Environmentally Induced Inter-Municipal Migration: The Case for Guatemala

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NEKN01

Master Essay I

MSc in Economics - First Year

Department of Economics

August 2021

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Abstract

This paper examines the impact of climate variability on inter-municipal household migration in the Guatemalan Dry Corridor (GDC) between 2013 and 2018. Monthly georeferenced precipitation and temperature data are used to build a climate shock variable that captures prolonged exposure to droughts and heatwaves at the municipality level. The data is used to understand if the occurrence of a shock affects the decision of households to migrate within the municipalities in the GDC in Guatemala.

The analysis shows that prolonged exposure to droughts and heatwaves (climate shocks) lowers the inter-municipal migration at the household level. These findings are consistent with existing studies but show no evidence to accept the hypothesis delimited in this research: a climate shock has a positive impact on the decision to migrate within municipalities in Guatemala.

Despite the limitations presented during the development of this study, this serves as a contribution to the literature on trying to understand how climate variability affects the GDC, specifically on the decision of households to migrate.

Keywords: Climate Change, Inter-Municipal Migration, Guatemala, Dry Corridor.

Contents

Abbreviations

- CGIAR - Consultative Group on International Agricultural Research
- ENCOVI – National Survey of Living Standards (Encuesta Nacional de Condiciones de Vida)
- FAO – Food and Agriculture Organization of the United Nations
- FEWS NET - Famine Early Warning Systems Network
- GDC - Guatemala Dry Corridor
- GMDAC - Global Migration Data Analysis Centre (part of IOM)
- INE - National Statistics Institute of Guatemala (Instituto Nacional de Estadística de Guatemala)
- INSIVUMEH - National Institute of Seismology, Volcanology, Meteorology, and Hydrology (Instituto Nacional de Sismología, Vulcanología, Meterología e Hidrología)
- IOM - International Organization for Migration
- IPCC - Intergovernmental Panel on Climate Change
- UNFCC - United Nations Framework Convention on Climate Change
- WRI – World Resources Institute

List of Definitions

- Climate hazard: "A physical process or event […] that can harm human health, livelihoods, or natural resources. […] Climate hazards may be defined in terms of absolute values or departures from the mean of variables such as rainfall, temperature, wind speed, or water level, perhaps combined with factors such as speed of onset, duration, and spatial extent. Hazards are also referred to as climate events" (Brooks, 2003).
- Drought risk: "Drought risk measures where droughts are likely to occur, the population and assets exposed, and the vulnerability of the population and assets to adverse effects." WRI Aqueduct (2019).
- Environmental migrant: "Environmental migrants are persons or groups of persons who, predominantly for reasons of sudden or progressive changes in the environment that adversely affect their lives or living conditions, are obliged to leave their habitual homes,

or choose to do so, either temporarily or permanently, and who move within their country or abroad." (IOM, 2011).

- Heatwave: "A heatwave is defined […] as 'a period of abnormally hot weather'. Heatwaves and warm spells have various and, in some cases, overlapping definitions" (IPCC, 2020).
- Livelihood zone: "An area within which people share broadly the same pattern of livelihood, including options for obtaining food and income and market opportunities." (FEWS NET, 2017)
- Remittance: "Remittances are largely personal transactions from migrants to their friends and families. They tend to be well targeted to the needs of their recipients." (UNDP: Chapter 4, 2015)
- Seasonal Variability: "Seasonal variability measures the average within-year variability of available water supply, including both renewable surface and groundwater supplies. Higher values indicate wider variations of available supply within a year." WRI Aqueduct (2019).

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1 Introduction

1.1 Research problem

Climate change has had already observable effects on the environment. Seasonal extreme variations are occurring more often: glaciers are shrinking, trees and plants are losing leaves sooner, more intense, and longer heatwaves and precipitation patterns have shifted (NASA, 2021).

The extent of the effects of climate change will vary across individual regions and over time (IPCC, 2021). Earth warming has resulted in an increased frequency, intensity, and duration of heat-related events. The frequency and intensity of droughts have increased in some regions such as many parts in South America, northeastern Asia, the Mediterranean, and West Asia. (IPCC, 2018).

In 1990, the Intergovernmental Panel on Climate Change (IPCC) noted that the greatest single impact of climate change could be on human migration particularly in developing countries (De Sherbinin, 2020).

Since then, diverse analyses have tried to put numbers on future flows of climate migrants but the consequences of climate change for human population distribution are unpredictable (Brown, 2008). Other social, economic, and environmental factors might affect migration; therefore, it has been difficult to establish a linear, causative relationship between climate change and migration (Brown, 2008).

Instead, environmental circumstances exist as one of several factors that drive the decision by an individual or community to migrate (De Sherbinin, 2020). Migration is selective, which means that depending on the context, some people[1] are more likely to move than others from their home province or country. Therefore, environmental factors can influence these elements (De Sherbinin, 2020).

Historically, Central America has suffered the impact of several extreme hydrometeorological events such as droughts. This phenomenon has directly affected the

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[1] More likely are young or male people tend to migrate (De Sherbinin, 2020)

agricultural sector, representing a threat of food security to the households that depend on it (Calvo-Solano et al, 2018). The impact of these events has been present especially in the Central American Dry Corridor (CADC), where the heatwaves (*canícula*, in Spanish) are prolonging, the aridity is increasing, and the extremes events are happening more often. The CADC is a region that represents areas from southern Mexico in Chiapas and extends to Guatemala, El Salvador, Honduras, Nicaragua, and the northern part of Costa Rica (Figure 1). According to FAO (2016), the criteria used to delimit the CADC is based on the dry season, which is greater than four months.

Figure 1: Geographical Delimitation of The Central American Dry Corridor (CADC)

Source: Calvo-Solano, et al (2018)

In the CADC, the constant threat of droughts is inherent. According to Calvo-Solano (2018), half of the population in these countries is categorized as poor, and two-thirds of the rural populations, which numbers vary through these territories, have inadequate nutrition.

