interplay in turning youth bulges into sources of conflict and violence. Alongside a lack of employment opportunities, limited levels

[133] Mulderig, M.C. (2013). An Uncertain Future: Youth Frustration and the Arab Spring. *The Pardee Papers, 16*. Retrieved at: https://www.bu.edu/pardee/files/2013/04/Pardee-Paper-16.pdf.

of political recruitment, i.e., low levels of participation by young people in political institutions and in political elites, alongside low responsiveness by political elites, can potentially exacerbate youth grievances. Moreover, increased access to education can generate higher expectations from young adults with respect to the expected income and job attainments after years of training and education, resulting in dynamics of relative deprivation if these expectations are not met due to high levels of unemployment.[134]

The concept of relative deprivation as a source of conflict refers to individual and collective feelings of being deprived of what they deserve – or expect to deserve. Relative deprivation, therefore, refers to the perception of political and social actors (such as youth) of a discrepancy between their value expectations – i.e., those goods and life conditions to which the actors believe they are justifiably entitled – and their environment's value capabilities – i.e., what the physical and socio-political conditions in which the individuals live can actually provide.[135]

Consequently, when people feel deprived of what they deserve, they start to develop grievances, which can translate into growing civil and political tensions. These grievances are therefore linked to unfavorable political, social, and economic conditions.

With respect to the interplay between youth bulges and relative deprivation as a fuel of violence, the nexus becomes particularly prominent when labor markets fail to integrate a growing percentage of youth into the economy.[136] Moreover, expansions in education can raise expectations in young adults regarding their future employment and life opportunities. Young people with higher education have increased expectations for higher-income jobs. If those expectations are not fulfilled due to

[134] Urdal, H. (2004). The Devil in the Demographics: The Effect of Youth Bulges on Domestic Armed Conflict, 1950-2000. *The World Bank Social Development Papers: Conflict Prevention and Reconstruction (Paper No. 14)*. Retrieved at: https://documents1.worldbank.org/curated/en/794881468762939913/pdf/29740.pdf.
[135] Gurr, T. (1968). Psychological Factors in Civil Violence. *World Politics 20*(2), 245-278. Doi: https://doi.org/10.2307/2009798.
[136] Apolte, T., & Gerling, L. (2018). Youth Bulges, Insurrections and Labor-Market Restrictions. *Public Choice 175*, 63-93. Doi: https://doi.org/10.1007/s11127-018-0514-8.

unemployment or underemployment, then feelings of frustration and disillusion can become widespread, fueling resentment and grievances.[137]

In the absence of alternative income-earning opportunities, young individuals – and particularly young men – may be more inclined to join violent groups and indulge in illicit activities. In the face of unemployment and poverty, young individuals may turn to unlawful activities – sometimes even to violence – as alternative ways to earn an income.[138]

As climate change threatens to disrupt the economic output of countries, its consequences on employment could be far-reaching. According to reports from the International Labour Organization, the rise of global temperatures and the worsening of the environmental deterioration have already yielded adverse effects on employment and work efficiency, and these effects are anticipated to intensify in the forthcoming years. Alterations in temperature and precipitation patterns are expected to impact entire sectors, particularly agriculture, while extreme weather events are likely to disrupt industries such as transportation and tourism. Rising sea levels have the potential to displace whole communities and result in the salinization of agricultural land. Ocean acidification, along with fluctuations in ocean temperatures and currents, reduces the ability of coral reefs to offer storm protection, diminishes biodiversity, and modifies the distribution and productivity of fisheries. The most severe repercussions are projected to manifest in economic domains that heavily rely on highly climate-sensitive resources, such as agriculture, and in regions frequently afflicted by extreme weather events.[139]

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[137] Weber, H. (2019). Age Structure and Political Violence: A Re-Assessment of the "Youth Bulge" Hypothesis. *International Interactions 45*(1), 80-112. Doi: https://doi.org/10.1080/03050629.2019.1522310.

[138] Collier, P. (2000). Doing Well Out of War: An Economic Perspective. In *Greed & Grievance: Economic Agendas in Civil Wars*, edited by Berdal Mats and Malone David M. Boulder: Lynne Rienner. Retrieved at: https://documents1.worldbank.org/curated/en/504671468762020790/pdf/28137.pdf.

[139] International Labor Organization (2018). *The employment impact of climate change adaptation. Input Document for the G20 Climate Sustainability Working Group*. International Labour Office – Geneva. Retrieved at: https://www.ilo.org/wcmsp5/groups/public/---ed_emp/documents/publication/wcms_645572.pdf.

As a consequence, the interplay between climate change and demographic growth in developing countries is set to further exacerbate the risk of violence associated with youth-bulges, as a consequence of rising unemployment in countries with large youth cohorts. In the absence of work opportunities and resources – set to be aggravated by global warming – the opportunity cost for young men of joining violent or illicit groups may be expected to increase, especially in fragile systems with high levels of corruption and low levels of political responsiveness to the challenges of unemployment and climate change.

3.2 Youth Bulge, Violence, and Climate Change in Guatemala

By considering its demographic composition, associated with its vulnerability to the economically disruptive effects of global warming to which the country is subject, Guatemala's growing population and emerging youth bulge could add further demographic pressure upon the country's political and economic stability.

Importantly, Guatemala is characterized by the youngest population in the entire Latin American and Caribbean region[140]. Roughly half of the nation's population is below the age of 19, and the country's median age was estimated at 21.7 years as of 2020. In the window between the second and the third stages of the demographic transition model, Guatemala is experiencing an increase in the percentage of its young adult population.

By applying the theories mentioned in the previous subchapter, and specifically focusing on the so-called *Youth Bulge Theory*[141], the present section of this work aims to shed light on the possible interconnection between economic disruptions caused by climate extremes, the youth bulge theory, and the level and intensity of gang violence in the country.

As stated in Chapter 3.1, a youth bulge may be defined as a high percentage of people aged 15-24 over the entire adult population. The population pyramid of Guatemala , which can be seen in Figure 18a below, presents a very youthful structure. As highlighted in Figure 18b, the overall percentage of individuals aged 15-24 in the country – the category traditionally associated with a youth bulge – constitutes 20.4% of the total population.

In addition to this, the *Youth Bulge Theory* also emphasizes the role played by gender variables in channeling violence and social unrest in societies characterized by a youth bulge and high unemployment; Indeed, most literature on the youth bulge

[140] O'Neill, A. (2023). *Median Age of the Population in Guatemala 2020*. Statista. Retrieved at: https://www.statista.com/statistics/441803/average-age-of-the-population-in-guatemala/.
[141] Boyden, J. (2007). Children, war and world disorder in the 21st century: a review of the theories and the literature on children's contributions to armed violence: Analysis. *Conflict, Security & Development*, *7*(2), 255-279.

theory correlates higher levels of sociopolitical risk with the presence of a large percentage of youthful *male* population[142]. With respect to the population structure of Guatemala, within the identified relevant category (namely, population aged 15-24), males accounted for 51% of the population in the relevant age group.

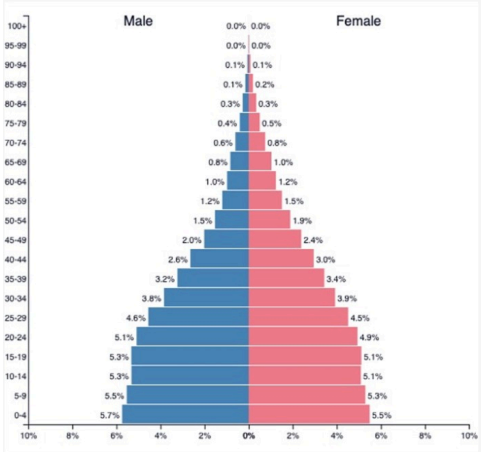

Figure 18a. Guatemala's population pyramid in 2022.

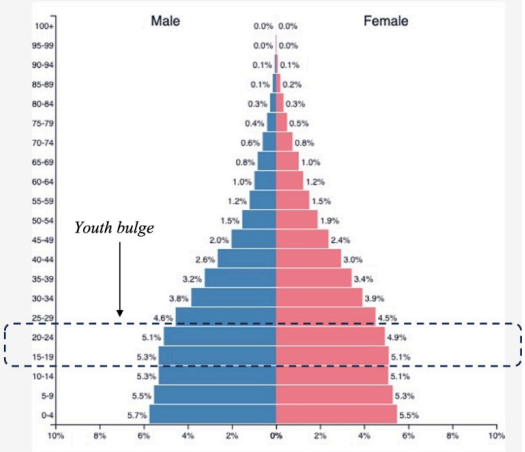

Figure 18b. Focus on the percentage of youth aged population (15-19, and 20-24) representing the so-called "youth bulge"

Since the end of Guatemala's civil conflict in 1996, there has been a notable surge in criminal activities, particularly violent crime. This surge involves various illicit entities, including drug traffickers, organized crime factions, and youth gangs, which seem to be engaged in an unconventional type of conflict against the state – which can be effectively characterized as a *criminal insurgency*. The country's law enforcement, judiciary, and local administrative bodies have themselves been subject to infiltration by criminal elements. Recent murder rates have even surpassed those experienced during the civil war era. Additionally, government officials and members of the political sphere find themselves targeted by criminal operatives. Consequently, certain regions now find themselves effectively controlled by these illegal groups – as much as 40 percent of the country's total territory has been estimated to be under the control of criminal gangs, according to governmental projections. The resulting

[142] Urdal, H., & Hoelscher, K. (2009). Urban youth bulges and social disorder: An empirical study of Asian and sub-Saharan African cities. *World Bank Policy Research Working Paper*, (5110). Retrieved at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1503804.

disillusionment within society has led to a decline in the government's authority and legitimacy, posing a significant challenge to the nation's democratic structure.[143]

These gangs tend to be composed by young males from the most disadvantaged and excluded social groups.[144] Poverty, inequality, and unemployment in the country and among youth are likely the main drivers behind the criminal insurgency affecting the nation. According to World Bank estimates, in 2019 the share of youth not in education, employment or training (NEET) in Guatemala represented 28.2 percent of the total youth population (measured for the age cohort 15-24).[145] The number is likely to have increased in recent years due to the effects of the Covid-19 pandemic.