The Dry Corridor in Central America, in particular Guatemala, is the most affected by the presence of the *El Niño*[2] climate pattern (FAO, 2016). Agricultural small-scale producers and

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[2] El Niño is a climate pattern that describes the unusual warming of surface waters in the eastern tropical Pacific Ocean. El Niño is the warm phase of a larger phenomenon called the El Niño-Southern Oscillation (ENSO) (National Geographic). For Guatemala, this generates a decrease on the precipitation on the northeast and central part of the country. (INSIVUMEH, 2017). During El Niño years, temperature rises, precipitation drops, and the *canícula* is longer (USAID, 2020).

rural communities are most vulnerable to droughts and changes in climate patterns. This is an important socio-economic phenomenon given its effects on the loss of capital of household economies, increasing numbers in people in poverty, and potential migration given the increasing duration of heatwaves or the changing precipitation patterns (FAO, 2016).

It cannot be assumed that climate variability has a direct effect on migration (Brown, 2008), but this can influence the decision to migrate given the social and economic context from each household.

Migration due to climate-related impacts is of interest given the direct effects it has on the economy. Climate-related migrants tend to arrive at places where are few job opportunities for them and they place a strain on public services. Creating a job market mismatch that generates a dependence on governmental aid (Dadush & Niebhur, 2016). However, if the person migrating arrives in a country or region that has lower fiscal constraints and average income, their access to public services will be halted given that the provision of healthcare and education barely satisfies the needs of the current population. From a household perspective, migration from a family member helps a household diversify their income sources, hence reducing their risk of losing completely their livelihood (Dadush & Niebhur, 2016) even if they move to lower-income regions or countries.

1.2 Objective and scope

This paper contributes to understand how climate change might be affecting the migration phenomenon in Latin America - specifically for the Central American region. Given the lack of country-specific research in this topic in the region, it is the objective to contribute by showing the potential impact of climate variability in the decision to migrate in Guatemala by the households in the Guatemala Dry Corridor (GDC). To provide a clear framework for this analysis, the research question is formulated as the following: Did a climate shock in the GDC induce inter-municipal migration?

Therefore, the following hypothesis will be tested:

- A climate shock, defined as low precipitation level and high temperature exposure, has a positive impact on the decision to migrate

The point of departure for the hypothesis stated above is the link between environmental stressors and migration made by Warner et al (2009) given that often environmental changes make it difficult for the individual or family to earn a living.

1.3 Outline

The paper proceeds as follows: section 2 presents the literature review, will be discussed the conceptual complexities of analyzing this topic, migration theories, and climate migration models done before. Section 3 details the context for Guatemala, what are main groups of people are affected due to climate variability, and how migration plays a role in the GDC.

Section 4 will present the methodology, detailing the model used to test the hypothesis mentioned above, the sources for the explanatory variables, and how these were built. Section 5 discusses the results of the empirical analysis. Lastly, section 6 concludes and discusses the limitations presented through the development of this paper and future possible research extensions that could add value to the study of how climate variability affects the decision of households to migrate from climate-vulnerable hot spots.

2 Literature Review

There is a vast availability of research that examines the often-adverse impacts of climate variability on migration. However, not much is known regarding the impact at the household level, and, with so many contextual specificities behind this phenomenon, makes it hard to have a clear picture about the complexity behind this situation.

After introducing the clarification of the key terms and theories behind climate change and migration, previous research is summarized to shed light about implications for the climate change - migration research scope.

2.1 Climate change

Climate change is defined by the United Nations Framework Convention on Climate Change (UNFCCC) as "a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period. It refers to any change in climate over time, whether due to natural variability or because of human activity" (UNFCC, 2011).

The linkages between climate change and migration typically are researched in developing countries as a response to slow or multiple rapid-onset events (De Sherbinin, 2020).

Rapid-onset events include climate extremes such as storms, heatwaves, drought, and floods. On the other hand, slow-onset events are gradual changes to climate regimes, such as temperatures or longer-term precipitation variations, and these could drive permanent migration. (De Sherbinin, 2020)

Auffhammer, Hsiangy, Schlenker & Sobelz (2013) discussed that weather and climate data have increasingly been used to model the economic impacts of climate change. Therefore, this research uses monthly temperature and precipitation data to capture climate variability in a specific period and tries to understand the impact of slow-onset events within a region. Another aspect of climate change lays in the exacerbation of already present problems within a country, these been either economic, political, social, or demographic (Black et al 2011). Climate change operates as a "threat multiplier" as it makes the gap between social and economic inequalities wider (Teppe, 2018), or intensifies political instability over conflict of resources (Black et al, 2011). However, the effects of climate change vary between places, which makes the economic driver a still dominant aspect for the decision to migrate (De Sherbinin, 2020).

Agricultural and other natural resource-dependent households settled in developing countries are particularly more vulnerable to the effects of climate change. For instance, droughts are an important negative climate shock that can threaten livelihoods and well-being (Gray & Mueller, 2012).

Consequently, migration has been seen as an adaptation strategy (Black et al, 2011) that can bring opportunities to cope with the environmental change within a region even though are temporary or permanent mobility situations (De Sherbinin, 2020).

2.2 Migration

The determinants of migration are related to the place of origin or destination, and an intervening set of obstacles[3] in between (Lee, 1966 & Adamo et al, 2011). According to IOM (2011), environmental migrants are "people or groups who, predominantly for reasons of sudden or progressive changes in the environment that adversely affect their lives or living conditions, are obliged to leave their habitual homes, or choose to do so, either temporarily or permanently, and who move within their country or abroad."

Ravenstein (1885) made the first attempt to define the laws of migration, which concerned migration between countries and attempted to summarize the economic push and pull forces influencing the decision to migrate (Ravenstein, 1885; De Sherbinin, 2020). Ravenstein (1885) found that the people from rural areas are more prone to move to centers of industry and commerce if their main activity is related to agriculture, but these movement is highly age selective, where adults in their working age display a greater propensity to migrate, and as De Sherbinin (2020) discussed, migration occurs due mainly to economic reasons.

Between voluntary and forced migration, there is a range of other mobility types, making it challenging to discuss migration in general terms (De Sherbinin, 2020), and there are often distinct differences in migratory patterns between developed and developing countries. For example, Nawrotzki & Bakhtsiyarava (2016) discussed that in rural areas of developing countries, adverse climate conditions increased migration from households dependent on agriculture. Environmental change can increase the incentive of people to move, but it can also limit the capacity to do so (Black et al, 2011; Lee, 1966; Marazzi, & Mpofu, 2011) This phenomenon should be seen, as mentioned before in this paper, as an influence on the interrelated drivers of migration.

However, migration as an adaptation strategy for climate variability is generally understood as having more control over the timing and direction and are less vulnerable to the context

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[3] Lee (1966) concluded that among the set of intervening obstacles such as costs of transportation, children, among others, the distance of the move is the one that is always present.

(Adamo & De Sherbinin, 2009; Black et al, 2011). For instance, migration to more stable environments can reduce household's exposure to climate hazards and increase resilience to climate change. Hence, the creation of financial stability by the inflow of remittances from migrants in destination areas to household members when climate hazards occur and these are cut off from their main income streams (Black et al, 2011).

At the same time, Lee et al (2015) discussed that there are some ambiguities concerning perceived risk towards levels of climate change which might cause some minimal adaptation behavior to it. Lee (1966) and Bryan, Chowdhury & Mobarak (2014) discussed that one of the intervening obstacles for migration as an adaptation strategy could be the costs of transportation, therefore, low-income households may not have sufficient means for mobility, which challenges the rhetoric regarding forced migration with the scenario that populations are trapped in a place (Black et al, 2011).

2.3 Previous Research: migration and climate change

Even though evidence on the link between migration and climate is rapidly growing and has gained increased visibility among the policy community, the subject has been used by a wide range of methodological approaches that make it hardly comparable across contexts, but interesting output has resulted from this research. For this case, it seems the subject remains under-researched at the regional scale, especially for Latin American and the Caribbean (from now on "Latin America") (Baez et al, 2017). Latin America is a region characterized by high migration rates and substantial exposure to climate hazards (Baez et al, 2017; GMDAC, 2020) and knowledge of this migration increase phenomenon is particularly important for the northern part of Latin America, such as Mexico and the United States, given the increase of waves of migration from Central America (O'Neil, 2020).

Baez, Mueller & Niu (2017) made a linkage between individual-level information from multiple censuses for eight countries in Latin America with natural disaster indicators constructed from georeferenced climate data at the province level to measure the impact of droughts and hurricanes on internal mobility. They found that younger individuals are more likely to migrate in response to disasters, especially when confronted with droughts.

In the same way, Baez, Caruso, Mueller & Niu (2017) analyzed census and georeferenced temperature data to quantify the impact of heat effects on internal migration in Central America and the Caribbean. They found that young people who experienced heatwaves were more prone to move to urban areas than when they were exposed to climate disasters.

Nawrotzki & Bakhtsiyarava (2016) utilized census and climate data to explore the relationship between climate and migration in rural Burkina Faso and Senegal in Africa, specifically the impact on household's dependent on agricultural productivity. In their research, they found that excessive precipitation increases international migration from Senegal while heatwaves decreased migration from Burkina Faso, which proved their theory about climate being an inhibitor of migration.

Similarly, Teppe (2018) analyzed the relationship between climate variability and migration across six Sub- Saharan African countries. In her research, she found mixed conclusions: first, she found that prolonged exposure to climate extremes such as droughts and cold events discouraged migration across provinces, suggesting the existence of an immobilizing effect, just as Nawrotzki & Bakhtsiyarava (2016) concluded, which climate change lowers the resources needed to finance the cost of migrating.

Therefore, despite diverse literature examining the often-adverse impacts of environmental shocks on households, not much is known about how the effect of climate events varies across households in countries in Latin America, specifically for Guatemala, and if these influence the decision to migrate internally or not.

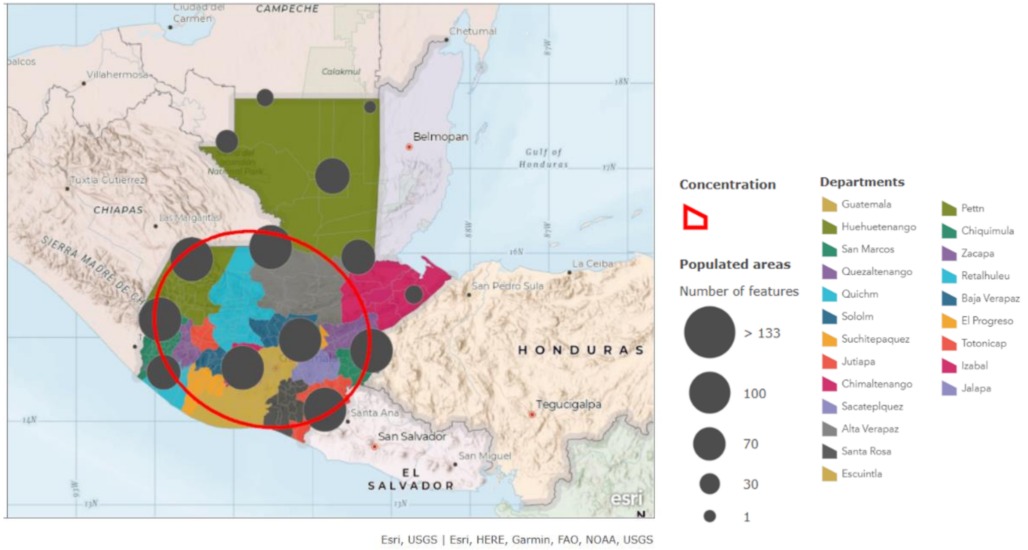
3 Guatemala

Figure 2: Location of Guatemala

Source: Geoscience News and Information

Guatemala (in Spanish, "República de Guatemala") is in Central America within the Latin America region, bordering the North Pacific Ocean, between El Salvador and Mexico, and the Caribbean Sea between Honduras and Belize (Figure 2) (CIA, 2021). Guatemala has 108,889 km^2 as an area and is divided into 22 departments, and 340 municipalities (CGIAR, 2014). The population in 2018 was 14.9 million people, and 46.1% resided in rural areas. In addition, it has a relatively young population, since more than half of the population are under 26 years of age, 85% of the population reside in the middle and southern half of the country, and most of the rural population is concentrated in the middle region of the country (Figure 3) (INE Guatemala 2018).

Figure 3: Population Concentration (2020) by Departments.