Moreover, *Climate change* has been recognized as a significant driver of poverty, inequality, and unemployment in the region as well.

Specifically, Guatemala, like many other Latin American countries, is susceptible to the adverse effects of climate change, including extreme weather events, changing precipitation patterns, and environmental degradation, as analyzed in Chapter 2 of this research project. These climate-related challenges may disproportionately affect vulnerable youth, particularly those living in poverty or marginalized areas with limited access to resources.[146]

In regions where agriculture plays a crucial role in livelihoods, climate change can lead to reduced agricultural productivity, crop failures, and loss of livelihoods for farmers. This can force many rural communities to migrate to urban areas in search of alternative sources of income and opportunities. The influx of people into cities and

[143] Brands, H. (2011). Crime, irregular warfare, and institutional failure in Latin America: Guatemala as a case study. *Studies in Conflict & Terrorism*, *34*(3), 228-247. Doi: https://doi.org/10.1080/1057610X.2011.545937.
[144] Lemus, L. (2018). Guatemala: Rethinking the Link between Youth and Violence in the Postwar Period. *LiminaR*, *16*(2), 45-59. Retrieved at: https://www.scielo.org.mx/pdf/liminar/v16n2/2007-8900-liminar-16-02-45.pdf.
[145] The World Bank (2023). *Share of youth not in education, employment or training, total (% of youth population) – Guatemala*. Retrieved at: https://data.worldbank.org/indicator/SL.UEM.NEET.ZS?locations=GT.
[146] Leichenko, R., & Silva, J. A. (2014). Climate change and poverty: vulnerability, impacts, and alleviation strategies. *Wiley Interdisciplinary Reviews: Climate Change*, *5*(4), 539-556. Doi: https://doi.org/10.1002/wcc.287.

towns, without adequate infrastructure or employment prospects, could lead to overcrowding, poverty, and social tensions.

As climate-induced unemployment rises, vulnerable youth become susceptible to recruitment by criminal groups. Criminal organizations often exploit desperate circumstances, offering a sense of economic security and belonging to individuals who see no other viable options for survival. In this domain, the lack of legitimate job opportunities, together with the allure of quick money and power from criminal activities, could eventually lead people towards illicit activities, thus boosting the ranks of criminal gangs.[147]

Furthermore, climate change can exacerbate resource scarcity, such as water and land, leading to competition and conflicts among communities. Criminal groups can exploit these tensions, engaging in territorial disputes and controlling illicit activities like illegal mining or deforestation. In areas where government institutions are already weak, criminal groups can more easily infiltrate and co-opt parts of the state apparatus, further eroding governance and the rule of law.

The combination of climate-induced unemployment, resource scarcity, and weak governance can create a vicious cycle of crime and violence, contributing to the erosion of democratic institutions and citizen trust in the government's ability to address their needs. As criminal groups expand their influence and control over territories, they undermine the state's legitimacy, leading to a loss of confidence in the democratic system.

The low median age, the lack of political representation in a country still characterized by high levels of corruption and inequality, and the high unemployment rates have created the preconditions for the presence of a youth bulge with the potential of becoming a demographic bomb. As climate change worsens the status of food and nutrition insecurity and further fuels unemployment and economic hardships, the social and political apparatus of the country could potentially become less stable. Thus,

[147] Kawachi, I., Kennedy, B. P., & Wilkinson, R. G. (1999). Crime: social disorganization and relative deprivation. *Social Science & Medicine*, *48*(6), 719-731. Doi: https://doi.org/10.1016/S0277-9536(98)00400-6.

despite demography is not destiny, by considering on one hand the critical situation characterizing Guatemala in terms of poverty and unemployment that may push large portions of young males towards gang associations, generating endemic violence, and on the other by considering similar case studies related to countries showing similar orthogonal characteristics, it may be predicted that Guatemala may be exposed to such risks.

In particular, rural areas tend to be more affected by criminal gangs' activities, as the level of state control is significantly lower than in urban areas and the lack of job opportunities for the local youth – due to a reduction in the demand for agricultural labor – contributes to the recruitment by gangs of unemployed young males.[148] The criminal activities of these gangs, which often include thefts and extortions, further aggravates the level of malnutrition and food insecurity in the areas plagued by their presence.

The relationship between food insecurity and gangs' violence in rural Guatemala has become a vicious circle, in which the activities of criminal gangs exacerbate the low availability of food products and at the same time the food scarcity contributes to escalating violence, as testified by the high number of assaults to women receiving food aid by the state.[149]

Additionally, the presence of criminal organizations controlling territory and *de facto* administering it threatens to further exacerbate the status of environmental degradation in the country due to illicit activities such as deforestation, the construction of illegal airlifts for transportation of drugs, and illegal mining.[150] Therefore, whilst from one side climate change – through its effects on unemployment and food security – is likely to further exacerbate the level of criminality and social unrest in the country, on the other side the activities of these criminal groups have the

[148] Lemus, L. (2018). Guatemala: Rethinking the Link between Youth and Violence in the Postwar Period. *LiminaR*, *16*(2), 45-59. Retrieved at: https://www.scielo.org.mx/pdf/liminar/v16n2/2007-8900-liminar-16-02-45.pdf.
[149] Pacciardi, A. (2020, March 30). Running Away from Hunger: The Food Security-Migration Nexus in Guatemala, Honduras and El Salvador. *IFAIR Young Initiative on Foreign Affairs and International Relations*. Retrieved at: https://ifair.eu/2020/03/30/running-away-from-hunger-the-food-security-migration-nexus-in-guatemala-honduras-and-el-salvador-2/.
[150] White, R. (2018). *Climate change criminology* (1st ed.). Bristol University Press. Doi: https://doi.org/10.2307/j.ctv5vddmg.

potential to further disrupt the local ecosystems with far-reaching consequences in terms of food security and agricultural employment.

With few job opportunities and the scarcity of food and water in rural areas, many young males – often coming from the most vulnerable social groups, and in particular indigenous groups – are left with the choice of either joining criminal gangs and steal food to survive or leave the country and go looking for better job opportunities away from endemic violence and chronic malnutrition.

3.3 Climate Change, Food Insecurity, and Migration in Guatemala

In demography literature, migration is defined as any permanent change in residence. It involves the "detachment from the organization of activities at one place and the movement of the total round of activities to another".[151] Human migration can be defined as the permanent change of residence by an individual or group, therefore excluding such movements as nomadism, commuting, and tourism, all of which are transitory in nature.[152] Within migration studies, a broad distinction can be made between internal migrants and international migrants; the former refers to those individuals who are internally displaced within their own countries or who move to other areas of their own country (e.g., as part of the urban transition leading individuals to move from rural areas towards urban areas within the broader demographic transition of societies), whilst the latter refers to the movement of individuals or groups of individuals from one country to another.[153]

International migration is not solely instigated by economic elements, but also by social, political, cultural, environmental, healthcare, educational, and transportation considerations. It frequently arises due to push factors such as limited prospects within the socioeconomic setting, as well as pull factors present in more developed regions. These push and pull factors serve as influences that can either attract individuals to relocate or compel them to depart from their current dwellings. [154] These influences can encompass economic, political, cultural, and environmental components. Push factors signify circumstances that impel individuals to abandon their residences, exerting significant pressure and being closely tied to the origin country of the migrant.[155]

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[151] Goldscheider, C. (1971). *Population, modernization, and social structure* (p. 58). Little, Brown.
[152] Britannica, T. Editors of Encyclopaedia (2023). *Human Migration*. Encyclopedia Britannica. https://www.britannica.com/topic/human-migration.
[153] Skeldon, R. (2018). *International migration, internal migration, mobility and urbanization: Towards more integrated approaches*. United Nations. Doi: https://doi.org/10.18356/a97468ba-en.
[154] Krishnakumar, P., & Indumathi, T. (2014). Pull and Push Factors of Migration. *Global Management Review*, *8*(4).
[155] Urbański, M. (2022). Comparing push and pull factors affecting migration. *Economies*, *10*(1), 21. Doi: https://doi.org/10.3390/economies10010021.

The impact of global warming as a push factor for human migration patterns is the subject of increasing academic and public debate.[156] Whilst the exact degree and magnitude of climate-related migration is still a subject of academic debate, the role of extreme weather events (e.g., as for drought or floods), as a push factor leading people to the decision to migrate, has been widely discussed in scientific literature.[157]

A comprehensive approach to the issue has been addressed by recent publications aiming to build a theoretical model around the relationship between climate change and migration. One of these models, elaborated by Black et colleagues[158] , identifies five distinct categories of factors that influence decisions related to migration: Economic, political, social, demographic, and environmental elements. Environmental factors shape migration by influencing the availability and reliability of ecosystem services, as well as exposure to potential hazards. The interaction of these drivers determines individual migration choices and flows. Notably, the environmental impact on migration heavily relies on the prevailing economic, political, social, and demographic context.

Environmental changes can directly alter the safety and viability of certain locations. Additionally, these changes indirectly affect migration through economic drivers, such as changes in livelihood opportunities, and political drivers, which can lead to conflicts over resources. This comprehensive framework is applicable to both international and internal migration scenarios, with a strong focus on human agency in migration decisions. It emphasizes the interconnected roles of family and household characteristics as well as the barriers and facilitators that influence movement based on the drivers identified.

As anticipated in Chapter 1 of this thesis, global warming is not a uniform phenomenon producing the same effects across the planet. Similarly, a model linking

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[156] Hoffmann, R., Šedová, B., & Vinke, K. (2021). Improving the evidence base: A methodological review of the quantitative climate migration literature. *Global Environmental Change*, *71*, 102367. Doi: https://doi.org/10.1016/j.gloenvcha.2021.102367.