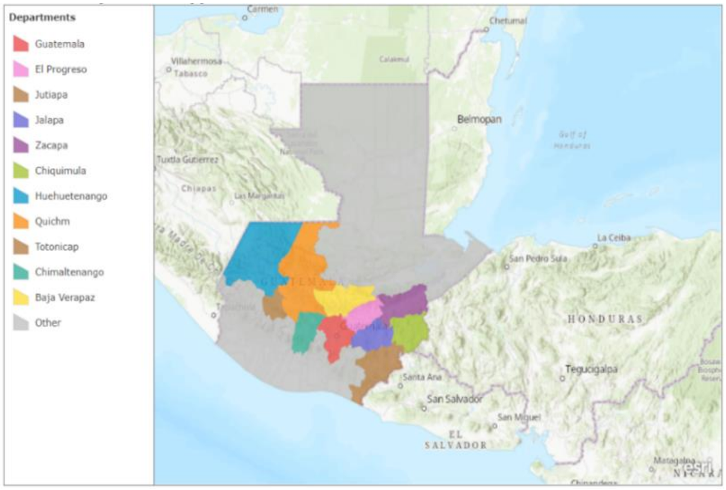


Source: Elaborated for this document with information from The University of Texas at Austin and the Humanitarian Data Exchange

The population is mainly concentrated (Figure 3) in 19 departments, which represent 304 municipalities (INE, 2018). In this area, 36.7% of the population live in rural denominated areas and 48.7% in urban areas (Table 1). Of the 36.7% of the population that reside in rural areas, 7.4% depend on agricultural activities[4]. Additionally, this population is mainly localized in a region that is characterized by exacerbated vulnerability factors (Fraga, 2020). This area is denominated as the Guatemalan Dry Corridor (GDC) (Figure 4).

The GDC is constituted by 11 departments within the middle and southern region of Guatemala. Although there is no precise geographical delimitation for the GDC, according to Fraga (2020), the area represents the departments of El Progreso, Jalapa, Jutiapa, Zacapa, Chiquimula, Huehuetenango, Quiche, Totonicapan, Chimaltenango, Baja Verapaz and Guatemala), implying an impacted population of 8.1 million (INE, 2018).

Figure 4: Guatemalan Dry Corridor (GDC), by Departments.



Source: Elaborated for this document with information from The University of Texas at Austin, and Fraga (2020)

At country level, Guatemala is categorized as having high vulnerability factors, especially in their rural areas. According to the ENCOVI, in 2011, 13.3% (1.9 million) of the population was living in extreme poverty and 40.3% (5.9 million) in poverty. The departments were the population living in extreme poverty were concentrated are Alta Verapaz (37.7%), Chiquimula (28.3%) and Zacapa (25%) (INEI, 2011).

In terms of food security, only 19.1% of the households in Guatemala were categorized as food secure, the rest range from low food insecure (39.2%) to severely food insecure (14.4%) (INEI, 2011). In 2019, it was

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[4] Given the missing disaggregation data for the 2018 Guatemala Population Census, the percentage is based on the one-digit activity as reported in INEI (2016). The one-digit activity is denominated as "6 Agricultores y trabajadores calificados agropecuarios, forestales y pesqueros". Therefore, this percentage will be lower if we only consider agriculture per se when data is available.

estimated that 49.3% of the population lived under the poverty line, up from 45% in 2000. 20% of the population lived with incomes between 5.5 USD and 13 USD per day, which means that 80% of the population is poor or vulnerable to falling into poverty in the event of a climate shock.

These vulnerability factors are exacerbated in the GDC is region: 72% of the population living in rural areas are located within this region (INEI, 2018). Additionally, in Chimaltenango, Jutiapa, and Totonicapan, the departments within the GDC, approximately half of the households live in moderate to severe food insecurity (Table 5 and Figure 7) (INEI, 2011).

Additionally, Guatemala is extremely affected by climate and weather events and its poorer populations are particularly vulnerable (World Bank, 2021). Guatemala is the country in Central America that is most impacted by recurrent droughts and lack of rainfall, making it extremely hard to harvest on a regular basis (European Commission, 2020), where their poorest populations are particularly vulnerable to climate events (Figure 5 and 6).

Figure 5: Drought Risk in Guatemala

Source: Aqueduct, Water Risk Atlas, World Resources Institute (2019)

Figure 6: Seasonal Variability of Water Supply in Guatemala

Source: Aqueduct, Water Risk Atlas, World Resources Institute (2021)

Guatemala's climate varies according to its diverse land conformation. It ranges from humid coastal areas to cool highlands, including tropical semi-dry savannah and jungles (World Bank, 2021). The average annual temperatures within Guatemala go from 25°C to 30°C in the coast region, to 15°C at higher altitudes. Guatemala is prone to climate-related disasters including droughts. Guatemala experiences two different seasons: from November to April is the dry season, and from May to October is the rainy season. However, in July, or sometimes is happens in August, the rainy season is interrupted by 5 to 15 days of little to no rain called the *canícula* (heatwave). The precipitation levels vary substantially across the country, which goes from a minimum of 600 mm in the east part of the GDC to 5,000 mm in the coast area (USAID, 2020).

Figure 7: Food Insecurity in Guatemala Departments

Source: USAID (2020)

The interannual variability in precipitation patterns is largely dictated by El Niño (ENSO) phenomenon (Figure 6). The GDC is particularly vulnerable to drought. 2012 to 2016 where a 4-year period where the region experienced one of its worst droughts in history (USAID, 2020). By 2030 (Figure 8 and table 9) temperatures are projected to keep increasing, prolonged heatwaves and droughts are also expected to happen more frequently, which will lead to lower water supply for economic activities in the region (USAID, 2020).

Figure 8: Seasonal Variability by 2030, business as usual

Source: Aqueduct, Water Risk Atlas, World Resources Institute (2019)

In 2019, agriculture contributed to 9.4% of Guatemala's GDP (World Bank, 2019). Coffee is the largest export, which is mostly cultivated by small-scale farmers (FEWS NET, 2017). Within the GDC these are in the departments of Zacapa, El Progreso, Huehuetenango, Jalapa, Chiquimula, and Jutiapa. The country's other produced crops include bananas, cardamom, rubber, fruits, and vegetables (FEWS NET, 2017). Large-scale agriculture employs many people in rural areas in the livelihood zones within the GDC[5] (Figure 9).

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[5] These are mainly employed from areas in 9 departments within the GDC: Jalapa, Chiquimula, Jutiapa, Huehuetenango, Zacapa, El Progreso, Quiché, Totonicapán, and Chimaltenango.

Figure 9: GDC Livelihood Zone[6]

Source: Elaborated for this document with information from FEWS NET (2017)

Better-off and middle-income households mainly earn income through trade and business, crop and livestock sales, and remittances (as for households in Huehuetenango, northern part of Quiche, Totonicapan, west part of Chimaltenango), while poorer households earn income mainly through agricultural labor (as for households in Baja Verapaz, and middle and southern part of Quiche). Smallholder farmers cultivate low-value staples (for example, maize and beans). Additionally, there are households that lack access to land, making them completely dependent on agricultural labor, and/or remittances for income (Figure 9). However, 71% of agriculture is rainfed (FEWS NET, 2017), therefore, household food security (Figure 7) is heavily affected by variability in precipitation and temperature, including heavy rainfall and drought (FEWS NET, 2017 & Calvo-Solano, et al 2018).

According to the INSIVUMEH, the GDC region will have an impact on the reduction of precipitation between 15-20% by 2030. This will directly impact the household's dependent on subsistence agriculture[7]. Additionally, the rise in temperature will continue to occur due

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[6] A livelihood zone is an area where people share the same pattern of livelihood, including options of income and food opportunities (FEWS NET, 2017).

[7] For this research, micro data at household level dependent on subsistence agriculture was not detailed in the Population Census, therefore it is assumed that the households' dependent on agriculture-related activities in the GDC are for rainfed crops.

to climate change. The Institute estimates that by 2050, the temperature is going to rise between 2.1 and 4.1°C (INSIMUVEH, 2018).

Climate variability such as a lack of precipitation and increasing temperatures outside of the adapted range of crops adversely affects the seasonality of crop cycles, often leading to delays on the harvesting periods or crop failures (World Bank, 2011).

According to the Guatemalan Population Census, in 2018, 1.1% people from the household's dependent on agriculture-related activities within the GDC reported that have migrated[8] recently (Table 12) and 8.0% reported that are permanent migrants. The highest proportion was concentrated in Huehuetenango, department with the highest share of population dependent on agriculture-related activities (Table 8) and with the greatest proportion of their population living in rural areas (Table 9).

4 Methodology

The scope of this section is to present the methodology, detail the model used to test the hypothesis mentioned in Section 1, the sources for the explanatory variables and how these were built.

This model will help answer the previously defined research question: Did a climate shock in the GDC induce inter-municipal migration? The following hypothesis will be tested:

- A climate shock, defined as low precipitation levels and high temperature exposure, has a positive impact on the decision to migrate.

4.1 Data Sources

The analysis is conducted using a compilation of secondary data sources. Below, it is detailed the source for household-level data in Guatemala and localized climate data, and how these data were used to design the model and construct the climate shock variable.

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[8] The reason for migration is not stated.

4.1.1 Climate data

The climate data used in this analysis is extracted from the NASA POWER 8 Release. The Prediction of Worldwide Energy Resources (POWER) Project provides solar and meteorological data sets to support agricultural needs – among others (NASA, 2021). For this research, monthly precipitation, and temperature data at municipality level in the GDC were extracted from the Agroclimatology database.

The POWER Release 8 meteorological parameters extracted for this research are based on Goddard's Global Modeling and Assimilation Office (GMAO) assimilation model and the Modern Era Retrospective Analysis for Research and Applications (MERRA-2) (NASA, 2019 & NASA, 2020).

The use of the NASA POWER time series is not known that has been used before in a population-based analysis. Therefore, this database provides possible limitations for this paper and the results shown in Section 5.

However, the NASA POWER climate series has been proven to depict reliable climate global estimates and geographic-localized extractions (Rodrigues & Braga, 2021), despite the scarce availability of climate information as public access within the INSIMUVEH.

Interannual monthly precipitation and temperature municipal time series were averaged in the sample from 1988 to 2018 (Figures 10 and 11 in Appendix A). The construction of the climate shock variable capturing the lower precipitation levels and the exposure to high temperatures is detailed in Section 4.2.2.

The temperature data was extracted as a monthly average of the temperature at 2 meters above the surface of earth. On the other hand, the precipitation data was extracted as monthly average rain rate in millimeters (mm). The data was extracted from 1988 to 2019 by municipality within the GDC.

4.1.2 Household-Level Data

For 2018, the data was extracted from the INE National Population Census. The Census is divided into household level, individual-based level, and property level. As the purpose for this research and the sample composition, the individual-based data was used based on people responded by being the head of the family. This was used as a direct assumption that if the person reported being the head of the family, this can count as a household within the GDC.

Additionally, the data was used at municipality level due that there was no significant proportion of migration reported within departments in Guatemala.

Moreover, the 2002 INE Population Census was used to identify characteristics of the households before their decision to migrate, such as their occupation, and number of children dependent on the household's income.

While it was not possible to match the 2002 and 2018 INE Population Census at household level given a lack of households' identifiers that were consistent between these years, the household were matched at municipality level to build the sample. Additionally, households in the cross-sectional data are linked to the climate situation by municipality.

4.1.3 Limitations of Data

Given the lack of a temporal dimension in the dataset prevents the analysis from differentiating short-term from long-term moves, and, therefore, it is assumed that all moves are permanent.

Additionally, the 2002, and 2018 INE Population Census had substantial number of missing observations which can represents bias on the migration behaviors occurring within the municipalities in Guatemala given climate variability.

4.2 Sample Construction

4.2.1 Household-Level Data

As stated, this study analyzes the impact of a climate shock on household's decision to migrate within the GDC using a one-period (2018) dataset of 165,713 observations. 2018 were chosen given the available INE National Population Census data for Guatemala and taken based on the assumption that before 2018 the decision to migrate from the head of the family in the household takes place and a shock of climate variability might have influenced their decision.

The sample is drawn from 76 municipalities within Guatemala that represent the region of the GDC (defined in Section 3) from the 2018 INE Population Census. The sample represents 165,713 households within the GDC, which will be explained further in Section 4.3.

4.2.2 Construction of the Climate Shock Variable

As stated in 4.2.1, this research analyzes the impact of a climate shock in the GDC. Therefore, monthly precipitation and temperature data for 1988 to 2018 was extracted from the NASA Power 8 Release time series at the municipal level. The POWER Single Point Data Access provides access to datasets by latitude and longitude (NASA, 2021).