[157] Carvalhaes, T., Kar, B., Thakur, G., & Christopher, C. (2022). A Spatially Non-Stationary Approach to Identify Multi-Dimensional Push Factors for International Emigration. *Available at SSRN 4307489*. Doi: http://dx.doi.org/10.2139/ssrn.4307489.

[158] Black, R., Adger, W. N., Arnell, N. W., Dercon, S., Geddes, A., & Thomas, D. (2011). The effect of environmental change on human migration. *Global Environmental Change*, *21*, S3-S11. Doi: https://doi.org/10.1016/j.gloenvcha.2011.10.001.

climate change to migration patterns cannot be conceived as a universal framework but should rather be formulated according to country-specific and region-specific variables. Thus, in the study of human migration and global warming, the role of economic and social factors is key to framing the magnitude of migration patterns as a result of extreme weather events.

Indeed, countries with a higher dependency on the agricultural sector for their macroeconomic stability are more likely to experience higher levels of climate-related migrations than countries with more industrialized economies. The connection between temperature and migration is not linear: Specifically, high temperatures may negatively affect agricultural productivity and lead to international migration. As a result, agriculture seems to play a crucial role as an intermediary factor between weather conditions and international migration.[159]

The growing unreliability on the agricultural sector in countries with higher exposure to extreme weather events is projected to exacerbate the phenomenon of human migrants from developing countries towards more industrialized countries. This phenomenon is becoming increasingly evident with respect to the emigration of Guatemalans towards the United States of America.[160]

The number of Guatemalans deciding to leave their country and migrate to the United States has been sharply increasing in the last years, with a growth rate of 33 percent in the period 2010-2021.[161] The median age of Guatemalan migrants in the US in 2021 was estimated to be 37 years old, indicating that the highest share of migrants consisted of people of working age deciding to move outside the Central American country and seek better job opportunities abroad. Among these, around 56 percent of

[159] Cai, R., Feng, S., Oppenheimer, M., & Pytlikova, M. (2016). Climate variability and international migration: The importance of the agricultural linkage. *Journal of Environmental Economics and Management*, *79*, 135-151. Doi: https://doi.org/10.1016/j.jeem.2016.06.005.
[160] Munoz, A., Pons, D., Giraldo-Mendez, D., Adamo, S. B., de Sherbinin, A. M., & Goddard, L. M. (2019, December). Can We Predict" Climate Migrations"? The 2018 Guatemalan Case. In *AGU Fall Meeting Abstracts* (Vol. 2019, pp. GC13E-1213). Retrieved from: https://ui.adsabs.harvard.edu/abs/2019AGUFMGC13E1213M/abstract.
[161] Migration Policy Institute (2023). *Central American Immigrants in the United States*. Retrieved from: https://www.migrationpolicy.org/article/central-american-immigrants-united-states.

those migrants lacked a high school education, having the lowest educational attainments, on average, among all Central American migrants in the US.[162]

Importantly, in 2021, Guatemala presented a negative net migration rate of -29,118, pursuant to World Bank statistics. In 2019, before the entry into force of restrictions to human mobility due to the spread of the Covid-19 pandemic, the net migration rate of Guatemala stood at -58,095.[163]

Besides external migration, Guatemala is currently also experiencing high rates of internal migration. This phenomenon is partly caused by the urban and demographic transition, driving people away from rural areas and towards urban areas as a result of industrialization and the economic shift from rural to industrial societies. However, high number of internal migrants in the country also consist of displaced individuals who left their houses due to extreme weather events.[164]

The primary cause attributed to migration is of an economic nature. Nearly 90 percent of migrants from Guatemala refer to economic factors as their primary incentive for departing the country. The economic factors cited encompass high levels of unemployment within the nation (i.e., 43 percent), inadequate employment opportunities to meet their requirements (i.e., 22 percent), and insufficient wages (i.e., 15 percent).[165]

Considering the nexus between climate change and agricultural production examined in Chapter 2 of the present thesis, it may be expected that, in the absence of adequate policies aimed at agricultural adaptation in the face of an increasingly unpredictable weather, the number of Guatemalans deciding to leave their country and

[162] Migration Policy Institute (2023). *Central American Immigrants in the United States*. Retrieved from: https://www.migrationpolicy.org/article/central-american-immigrants-united-states.
[163] World Bank (2023). Indicators. Retrived at: https://data.worldbank.org/indicator/SM.POP.NETM?locations=GT.
[164] Sivisaca, D. L., Robalino, J., Cascante, A. C., Imbach, P., & Sandoval, C. (2021). Effects of Extreme Weather Events on Internal Migration in Rural Guatemala. *Extreme Events and Climate Change: A Multidisciplinary Approach*, 135-146. Doi: https://doi.org/10.1002/9781119413738.ch9.
[165] Abuelafia, E., Del Carmen, G., & Ruiz-Arranz, M. (2019). *In the Footprints of Migrants: Perspectives and Experiences of Migrants from El Salvador, Guatemala and Honduras in the United States*. Retrieved at: https://publications.iadb.org/publications/english/document/In-the-Footprints-of-Migrants-Perspectives-and-Experiences-of-Migrants-from-El-Salvador-Guatemala-and-Honduras-in-the-United-States.pdf.

seek better job opportunities elsewhere is likely to increase.[166] This is especially true for rural and Maya individuals, due to their higher dependency on agricultural output for their economic survival. As changes in precipitation patterns affects the production of crops and lead to losses in the family income of rural households, higher numbers of individuals can be expected to abandon the Guatemalan countryside and seek means of sustenance for their families abroad, typically in the form of remittances.

Remittances, in the context of migration, refer to the money or financial resources that migrants send back to their home country or to their families and communities of origin. [167] These funds are typically sent by individuals who have migrated to another country in search of better economic opportunities or improved living conditions: Remittances thus include cash transfers, bank deposits, or in-kind contributions that are intended to support the well-being of the recipient households or to address specific needs, such as education, healthcare, housing, or daily living expenses.

As shown in the Figure 19 below, remittances sent by migrants living abroad represent an extremely important element in the macroeconomic outlook of Guatemala. The percentage of personal remittances over the country's Gross Domestic Product has been sharply increasing in the last years, as a result of growing rates of emigration towards the United States. As of 2022, personal remittances represented more than 19 percent of Guatemala's Gross Domestic Product. Personal remittances are often conceived as the only alternative for rural households who lost most of their income due to widespread damages to agricultural production caused by extreme weather events.[168]

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[166] Bermeo, S., Leblang, D., & Nagle Alverio, G. (2022). Root Causes of Migration from Guatemala: Analysis of Subnational Trends. *Duke Sanford Center for International Development*. Retrieved at: https://dcid.sanford.duke.edu/wp-content/uploads/sites/2/2022/03/Migration-Policy-Brief-Guatemala-FINAL.pdf.

[167] Adams, R. H., & Page, J. (2003). *International migration, remittances, and poverty in developing countries* (Vol. 3179). World Bank Publications: Washington. Retrieved at: https://books.google.com/books?hl=en&lr=&id=0wUx3SvAAjsC&oi=fnd&pg=PA1&dq=international+migration+remittances+and+poverty&ots=aXq8VwUxda&sig=wyTEtigsiH9uA12kX8Z8siqjr9I.

[168] New York Times, & Lustgarten, A. (2020). *The great climate migration*. New York Times Magazine. Retrieved at: https://pulitzercenter.org/sites/default/files/inline-images/jEu86t17dIVE7rPSH1JU9CYyVvZ8EZZKIfTzWyIVFCXzLHT62m.pdf.

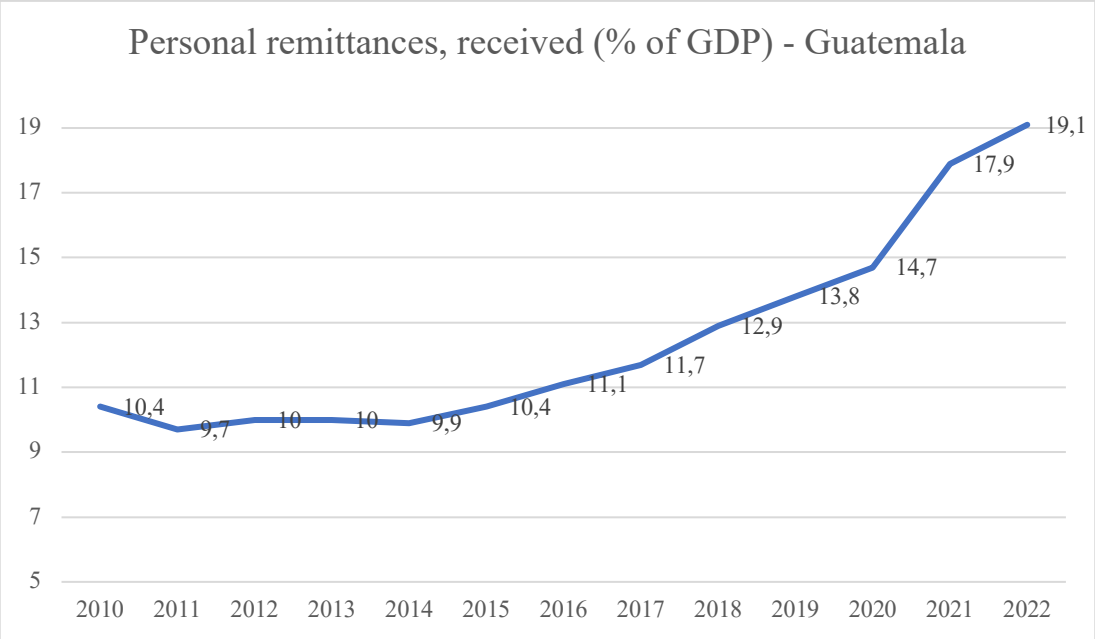

Figure 19: Personal remittances as a percentage of Guatemala's Gross Domestic Product. *Source*: The World Bank (2023)[169].

Whilst most areas of Guatemala are exposed to natural hazards and the effects of climate change, the rural communities living in the country's Western Highlands are more likely to be affected by the food insecurity-poverty-global warming nexus and its effects on migration patterns. The conditions that shape the way people live in the Western Highlands include physical and economic isolation, rugged terrain and fragmentation of land, exposure to cold temperatures, and challenges in accessing markets.[170]

In remote mountain communities like the Guatemalan Western Highlands, where people rely on subsistence rain-fed farming for their livelihoods, their well-being is greatly influenced by the environment and climate-related factors. This makes them highly susceptible to various environmental threats and climatic changes.

[169] Graph drawn by the author based on data retrieved from the World Bank's databases.
[170] Afifi, T., Milan, A., Etzold, B., Schraven, B., Rademacher-Schulz, C., Sakdapolrak, P., ... & Warner, K. (2016). Human mobility in response to rainfall variability: opportunities for migration as a successful adaptation strategy in eight case studies. *Migration and Development, 5*(2), 254-274. Doi: https://doi.org/10.1080/21632324.2015.1022974.

Interestingly, while migration might appear driven primarily by economic reasons and food insecurity, the underlying trigger could actually be climatic in its nature.[171]

Given this scenario, the issues of climate change and unpredictable shifts in rainfall patterns are expected to further worsen these challenges, particularly for households that are unable to relocate from areas where their vulnerability to climate change is extreme.

Reconstructing the link between global warming and human migration may be academically challenging, especially because of the recentness of the phenomenon and the low availability of data. However, a growing body of literature (e.g., as for Black et al., 2011[147], Cai et at., 2016[148], Coniglio & Pesce, 2015[172], Hoffmann et al., 2021[146]) is starting to recognize the existence of a nexus between global warming and human migration, particularly in the presence of peculiar socio-economic and cultural conditions.

Elevated levels of greenhouse gas emissions are poised to worsen the occurrence and severity of extreme weather events, as well as escalate processes of environmental decline.[173] These processes present significant hazards to food security, public health, and the availability of water resources.[174] These trends disproportionately impact the populations of less affluent nations, who rely extensively on agriculture and lack sufficient access to technological and infrastructural resources to mitigate and alleviate adverse environmental repercussions.

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[171] Milan, A., & Ruano, S. (2014). Rainfall variability, food insecurity and migration in Cabricán, Guatemala. *Climate and Development*, *6*(1), 61-68. Doi: https://doi.org/10.1080/17565529.2013.857589.

[172] Coniglio, N.D., & Pesce, G. (2015). Climate variability and international migration: an empirical analysis. *Environment and Development Economics*, *20*(4), 434-468. Doi: https://doi.org/10.1017/S1355770X14000722.

[173] Mikhaylov, A., Moiseev, N., Aleshin, K., Burkhardt, T. (2020). Global climate change and greenhouse effect. *Entrepreneurship and Sustainability Issues, 7*(4), 2897-2913. Doi: https://doi.org/10.9770/jesi.2020.7.4(21)

[174] Anser, M. K., Yousaf, Z., Usman, B., Nassani, A. A., Abro, M. M. Q., & Zaman, K. (2020). Management of water, energy, and food resources: go for green policies. *Journal of Cleaner Production, 251,* 119662. Doi: https://doi.org/10.1016/j.jclepro.2019.119662

In response to these shifts, migration can emerge as a potential strategy for managing and adapting to these alterations: Individuals or households may opt to temporarily or permanently relocate as a means to sidestep the detrimental effects of environmental shocks and enduring transformations. Specifically, Latin America has been recognized as one of the global regions which will be affected the most by climate migration in the 21st century.[175]

In this context, the Guatemalan migration towards the US, may indeed provide an interesting case study. Whilst those migrants have been largely treated from a legal point of view as economic migrants (and particularly because of the absence at the international level of a legal recognition of the status of climate refugee), many of those individuals' lack of income opportunities in Guatemala was the result of extreme weather events and changes in the local climate. In particular, variability in traditional rainfall patterns and its consequences on agricultural production and food security plays a pivotal role in influencing risk management decision with respect to income opportunities and migration.[176] Therefore, by directly impacting food production and consumption in agricultural-dependent regions, changes in the precipitation patterns – such as those observed in Guatemala in the last decades, shown in Chapter 2 – can add further stress on rural households in terms of income and food security, leading to increased rates of migration as an alternative source of income-earning (i.e., in terms of personal remittances) for families losing their main income sources (i.e., as for agricultural products).

[175] Hoffmann, R., Dimitrova, A., Muttarak, R., Crespo Cuaresma, J., & Peisker, J. (2019). Quantifying the evidence on environmental migration: A meta-analysis on country-level studies. In *Population Association of America Annual Meeting, Austin, USA*. Retrieved at: https://pure.iiasa.ac.at/id/eprint/16587/1/192548.pdf.

[176] Warner, K., & Afifi, T. (2014). Where the rain falls: Evidence from 8 countries on how vulnerable households use migration to manage the risk of rainfall variability and food insecurity. *Climate and Development*, *6*(1), 1-17. Doi: https://doi.org/10.1080/17565529.2013.835707.

Chapter 4: Demography, Climate Change and Migration in the Northern Triangle of Central America

4.1 Beyond Guatemala: Assessment of the Effects of Climate Change in the Dry Corridor

The Central American Dry Corridor constitutes a geographical region along the Pacific Coast of Central America. The term refers to the increasing prevalence of drought ad irregular rainfall which has characterized the area in the past decades, rendering it particularly susceptible to variations in global climate due to the prevalence of subsistence agriculture and the high rates of poverty and rural population.[177]

Most of the area known as "Central American Dry Corridor" encompasses the territory of three countries: Guatemala, El Salvador, and Honduras. These nations converge at a three-way border point: Connecting the capitals of these three countries, namely Tegucigalpa, San Salvador, and Guatemala City, they create an "ideal" triangular formation commonly referred to as the Northern-Central America Triangle (NTCA) [178].

[177] Gotlieb, Y., Pérez-Briceño, P. M., Hidalgo, H., & Alfaro, E. (2019). The Central American Dry Corridor: a consensus statement and its background. *Revista Yu'am*, *3*(5), 42-51. Retrieved at: https://www.researchgate.net/profile/Eric-Alfaro/publication/331499050_The_Central_American_Dry_Corridor_A_Consensus_Statement_and_its_Background/links/5c7d564ea6fdcc4715af5f7e/The-Central-American-Dry-Corridor-A-Consensus-Statement-and-its-Background.pdf.

[178] McIlwraith, T. F., & Muller, E. K. (Eds.). (2001). *North America: the historical geography of a changing continent*. Rowman & Littlefield.

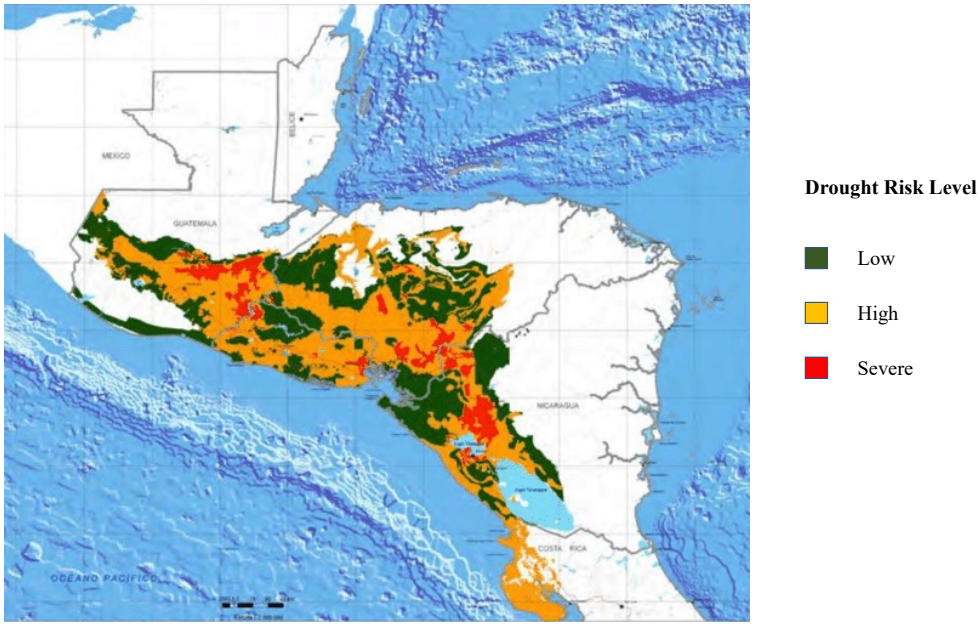

Figure 20: Drought Risk in the Dry Corridor. *Source*: Estudio de caracterizacion del Corredor Seco Centroamericano (2012).

As shown is Figure 20 above, a vast portion of the territory of those countries is at high risk of drought, as a result of the combined effect of the El Niño-Southern Oscillation (ENSO) and anthropic climate change. The region is considered to be one of the most vulnerable places on earth to the effects of global warming, due to its high susceptibility to drought and extreme weather events, the rates of poverty and food insecurity, and the importance of subsistence agriculture for their macroeconomic stability.[179]

Because of their peculiarities, Guatemala, El Salvador, and Honduras have emerged as compelling subjects for comparative study due to their geographical proximity and shared historical, social, demographic features, and economic characteristics within the Central American region[180]. Indeed, these three countries share common challenges, including high levels of poverty, income inequality,

[179] Gotlieb, Y., Pérez-Briceño, P. M., Hidalgo, H., & Alfaro, E. (2019). The Central American Dry Corridor: a consensus statement and its background. *Revista Yu'am*, *3*(5), 42-51.
[180] Arana, M. and Sánchez-Ancochea, D. (2019). *Central America: Fragile Transition*. Oxford University Press.

political instability, and violence[181]. Additionally, such countries have experienced similar historical trajectories, such as colonial legacies and civil conflicts, which have shaped their current political and social landscapes[182]. Furthermore, all three nations face comparable issues related to migration, drug trafficking, and environmental challenges, resulting in complex and interconnected regional dynamics[183].