The climate shock variables were constructed following the methodology utilized by Teppe (2018), Thiede, Gray & Mueller (2016), and Nawrotzki & DeWaard (2018). These two sets of variables (temperature and precipitation) were composed into a single composite variable, to avoid the classic omitted variable detailed by Auffhammer et al. (2013). To be able to obtain unbiased estimates of the effect of precipitation and temperature variability, which are correlated historically, both variables should be included in the model, specifically, if this is expected to change in the future (Auffhammer et al., 2013)

As done by Teppe (2018) and Thiede, Gray & Mueller (2016), climate measures were computed by extracting the annualized monthly data for precipitation and temperature from a 30-year term climate normal period. These municipal-level variables were transformed to z-scores to allow inter-municipal comparisons.

The steps to construct the climate z-scores for each municipality within the GDC were as follows: first, the average monthly temperature and total monthly precipitation over 1988-2018 were extracted from the single-point database at municipality level. A 30-year climate normal period was defined as the benchmark for this analysis to assess climate variability as recommended by the World Meteorological Organization (WMO, 2007); second, the standard deviations and averages of the climate normal averages of temperature and precipitation were extracted for each municipality within the GDC for the climate normal period defined. Third, a monthly observation set for 2013-2017 was defined; this was chosen given the information recorded in 2018 INE Population Census about the municipality the household was living in 2013. Fourth, a z-score was calculated given by the following formula:

$$z - score_{i,m} = \frac{Observation\ Set_{mth,i,m} - Mean\ Climate\ Normal_{i,m}}{Standard\ Deviation\ of\ the\ Mean\ Climate\ Normal_{i,m}}$$

Where mth stands for month, i stands for either temperature or precipitation series; and m is the municipality within the GDC. Based on these z-scores, a set of climate anomalies were recorded. Negative precipitation and positive temperature anomalies were defined within the municipalities. Negative precipitation anomalies are represented as negative z-score, which are the standard deviations below the average precipitation in 1988-2018, which indicates a drier period than usual. On the other hand, positive temperature anomalies are captured by positive z-scores and represent the number of standard deviations over the average temperature during 1988-2018 (climate normal period) and reflect warmer periods than usual (Teppe, 2018).

To define if the temperature and precipitation anomalies were climate shocks within each municipality, a threshold of two standard deviations was chosen (Teppe, 2018) rather than one standard deviation (Nawrotzki & DeWaard, 2018), to be able to identify the extreme changes in temperature and precipitation such as droughts and heatwaves. As done by Thiede, Gray & Mueller (2016) and Teppe (2018), the monthly z-scores for each municipality were used and the monthly deviations from the 30-year climate normal period were computed. Then the number of months exceeding two standard deviations (2 SD) below or above the 30-year climate normal mean (1988- 2018) were counted (months for which the z-score is either greater than +2 SD for temperature or lower than -2 SD for precipitation). If the months of temperature exposure (> +2 SD) is equal to 1, households are exposed to one-time heatwave but if the value is greater than 1, indicates that the households are experiencing prolonged heatwaves, and if the months of precipitation exposure (< -2 SD) is equal to 1, households are experiencing one-time single drought, and if this value exceeds 1, signifies that the households are experienced prolonged droughts (Teppe, 2018).

Last, a composite climate shock variable was built from the z-scores (Song, Lin, Ward, & Fine, 2013) computed and detailed in the previous point, and defined as follows:

$$Climate\ Shock_m = months\ of\ exposure_{p,m} + months\ of\ exposure_{t,m}$$

Where p stands for precipitation, t for temperature and m stands for municipality. The climate shock was recorded as the addition of months with climate variability exposure. Only prolonged events (number of months greater than 1) either for temperature or precipitation exposure are counted into the climate shock, detailed situations per municipality are shown in section 4.3.1.

4.2.3 Cross-Municipal Migration

The definition of cross-municipal migration is extracted from the 2018 INE Population Census based on a specific question answered: “Municipality of residence in April 2013”. If the municipalities reported were different between 2013 and 2018, the household was categorized as it migrated within municipalities in the GDC between this period.

4.2.4 Explanatory variables

The model detailed in section 4.3 will be using three explanatory variables. First, if the municipality where the household is located experienced a climate shock. Second, if the household reported being dependent on agricultural-related activities before their decision to migrate within municipalities in GDC. In this case, after matching 2002 and 2018 INE Population Census data by municipality-level, the occupation was revised and categorized an identifier in case the household reported agricultural-related activities as their main occupation. This was reported as being farmers and qualified workers of agricultural activities directed to the market according to the INE National Occupations Classifier (INEI, 2015).

The third explanatory variable utilized is household's dependent on agricultural-related activities that reported having children. This was chosen given that could be a determinant of migration, according to Lee (1996), but also can be an obstacle for the decision.

4.3 Model delimitation

The model for this research is composed of simple and multiple linear regressions, which in the first case the statistical technique uses one explanatory variable to predict the outcome of a response variable, and in the second case, several explanatory variables are used.

The set of regressions will help understand if a climate shock affects the decision of people to migrate within municipalities in Guatemala based on their main occupation and if they have children dependent on the household's income.

First, the following equation (1) will be conducted to predict the migration outcome at household and municipality level due to a climate shock, which is defined as follows,

$$(1)\quad MI_{i,m} = \beta_0 + \beta_1 Climate\_shock_m + \varepsilon_{i,m}$$

Where i stands for household; m stands for the municipality within the GDC where the household lived in 2013; $MI_{i,m}$ is the outcome variable and it indicates if the household has migrated from its municipality by 2018 for household i that is in municipality m in 2013; $MI_{i,m}$ represents a dummy variable. If the municipality reported that the household i lived in 2018 is different from the reported in 2013, a value of 1 is reported. If it is not the case, it takes a value of 0; $Climate\_shock_m$ stands for the climate shock that occurred in 2013 in municipality m where the household is living in 2013. It captures the climate shock before the decision to migrate. This is reported as the number of months that the municipality experienced prolonged (greater than 1 month) heatwaves and droughts, as detailed in section 4.2.2; and $\varepsilon_{i,m}$ is the error term by household i in the municipality m within the GDC.