By conducting a comparative analysis of Guatemala, El Salvador, and Honduras, previous literature in terms of both seminal research (e.g., as for Adams, 1957[184], Anderson, 1988[185]; Fogelbach, 2010[186]) and recent contributions (e.g., as for (Baranowski *et al.*, 2018[187]; Obinna, 2019[188]) tried to gain valuable insights into the underlying factors influencing their development trajectories and how climate change can threaten the status of food security and inequalities in the region, and design targeted policies to address common challenges and promote sustainable development in the three countries.

Based on such experiences, this Chapter aims to compare the aforementioned countries trying to assess the impact of climate change on Guatemala, by comparing its experience and its socio-economic dynamics with the other two reference countries (i.e., Honduras and El Salvador).

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[181] Buvinic, M., Morrison, A., and Shifter, M. (2017). *Working together: Integration, institutions and the Sustainable Development Goals in Latin America and the Caribbean*. Inter-American Development Bank.
[182] Haggard, S., and Kaufman, R. R. (2017). *Development, democracy, and welfare states in Latin America*. Princeton University Press. Doi: https://doi.org/10.1515/9780691214153.
[183] Pérez-Brignoli, H. (2019). *A Brief History of Central America*. University of California Press.
[184] Adams, R. N. (1957). Cultural Surveys of Panama, Nicaragua, Guatemala, El Salvador, Honduras. *Scientific Publication, 33*. Retrieved at: https://iris.paho.org/bitstream/handle/10665.2/1314/42161.pdf?sequence=1&isAllowed=y.
[185] Anderson, T. P. (1988). *Politics in Central America: Guatemala, El Salvador, Honduras, and Nicaragua*. Bloomsbury Publishing USA.
[186] Fogelbach, J. J. (2010). Gangs, violence, and victims in El Salvador, Guatemala, and Honduras. *San Diego International Journal*, *12*, 417-423. Retrieved at: https://digital.sandiego.edu/cgi/viewcontent.cgi?article=1100&context=ilj.
[187] Baranowski, K. A., Wang, E., D'Andrea, M. R., & Singer, E. K. (2019). Experiences of gender-based violence in women asylum seekers from Honduras, El Salvador and Guatemala. *Torture Journal*, *29*(3), 46-58. Doi: https://doi.org/10.7146/torture.v29i3.111970.
[188] Obinna, D. N. (2019). Transiciones e incertidumbres: La emigración de El Salvador, Honduras y Guatemala. *Latino Studies*, *17*, 484-504. Doi: https://doi.org/10.1057/s41276-019-00209-8.

Specifically, by following similar approaches[189], this Chapter seeks to conduct a comparison of Guatemala, Honduras, and El Salvador, considering such countries as case studies[190], by considering their economic, geographic, and especially demographical similarities. By analyzing the common challenges faced by these nations concerning climate change, food security, economic development, and social wellness, the final object is to provide future in a diagnostic coherent manner.

Thus, anticipating and proposing solutions that may counteract the probable, and potentially similar, negative impacts of climate change in Guatemala is crucial: Through this comparative approach, this Chapter aims to identify key characteristics and patterns that can inform policy interventions and strategies to effectively address the climate change's impacts on development and societal well-being in all three countries, ultimately fostering sustainable and inclusive growth across the region.

The Central American Dry Corridor is particularly relevant in the analysis of the effects of climate irregularities on food security; indeed, climate extremes are having tangible and devastating effects on agricultural production in the region, with serious financial losses in rural areas and widespread crop failures in the three countries as a result of extreme weather events in the past years, such as the prolonged droughts affecting Central America between 2014 and 2016, or the floodings and mudslides caused by Hurricanes Eta and Iota in 2020.[191]

[189] Terluin, I. J. (2003). Differences in economic development in rural regions of advanced countries: an overview and critical analysis of theories. *Journal of Rural Studies*, *19*(3), 327-344. Doi: https://doi.org/10.1016/S0743-0167(02)00071-2.
[190] Tellis, W. (1997). Application of a case study methodology. *The Qualitative Report*, *3*(3), 1-19. Doi: https://doi.org/10.46743/2160-3715/1997.2015.
[191] Pons, D. (2021). *Climate Extremes, Food Insecurity, and Migration in Central America*. Retrieved at: https://reliefweb.int/report/guatemala/climate-extremes-food-insecurity-and-migration-central-america-complicated-nexus.

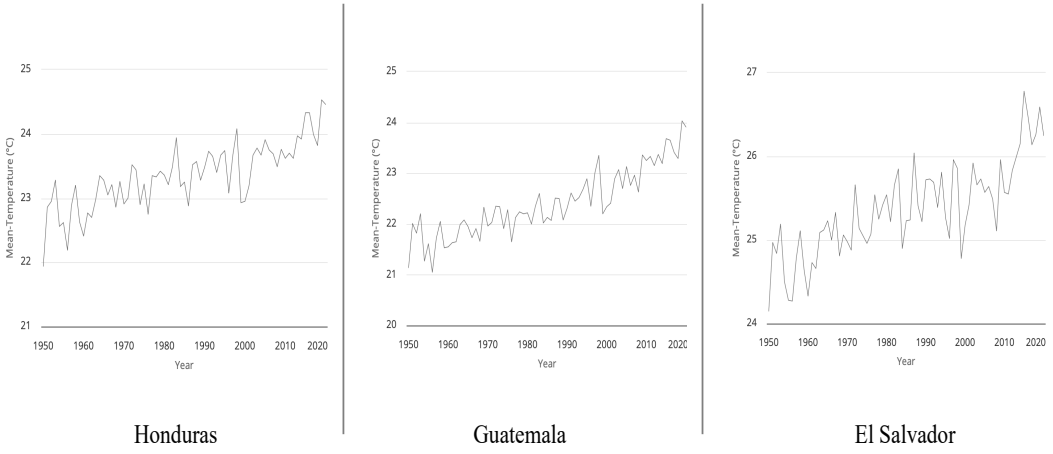

Figure 21: Annual Mean Temperature Increase in the Dry Corridor Countries, 1950-2020. *Source*: The World Bank (2021).

To clarify, as shown in Figure 21 above, all three countries have experienced a sharp increase in their annual mean temperature values in the period 1950-2020. During that period, Guatemala experienced an increase of +2,77°C in its annual mean temperature; Honduras experienced an increase of +2,52°C, whilst the annual mean temperature in El Salvador increased by +2,1°C.

Furthermore, Figure 22 below compares the changes in the distribution of the mean temperatures in the selected countries: Each bell-shaped distribution represents a 30-year climatology interval. The progressive shift to the right of each country's distribution indicates an increase in the country's mean temperature. In line with Figure 21, Guatemala presents the farthest shift to the right (the highest increase in its mean temperature in the period 1991-2020 compared to the period 1951-1980), followed by Honduras, whilst El Salvador presents the lowest increase among the three. The 1991-2020 distributions for each country appear wider than previous distributions; Thus, this indicates that besides increases in the annual mean temperature, more intense temperatures are occurring more frequently in all countries. Among the three considered countries, Guatemala presents the widest distribution for the period 1991-2020.

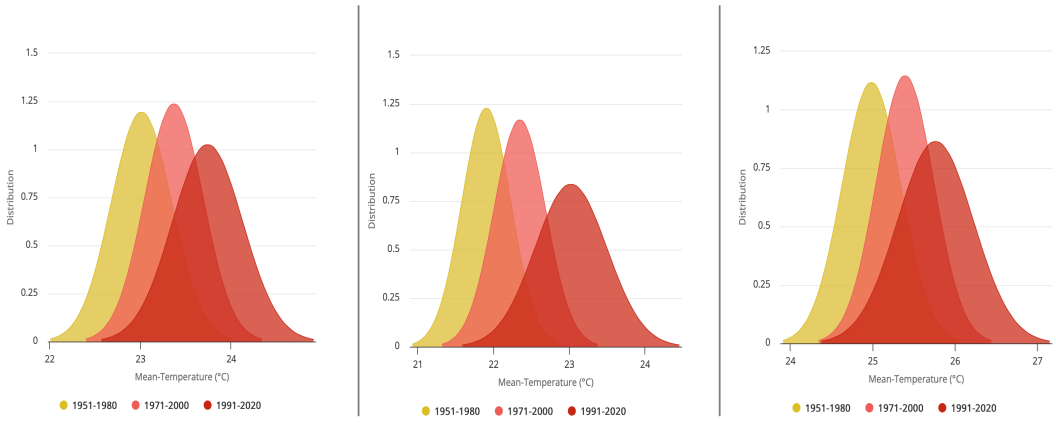

Figure 22: Change in Distribution of Mean-Temperature in the Dry Corridor Countries. *Source*: The World Bank (2021).

The effects of a warming climate on the region are particularly concerning, especially because of the high levels of social inequality characterizing the Central American countries, the low level of readiness and adaptation strategies for extreme weather events, the precarious status of food security, the presence of violent criminal groups further aggravating political instability and food insecurity, and the macroeconomic vulnerabilities of the region's economic outlook.[192]

In this wider context, global warming is set to further exacerbate the vulnerabilities and socioeconomic threats faced by the Dry Corridor countries and their most vulnerable populations, with the potential of further intensifying the migratory phenomenon from the rural areas of the region towards its urban centers and its northern neighbors, as will be explained in Chapter 4.3 of this Thesis.

Specifically, climate change is set to impact the region by accentuating drought and rainfall irregularities, with potentially catastrophic consequences in terms of water

[192] Gotlieb, Y., Pérez-Briceño, P., Hidalgo, H. and Alfaro, E. (2019). The Central American Dry Corridor: a concensus statement and its backgroud. *Revista Yu'am 3*(5), 42-51. Retrieved from: https://www.researchgate.net/profile/Eric-Alfaro/publication/331499050_The_Central_American_Dry_Corridor_A_Consensus_Statement_and_its_Background/links/5c7d564ea6fdcc4715af5f7e/The-Central-American-Dry-Corridor-A-Consensus-Statement-and-its-Background.pdf.

supply and availability, in turn threatening agriculture and hydroelectrical generation.[193] The predicted increase in drought in the region, alongside the higher risk of floodings and extreme weather events, also directly threatens food security in the region, where the majority of the rural population depends on subsistence agriculture.[194]

[193] Magrin, G., Marengo, J.,Boulanger, J.F., Buckeridge, M.S., & Castellano, E. (2014). Central and South America. *Climate change 2014: impacts, adaptation, and vulnerability. Working Group II Contribution to the IPCC Fifth Assessment Report. Volume 2. Regional Aspects*. Cambridge University Press, pp.1499-1566. Doi: https://doi.org/10.1017/CBO9781107415386.007.
[194] Pérez-Briceño, P. M., Alfaro, E. J., Hidalgo, H., & Jiménez, F. (2016). Distribución espacial de impactos de eventos hidrometeorológicos en América Central. *Revista de Climatología*, *16*, 63-75.

4.2 Geo-Demographic Comparison of the Dry Corridor Countries

The countries constituting the area known as "Central American Dry Corridor" present several characteristics, in terms of demography and geography, which make them comparable, and which can serve as potential amplifiers of the negative consequences of extreme weather events on food security and migration.

Therefore, the present section offers a comparison among Guatemala, Honduras, and El Salvador, with the aim of highlighting their differences and similarities and how their specific demographic and geographic features could potentially influence their vulnerability to climate change.

The aim of this section is therefore to show how the analysis of the Guatemalan case study presented in the previous three chapters of this thesis can apply to other regions with similar geo-demographic characteristics, thereby providing an insight into how climate variations – both natural and anthropogenic – can impact vulnerable countries in terms of food security and migration.

While each nation possesses distinct cultural and historical backgrounds, their demographic and geographic resemblances heighten the impact of extreme weather events on food security and migration. These countries exhibit young populations and a lack of employment opportunities, particularly in rural settings. This demographic dynamic – the youth bulge – can heighten the potential for violent crimes, perhaps one of the biggest challenges to the stability of the area. The geographical concentration of people in rural areas, often lacking resilient infrastructure and access to resources, further magnifies their vulnerability to climate-induced disruptions.

Table 2 below presents a comparison of different demographic, geographic, and economic variables among the three countries.

Table 2. Comparison of Guatemala *vs.* Honduras and El Salvador (Dry Corridor Countries). *Source*: Author's elaboration.

Countries Variables	**Guatemala**	**Honduras**	**El Salvador**
Total population *	17,35 *	10,43 *	6,34 *
Annual Growth Rate 2019-2020 (%)	1.90	1.63	0.53
Gross Domestic Product GDP **	95 **	32 **	31,5 **
Percentage of population aged 15-24 over total population (%)	20.4	20.5	20.3
Vulnerability to climate change index	43.9	40.3	45.9
Percentage of agricultural sector over total GDP	9.3	12.6	4.7
Net migration rate (2021)	-29,118	-5,779	-27,343
Food insecurity index †	62.8 †	61.5 †	64.2 †
Percentage of rural population over total population (%)	47	40	25
Percentage of Indigenous population over total population (%)	40	6.3	>1

Notes. * = Population expressed in millions of individuals; ** = GDP expressed in billions of dollars; † = On a scale of 0 to 100 in which 0 indicates total food insecurity (i.e., no food availability at all) and 100 indicates total food security.

As can be seen from Table 2 above, the three countries present certain similarities and differences among them, which impact their vulnerabilities to climate alternations and food security. Among the three, Guatemala presents the highest population, being the biggest country in terms of population both in the Dry Corridor and in the entire Central American region south of Mexico and having the biggest area among the three.[195] On the other hand, El Salvador exhibits the lowest population, being also the smallest country in terms of area among the three. With respect to the annual population growth rate, Guatemala presented the highest growth rate among the three in the period 2019-2020, followed by Honduras and El Salvador.[196]

From an economic point of view, Guatemala presents the biggest Gross Domestic Product amongst the three, with a value three times higher than the GDPs of Honduras and El Salvador.[197] However, part of this difference can be attributable to Guatemala's larger population and bigger land area; indeed, calculating the GDP per capita adjusted in Purchasing Power Parity in current international dollars, El Salvador presents a higher value than Guatemala. Moreover, among the three, El Salvador presents the lowest dependency on the agricultural sector for its macroeconomic stability (4.7 percent of its Gross Domestic Product), whilst Honduras presents the highest value, with agriculture accounting for over 12 percent of its GDP.[198]

In terms of food security, all three countries present similar levels of food insecurity, with the highest value recorded in El Salvador and the lowest level among the three recorded in Honduras.[199] Nevertheless, the values are high for all three countries, with malnutrition being prevalent in the region. The three countries also exhibit very high levels of vulnerability to climate change as measured by the Climate Change Vulnerability Index. El Salvador has a slightly higher level of vulnerability

[195] Data collected from the World Bank databases, retrieved at https://data.worldbank.org/indicator/SP.POP.TOTL?locations=HN-GT-SV.
[196] Data collected from the World Bank databases, retrieved at https://data.worldbank.org/indicator/SP.POP.GROW?locations=GT-HN-SV.
[197] Data collected from the World Bank databases, retrieved at https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=GT-HN-SV.
[198] Data collected from the World Bank databases, retrieved at https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?locations=GT-HN-SV
[199] According to The Economist's Global Food Security Index 2022, retrieved at https://impact.economist.com/sustainability/project/food-security-index/.

than Guatemala, whilst Honduras is slightly less vulnerable to climate change compared to its two neighbors.

Demographically, the countries present a very different ethnic composition. Indeed, whilst mestizos constitute the majority in all of the Dry Corridor's nations, the presence of indigenous minorities varies greatly. Indigenous represent the biggest minority group in Guatemala, the country with the most diverse society amongst the three, where over 40 percent of its population identifies as Indigenous; Whilst constituting the second-biggest ethnic group in Honduras, only around 6.3 percent of Hondurans identify as Amerindian; the value drops to less than 1 percent amongst Salvadorans, where the biggest minority group was constituted by Whites (12.7 percent).

Moreover, Guatemala presents the highest percentage of rural people in the region, with around 47 percent of Guatemalans living in rural areas. Honduras has a higher urbanization rate, with roughly 40 percent of its population living in rural areas. Amongst the three, El Salvador is the most urbanized country, with almost 85 percent of Salvadorans living in urban areas, and particularly in the area of San Salvador.[200] One of the biggest differences among the three, therefore, seems to be in the level of urbanization, with Guatemala and Honduras having more people living in rural areas (as also testified by their higher dependency on agriculture in comparison to El Salvador).

All three countries present negative net migration rates[201]. A negative net migration rate indicates that more people are leaving a particular geographic area than are moving into it over a specific period of time. In other words, there is an outflow of individuals migrating away. All three countries are therefore countries of origin for international migrants, as will be explored in subchapter 4.3 of this thesis.

One of the starkest similarities amongst the three is the percentage of youthful population (aged 15-24) over the total population, with the three nations presenting an

[200] Data collected from the World Bank databases, retrieved at https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS?locations=GT-HN-SV.
[201] Data collected from the World Bank databases, retrieved at https://data.worldbank.org/indicator/SM.POP.NETM?locations=GT-HN-SV.

almost identical value in percentage. The high number of youthful individuals in the region indicates the presence of a youth bulge in the Dry Corridor.

Coherently, as shown in the previous Chapter (Chapter 3) of this thesis, the so-called youth bulge, characterized by a significant proportion of young people in the population may have a negative impacts on development and wellness of such countries like Guatemala, Honduras, and El Salvador, because of several factors, mostly related to limited employment opportunities; Indeed, the youth bulge places immense pressure on the job market, leading to a mismatch between the number of young job seekers and available opportunities; consequently insufficient job perspectives may result in high youth unemployment rates, which can lead to frustration, social unrest, and reduced productivity.

Similarly, such occurrence may negatively affect the countries' wellness because rising important educational challenges to face: Indeed, the inadequate access to education can perpetuate cycles of poverty and hinder human capital development, negatively impacting the overall socio-economic progress of these countries. Most importantly, the youth bulge, as anticipated in the previous chapter, may increase poverty and augment inequalities, due to its potential to exacerbate poverty and income inequality as large numbers of young people enter the labor market with limited skills and experience (see Figures 18a; b). This can lead to lower wages and reduced opportunities for upward mobility, widening the gap between the rich and the poor.[202]

Such combination of negative features may finally also impact on both social and political instability, because, by considering that portion of the population comprising young individuals may feel excluded from the political process and societal decision-making, the potential for social and political instability increases.[203] Importantly, remarking the final concepts exposed in the last part of the previous

[202] Pérez, O. J. (2013). Gang violence and insecurity in contemporary Central America. *Bulletin of Latin American Research*, *32*(s1), 217-234. Retrieved at https://www.researchgate.net/profile/Orlando-Perez-6/publication/262874224_Gang_Violence_and_Insecurity_in_Contemporary_Central_America/links/5a54dfe3aca2726c0ff20083/Gang-Violence-and-Insecurity-in-Contemporary-Central-America.pdf.
[203] Rodgers, D., & Jones, G. A. (2009). Youth violence in Latin America: An overview and agenda for research. *Youth violence in Latin America: Gangs and juvenile justice in perspective*, 1-24. Doi: https://doi.org/10.1057/9780230101333_1.

chapter, the migration pressures unleash youth bulge consequences, because, in countries characterized by low opportunities and resources, the youth bulge can contribute to increased migration as young people seek better prospects elsewhere, eventually leading to brain drain and the loss of skilled labor from these countries.