For (1), β_0 is the intercept term and β_1 captures the impact of an increase exposure to a climate shock during 2013 on the decision that the household migrated to another municipality in 2018. It is expected that β_1 has a positive sign, indicating an increase effect on migration of households due to an exposure of climate shock within the municipality. Second, the linear regression (1) will introduce an explanatory variable defined as household's dependent on agricultural-related activities. This equation (2) is as follows,

$$(2) \quad MI_{i,m} = \beta_0 + \beta_1 Climate\_shock_m + \beta_2 frac\_agri_{i,m} + \varepsilon_{i,m}$$

Where $frac\_agri_{i,m}$ represents the share of households in the municipality that reported agricultural-related activities as their main occupation. This is a dummy variable, where values of 1 are households that were dependent on agricultural-related activities. The addition of this is to understand if households dependent on agriculture are more prone to migrate given the occurrence of a climate shock within municipalities. It is expected that β_2 results with a positive sign, indicating an increase effect of migration at household level within municipalities driven by their dependence on agricultural-related activities. Given that households dependent on agricultural-related activities are most vulnerable to climate variability such prolonged exposure to droughts and heatwaves (FAO, 2016).

Lastly, equation (3) introduces household's dependent on agricultural-related activities that reported having children. This equation (3) is as follows,

$$(3) \qquad MI_{i,m} = \beta_0 + \beta_1 Climate\_shock_m + \beta_2 frac\_agri\_child_{i,m} + \varepsilon_{i,m}$$

Where $frac\_agri\_child_m$ represents the share of households in the municipality that reported agriculture as their main occupation and having children. This is a dummy variable, where values of 1 are households that were dependent on agricultural-related activities and reported having children.

For equation (3), β_2 will capture the impact of a household dependent on agriculture and having children on the decision to migrate within municipality. The sign expected for β_2 is negative given the discussion made by Lee (1996), Bryan, Chowdhury & Mobarak (2014), and Teppe (2016) that some obstacles for migration could be the costs of transportation and the number of reported children. Households might have a higher number of reported children that could be correlated to lower economic resources, which reduces the likelihood of moving (Teppe, 2016) given that they do not have sufficient means for mobility (Lee, 1996; Bryan, Chowdhury & Mobarak; 2014).

The descriptive statistics for the sample data used for this model are detailed in section 4.3.1 and the results are presented in section 5.

4.3.1 Descriptive statistics for model delimitation

Tables 1 and 2 present the descriptive statistics of the individual-level data used in this analysis. The individual-level data was transformed to household-level data restricting only to individuals who responded to being head of the family, as detailed in 4.1.2.

Table 1. Descriptive statistics of the individual–level variables included in the model.

Area	Obs.
Urban	80,064
Rural	85,649
Total	**165,713**

Gender	Obs.
Male	147,011
Female	18,702
Total	**165,713**

Migrated by 2018	Urban	Rural	Total
Yes	63,419 (79.2%)	79,870 (93.2%)	143,289
No	16,645 (20.7%)	5,779 (6.7%)	22,424
Total	**80,064**	**85,649**	**165,713**

Migrated by 2018	Male	Female	Total
Yes	67,031 (45.6%)	13,033 (69.9%)	80,064
No	79,980 (54.4%)	5,669 (30.3%)	85,649
Total	**147,011**	**18,702**	**165,713**

Notes: These variables are defined per household before the decision to migrate took place. The 2002 INE National Population Census was used to define these. Percentages reported in parenthesis are with respect to the total reported vertically on each column.

Table 2: Descriptive statistics for household level data included in the model.

Variable	Name	Obs.	Mean
Migration	MI_2018	165,713	0.135
Households' dependent on agriculture	Frac_agri_2002	165, 713	0.113
Households' dependent on agriculture that reported having children	Frac_agri_child_2002	165, 713	0.408
Climate shock	climate_shock	165,713	13.987(3)

Notes:

1. The standard deviation is not reported due that MI_2018, frac_agri_2002 and frac_agri_child_2002 are dummy variables.
2. The variables frac_agri_2002, frac_agri_child_2002 and climate_shock are defined before the decision to migrate took place.
3. This percentage shows a value above 12 months because the maximum number of months for exposure is 24 months. As detailed in section 4.2.2, the climate shock is built from months exposed to prolonged events for temperature (12 months) and precipitation (12 months).

Table 3 presents the descriptive statistics of the municipalities given their exposure to climate variability. As section 4.2.2, to define if the municipalities experienced temperature and precipitation anomalies, a threshold of two standard deviations was chosen (Teppe, 2018) to identify the extreme changes in temperature and precipitation such as droughts and heatwaves. The municipalities within the sample experienced only prolonged droughts, and 86.8% of the sample reported prolonged heatwaves between the years of 2013-2017.

Table 3: Municipalities exposed to climate variability between 2013-2017

Climate exposure	Description	Municipalities exposed (n)	Municipalities exposed (%)
One-time drought	Months of temperature exposure (<(-) 2 SD) that were equal to 1. This is an analysis of monthly z-scores from a 30-year climate normal mean.	0	0.0%
Prolonged droughts	Months of temperature exposure (< (-) 2 SD) that were greater than 1. This is an analysis of monthly z-scores from a 30-year climate normal mean climate normal mean	76	100.0%
One-time heatwave	Months of temperature exposure (> +2 SD) that were equal to 1. This is an analysis of monthly z-scores from a 30-year climate normal mean	9	11.8%
Prolonged heatwave	Months of temperature exposure (> +2 SD) that were greater than 1. This is an analysis of monthly z-scores from a 30-year climate normal mean	66	86.8%

Notes: Total municipalities (n) in the sample equals to 76.

Source: Own construction with information from NASA Power 8 Release.

5 Results

As the first step in the analysis, it was explored the impact of a climate shock in the decision to migrate within municipalities in Guatemala. The two aspects of climate exposure (droughts and heatwaves) are considered in the climate shock, as explained in section 4.2.2

As first step in the analysis corresponding to equation (1) in section 4.3, it was explored if a climate shock by municipality has an impact on inter-municipal migration in Guatemala. Second, it was explored if a climate shock and the household being dependent on agricultural activities by municipality has an impact on inter-municipal migration in Guatemala, corresponding to equation (2) in section 4.3. Lastly, it was explored if a climate shock and the household being dependent on agricultural activities that reported having children by municipality has an impact on inter-municipal migration in Guatemala, corresponding to equation (3) in section 4.3. The results of these three equations are in table 4.