Moreover, this phenomenon is made even more worrisome in the Dry Corridor due to the high level of vulnerability to climate change in the region. The effects of increased irregularities in the weather of the region and the observed increase in drought frequency and occurrence affecting the area are threatening the macroeconomic stability of the three countries and their employment opportunities, making the presence of a youth bulge a potential source of instability.[204]

Central America is already an area of particular concern due to the presence of criminal gangs that exert extreme power and influence over the social and political institutions in the region. As stated in Chapter 3 of this thesis, the presence of a high percentage of the youthful population (the youth bulge) alongside low employment opportunities can potentially further fuel the phenomenon of criminal gangs engaging in illicit activities such as drug smuggling and human trafficking, as large percentages of young males find no viable job opportunity and therefore turn to either migration or violent criminal activities as means of subsistence.

[204] Pacillo, G., Achicanoy, H. A., Ramírez Villegas, J., Craparo, A., Basel, A., Villa, V., ... & Läderach, P. (2021). *Is climate a risk multiplier in the Central American Dry Corridor? A CGIAR study*. Retrieved at https://cgspace.cgiar.org/bitstream/handle/10568/116294/31%20October_CGIAR_Factsheet_CADC.pdf?sequence=6&isAllowed=y.

4.3 Youth Bulge, Violence, and Migration in the Region

The 21st century has witnessed a significant increase in human mobility within the Northern Triangle of Central America and across its northern borders, constituting a prominent aspect of contemporary migration patterns. The Dry Corridor countries have become the source of an increasing flow of migrants which, starting from the Central American region, heads north through Mexico and into the United States.[205]

As explained in section 3.3 of this thesis, international migration refers to the process of individuals or groups of people crossing international borders to establish a new residence or temporary stay in a foreign country. As shown in Figure 23 below, the number of Central American migrants in the USA has been steadily increasing in the past decades, with important demographic and socio-political consequences both in the United States and in their countries of origin.

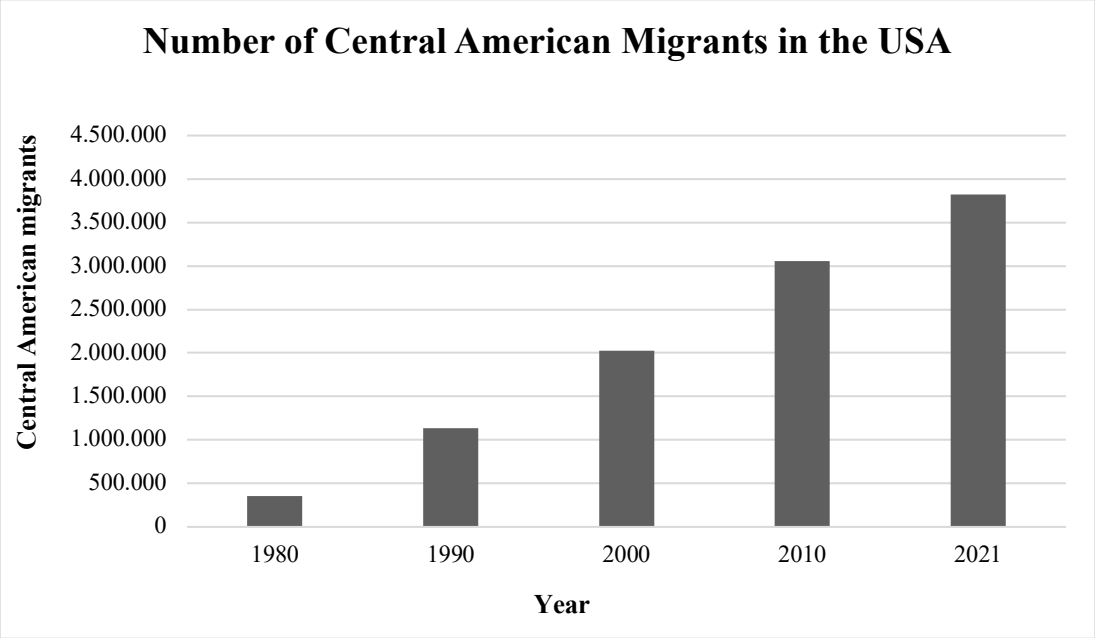

Figure 23: Number of Central American Migrants in the United States in the period 1980-2021. *Source*: Migration Policy Institute (2023).

[205] Faret, L., Téllez, M. E. A., & Rodríguez-Tapia, L. H. (2021). Migration management and changes in mobility patterns in the North and Central American Region. *Journal on Migration and Human Security*, *9*(2), 63-79. Doi: https://doi.org/10.1177/23315024211008096.

The data reported in Figure 23 above refers to migrants in the United States originating from the entire Central American region; Nevertheless, among these, citizens of the Dry Corridor countries accounted for over 86 percent of the total Central American migrant population in the United States. Specifically, Salvadorans accounted for 37.1 percent of the Central American migrant community in the United States, followed by Guatemalans (29 percent) and Hondurans (20.1 percent).[206]

Importantly, the reasons behind the increasing flow of emigrants abandoning the Dry Corridor countries are multiple and varied, often resulting from a combination of demographic, environmental, social, and economic factors. The presence in the region of the aforementioned youth bulge has been indicated[207] as one of the potential root causes behind the migration crisis; Specifically, the youth bulge characterizing the demographic structure of the Northern Triangle of Central America – that is the result of declining child mortality rates and high fertility rates in the region – has resulted, in the last decades, in a sharp increase of young workers attempting to enter a labor market that – because of significant structural constraints – did not have the capacity to accommodate them.

The presence of a youth bulge in the countries is likely to have an effect on emigration, as a large cohort of young people with low job opportunities in their own countries decides to seek better opportunities in more developed economies. Moreover, several other elements, which influence and are influenced by the demographic structure of the region, function as push factors in the current migration crisis. These factors include, for example, endemic violence and poverty.[208]

Indeed, the Central American Northern Triangle presents some of the highest crime rates in the world, being one of the most violent regions at the global level. Collectively, the economic cost of violence in the Northern Triangle countries

[206] Migration Policy Institute (2023). *Central American Immigrants in the United States*. Retrieved from: https://www.migrationpolicy.org/article/central-american-immigrants-united-states.
[207] Clemens, M. & Graham, J. (2019). Three Fact You Haven't Heard Much About Are Keys to Better Policy Toward Central America. *Center For Global Development*. https://www.cgdev.org/blog/three-facts-you-havent-heard-much-about-are-keys-better-policy-toward-central-america.
[208] Rose, S., Resstack, R., Dempster, H., Cascardi, E., & Weinstein, J. (2021). Addressing the 'Root Causes' of Irregular Migration from Central America: An Evidence Agenda for USAID. *Center for Global Development Policy Paper*, *243*. Retrieved at: https://www.cgdev.org/publication/ addressing-root-causes-irregular-migration-central-america-evidence-agenda-usaid.

amounted to over 34.152,9 million USD in 2021; In Guatemala alone, the economic cost of violence was estimated at approximately 14.5 billion USD in 2021. Honduras and El Salvador, on the other hand, were the countries with the highest costs of violence as a share of their GDP, both losing more than 10 percent to violence and crime.[209]

In 2018, El Salvador was the country with the highest homicide rate in the world, with 52.02 homicides per 100,000 inhabitants; Honduras was the fourth at the global level, with a rate of 38.93 homicides per 100,000 inhabitants. Guatemala was 19th at the global level, with a homicide rate of 22.50 homicides per 100,000 inhabitants, a value below the two other case studies analyzed in this chapter but still more than double the global average of 6.1 homicides per 100,000 inhabitants.[210]

The main socioeconomic factor driving homicide rates in the Northern Triangle of Central America is reported to be the endemic presence of gangs, organized crime, and the drug trade.[211] The presence of a large percentage of young people (youth bulge) in the Northern Triangle of Central America alongside high youth unemployment rates has been indicated as one of the main causes contributing to maintaining high levels of violence, instability, and illicit activities in the region[212], eventually functioning as a likely push factor triggering the current migration crisis.

Therefore, the interplay between youth bulge and low employment opportunities may play a role in the endemic high levels of violence and criminal activities plaguing Central America. In light of these considerations, the risks posed by climate change in the form of irregular and unpredictable rainfall patterns on the macroeconomic stability of the region – and particularly of the Dry Corridor areas – may add further pressure on the demographic and economic challenges faced by the three countries.

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[209] Statista (2023). *Crime in Central America – Statistics & Facts*. Retrieved at: https://www.statista.com/topics/10610/crime-in-central-america/#topicOverview.
[210] World Population Review (2023). *Murder Rate by Country*. Retrieved at: https://worldpopulationreview.com/country-rankings/murder-rate-by-country.
[211] Ritchie, H., Spooner, F., & Roser, M. (2018). Causes of death. *Our world in data*. Retrieved at: https://ourworldindata.org/causes-of-death.
[212] Ali, M. (2014). Youth unemployment a global security challenge. *Harvard International Review*, *36*(1), 13.

4.4 The Impact of Climate Change on Agriculture in the NTCA

As stated in the previous section, migration from the Northern Triangle of Central America (NTCA) is intricate and typically results from a combination of diverse factors. While factors such as violence and poverty may be attributed as primary drivers of this kind of movement, it is nevertheless essential to recognize the influence of climate change in the analysis of emigration from Central America. Climate change plays a dual role in instigating migration, directly through the destruction of agricultural resources and indirectly by intensifying various other motivating factors.[213]

As previously stated in the present chapter, the three countries of the Northern Triangle of Central America are among the most vulnerable nations in the world in the face of global warming. The changes in the regional climate in terms of rainfall predictability, intensity, and frequency have the potential to threaten life and property across the three countries, as well as cause broad and negative implications for their macroeconomic stability. Considering the importance of the agricultural sector within the national economies of the Northern Triangle of Central America, especially in rural areas such as the Dry Corridor, global warming may aggravate the food insecurity crisis in the region and potentially exacerbate the economic woes of the three countries – especially in terms of unemployment.

Climate extremes, food insecurity, and migration in the analyzed region are intricately linked, with environmental change being just one among several factors that drive migration. The region is becoming increasingly subject to extreme climatic events, with some of the most prominent cases in recent times being the prolonged droughts of 2014-2016 and the disastrous floodings caused by Hurricanes Eta and Iota, both of which struck Central America within a mere two-week timeframe in 2020. These events have had a particularly devastating impact on the livelihoods of farmers

[213] Lynch, C. (2019). The Impacts of Warming Coffee: The Climate Change-Coffee-Migration Nexus in the Northern Triangle of Central America. *Independent Study Project (ISP) Collection*. 3008. Retrieved at: https://digitalcollections.sit.edu/isp_collection/3008.

in El Salvador, Guatemala, and Honduras, jeopardizing their food security and potentially acting as a catalyst for migration.[214]

The ways in which climate change affects livelihoods and households in the region are complex and multifaceted, making it difficult to frame its exact effects. However, one of the most serious consequences of climate variation in the Northern Triangle of Central America regards the decline in agricultural production. This is particularly evident in the two countries showing the highest share of their GDP covered by the agricultural sector – namely Honduras and Guatemala – and which also are the two countries with the highest percentage of rural population among the three. In Honduras and Guatemala, climate change and environmental degradation are affecting, in particular, the percentage of arable land (decreased by 35.5 percent in Guatemala in the period 1993-2020, and by 39 percent in Honduras in the same period)[215] as an effect of drought, salinization and human-made land degradation[216]; Moreover, changes in rainfall are strongly affecting the main staples of the two countries, namely beans and especially maize, whose production could decrease by as much as 22 percent in the following years as an effect of warmer weather.[217]

Thus, climate change poses a significant risk to stability in the Northern Triangle of Central America, primarily due to the vital role of agriculture in the region's economy. One of the most widely grown products of Central America is coffee, upon which millions of individuals depend for their livelihoods; As explained in section 2.2 of this thesis, climate change is leading to alarming levels of Coffee Leaf Rust (CLR) and unprecedented droughts. Given that coffee cultivation predominantly occurs on small-scale farms in the Northern Triangle of Central America, even

[214] Pons, D. (2021). *Climate Extremes, Food Insecurity, and Migration in Central America*. Retrieved at: https://reliefweb.int/report/guatemala/climate-extremes-food-insecurity-and-migration-central-america-complicated-nexus.
[215] Data collected from the World Bank databases, retrieved at: https://data.worldbank.org/indicator/AG.LND.ARBL.ZS?end=2020&locations=GT-HN&start=1961&view=chart.
[216] Waddick, K. (2017). Effects of Climate Change on Agriculture in Guatemala and Honduras. *Global Majority E-Journal*, *8*(2), 109-120.
[217] Arnés, E., Astier, M., Marín González, O., & Hernandez Diaz-Ambrona, C. G. (2019). Participatory evaluation of food and nutritional security through sustainability indicators in a highland peasant system in Guatemala. *Agroecology and Sustainable Food Systems*, *43*(5), 482-513. Doi: https://doi.org/10.1080/21683565.2018.1510871.

relatively minor shifts in climate patterns can have widespread repercussions, affecting a substantial portion of the population. Consequently, climate-induced challenges within the coffee industry – and the wider agricultural industry – may emerge as a significant factor driving both internal and external migration in the region.[218]

The Central American Dry Corridor has increasingly experienced more frequent and intense droughts in the past decades. These droughts have had significant repercussions on the region's predominantly subsistence farming community, by affecting both their livelihoods and food security. According to climate predictions[219], both short and long-term droughts are anticipated to exacerbate considerably across the region by the end of the century, regardless of whether emissions are moderate or high.[220]

During the crucial rainy season when farmers heavily rely on consistent and predictable rainfall patterns, short-term droughts are predicted to prolong, intensify, and become more frequent. These changes are expected to surpass the projected alterations in mean annual precipitation.[221] Long-term droughts, which can have substantial regional consequences, are also anticipated to worsen by 2100. This means that even if the overall annual rainfall experiences a modest decline by the century's end, droughts and their associated impacts are likely to be disproportionately severe.[222]

The insufficient water supply, especially during the midsummer months, could severely affect crops like maize and beans in the Central American Dry Corridor, where the initial planting season, known as the *Primera*, sets the agricultural calendar for the entire season. Both staple crops and cash crops like coffee are projected to be impacted by reduced rainfall and worsening drought patterns. This could lead not only

[218] Lynch, C. (2019). The Impact of Warming Coffee: The Climate Change-Coffee-Migration Nexus in the Northern Triangle of Central America. *Independent Study Project (ISP) Collection 3008*. Retrieved at: https://core.ac.uk/download/pdf/232741188.pdf.
[219] Karmalkar, A. V., Bradley, R. S., & Diaz, H. F. (2011). Climate change in Central America and Mexico: regional climate model validation and climate change projections. *Climate dynamics*, *37*, 605-629. Doi: https://doi.org/10.1007/s00382-011-1099-9.
[220] Depsky, N., & Pons, D. (2020). Meteorological droughts are projected to worsen in Central America's dry corridor throughout the 21st century. *Environmental Research Letters*, *16*(1), 014001. Doi: https://doi.org/10.1088/1748-9326/abc5e2.
[221] Depsky, N., & Pons, D. (2020).
[222] Depsky, N., & Pons, D. (2020).

to a shortage of staples for subsistence farmers but also reduced incomes and potential food insecurity for workers involved in cash crop farming.[223]

The demographic structure of the region may play a prominent role in this scenario, as the worsening of climate extremes in the region is projected to take place whilst the three countries population's composition remains significantly young, with high percentages of youth over the total population. In turn, this phenomenon may have positive implications, as increases in the youth population may result in better technological innovations which may develop new strategies in climate change mitigation and adaptation. However, this process may require deep changes in the current educational system of the three countries and in their labor markets, allowing for the youth to receive adequate educational training and be then absorbed in the labor market.

The current status of the three developing countries, however, may intensify the potentially negative impacts of their youth bulges, especially due to the combined effect of climate change on employment and food security. As stated in the previous sections of this thesis, large portions of youth – and particularly young males – with few employment opportunities may turn to illicit activities as an alternative to regular employment or choose to emigrate instead and find better life opportunities abroad, sending money back to their families through remittances.

Thus, the concurring impact of demographic changes, labor market inefficiencies, and climate change may have potentially disastrous impacts on developing countries in terms of stability, food security, environmental degradation, and migration. As such, climate change may serve as an amplifier of the existing vulnerabilities within developing countries, worsening the food and water insecurity levels and reducing the opportunities for employment in the agricultural sector.

[223] Depsky, N., & Pons, D. (2020).

Conclusion

The present thesis has sought to shed light on the relationship existing between Climate Change, Demographical Structure, and Economics in developing countries such as Guatemala, and how these elements can contribute to exacerbating issues of food insecurity and migration. Guatemala's geographic features make it particularly susceptible to suffering from the potentially disruptive effects of climate variations, and the country has been struggling with a surge in irregular rainfall patterns, prolonged droughts, and more intense tropical cyclones and floodings. These phenomena are projected to further increase in magnitude and frequency, with far-reaching consequences. Besides representing a direct threat to the life and property of affected communities, these events, in the absence of effective adaptation strategies, may result in irreversible damage to agricultural production in the country.

These climate-induced disruptions to the agricultural sector may have a double effect: On the one side, they may directly threaten the status of food security in the country, particularly across its most vulnerable population, e.g., as for the indigenous communities living in the rural areas of the Western Highlands, one of the regions suffering from the highest level of drought, and where large percentages of the population depend on traditional subsistence agriculture for their survival; On the other side, climate-related disasters threaten the overall macroeconomic stability of the country since agriculture represents one of the most important export sectors in Guatemala's economy. Indeed, for instance, the recent losses in the coffee production sector caused by flooding and by the proliferation of parasites favored by higher mean temperatures in the country have already resulted in catastrophic economic losses and unemployment.

At the same time, the demographic structure of Guatemala may add further pressure on the overall stability of the country. As the country's population structure evolves from the second to the third stage of the Demographic Transition Model, the resulting youth bulge may present new challenges to the nation. With high rates of unemployment, frustrated youth may turn to alternatives for their economic survival, by either choosing to migrate – further exacerbating the migration crisis already

affecting the region – or to engage in illicit and violent activities such as drug smuggling or human trafficking.

Whilst it should be noted that demography is not destiny, the demographic vulnerabilities of developing societies, with high percentages of youth over their total population, make it particularly important to address the potential for economic losses and resulting unemployment due to climate-related catastrophes, in order to ensure that youth bulges in developing countries turn into opportunities for better technological and social development.

Importantly, this thesis has also tried to shed light on the role played by global warming as a push for migration. This issue appears to be of particular relevance, especially considering that the definition of "climate refugee" is legally void of any meaning and therefore legal protection. Almost all Guatemalan migrants are considered to be economic migrants under American law and international law, even though the impact of extreme weather events has been shown, also in this thesis, to act as a significant factor in influencing many individuals' choice to migrate. Therefore, it is essential for future literature to further analyze this relationship.

The effects of climate change become increasingly evident in Central America, and as the region undergoes profound demographic changes, it is imperative to study how these elements can exacerbate the economic and social vulnerability of these countries. Future research should specifically look at the correlation between youth bulge and climate-related unemployment in Maya communities in Guatemala, to better understand how these factors affect a particularly vulnerable social group in the country.

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