Table 4: Inter-municipal migration in the GDC

Variables	**Equation 1**	**Equation 2**	**Equation 3**
Climate Shock	-0.1308*** (0.0077)	-0.1275*** (0.0077)	-0.13081*** (0.0077)
Frac_agri_2002		-0.0825*** (0.0019)	
Frac_agri_child_2002			-0.0826*** (0.0075)
Constant	1.9653*** (0.1084)	1.9293*** (0.1083)	1.96562*** (0.1084)
R^2	0.0035	0.0093	0.0038
Adjusted R^2	0.0035	0.0093	0.0038

Notes: Robust standard errors in parenthesis. Significance of estimates are reported as *p<0.1, **p<0.05, *** p<0.001.

The coefficient for *climate shock* is negative and significant across the three equations. The coefficient value *climate shock* in Equation 1 implies that the inter-municipal migration was reduced by 13.0% upon experiencing prolonged exposures to heatwaves and droughts. However, by equation (2) and (3) the coefficient of climate shock does not change significantly even though controls variables were added to the model. The negative effect of a climate shock to inter-municipal migration follows the discussion made by De Sherbinin (2020), which the households within the region might be migrating due to other factors and there could be economic drivers dominating this decision. Also, the negative coefficient follows directionally what Black et al (2011), Lee (1996) and Marazzi & Mpfou (2011) discussed that environmental change can increase the incentive of people to move, but it can also limit the capacity to do so. Therefore, climate variability and migration should not be seen as a linear, causative relationship (Brown, 2008).

For equation (2), the coefficient for *Frac_agri_2002* is negative and statistically significant. The coefficient value implies that the inter-municipal migration was reduced by 8.2% upon being a household dependent on agricultural-related activities. The negative effect follows discussion by Nawrotzki & Bakhtsiyarava (2016) and Teppe (2018), that climate extremes, such as heatwaves, decreased migration from households, who are dependent on agricultural productivity, but does not follow the expected sign for this analysis given that households dependent on agricultural-related activities are most vulnerable to climate variability (FAO, 2016).

For equation (3), the coefficient for *Frac_agri_child_2002* is negative and statistically significant. The coefficient value implies that the inter-municipal migration was reduced by 8.2% upon being a household dependent on agricultural-related activities that reported having children. The negative coefficient follows the discussion made by Lee (1996), Bryan, Chowdhury & Mobarak (2014), and Teppe (2016) that some obstacles for migration could be the costs of transportation and the number of reported children. Households might have a higher number of reported children that could be correlated to lower economic resources, which reduces migration (Teppe, 2016) given that the households could not have sufficient means for mobility (Lee, 1996; Bryan, Chowdhury & Mobarak; 2014).

Overall, the results reveal that households are not likely to migrate when they are exposed to prolonged droughts and heatwaves and despite that their main occupation could be highly affected by climate variability. Their decision to migrate could be explained by other factors not covered in this analysis. The results of this research provide no support to accept the hypothesis detailed in section 1.

The estimates shown in table 4 were revised for heteroscedasticity and there was a serious problem reported. Therefore, the equations were corrected using robust standard errors to obtain unbiased standard errors of the OLS model coefficients. Additionally, each equation was revised for multicollinearity with the Variance Inflation Factors (VIF). The VIF identifies correlation between the independent or explanatory variables and the strength of their correlation. This test resulted in no correlation in any of the equations specified between explanatory variables.

However, the R^2 for each equation is considerably low. This represents the proportion of variance in the dependent variable (MI_2018) which can be predicted from the independent variables (climate_shock, frac_agri_2002 and frac_agri_child_2002). For each equation, the variance of the migration variable can only be explained by 5%, which means that migration within municipalities at household level is explained by other factors not defined in this research.

This research is prone to diverse set of limitations, exposed in section 4.1.3. These range from data availability to the combination of individual- level data with climate data. The results can be biased given the process of elimination of missing values from the main Census database, which were substantial.

Due to the absence of a harmonized census data set for various years for Guatemala, this study has a time narrow focus. Consequently, this can lead to time-specific results which cannot be extrapolated to other areas. Additionally, this is a country-specific research where the methodology can indeed be extrapolated to other countries, interesting to enrich the results for the Latin American Case and for Guatemala if additional data is generated.

6 Conclusion

This study contributes to the research on the impact of climate variability in migration in Latin America, specifically for Guatemala. A sample of households at municipality level for the Guatemalan Dry Corridor (GDC) in Guatemala was used and matched with georeferenced climate data using the 2002 and 2018 Guatemalan Population Census data.

The results show that inter-municipal migration was discouraged by a prolonged exposure to droughts and heatwaves. Additionally, by understanding their decision to migrate if the households were dependent on agricultural related activities and have children, showed that migration was reduced.

These findings show evidence of a climate inhibitor mechanism within municipalities in the GDC to the decision to migrate due to their exposure to prolonged droughts and heatwaves.

However, this research suggests several courses of action for climate-related migration. Greater efforts should be made to increase the quality of individual and household level data in Guatemala and at identifying the households that are most affected by climate change and are most likely to be trapped due to a lack of resources to move.

6.1 Future Research

Although results of this research might be driven by the nature of the data used – and the lack of it -, how the climate shock variable was built, and the chosen control and explanatory variables, there are further research that could be done to have more insights on what drives people to migrate to other municipalities in Guatemala.

It is known that forced migration, and in this case migration due to climate shocks, hinders development in diverse ways such as by increasing pressure on end-place services and infrastructure, and by increasing risk of social indicators worsening amongst migrants such as is health, education accessibility and unemployment.

It would be of interest to understand the migration flows across time and if the increase of temperature levels and risk of droughts can make these flows occur and if they grow bigger and closer in time. This will be of interest of policy makers to know where the potential migration spots are due to climate within Guatemala and direct resources to help vulnerable communities to reduce the potential impact of future climate shocks.

For future research will be interesting to control the analysis by age group, gender, if the person head of the family consider themselves as indigenous, and by income level. Furthermore, it will be interesting to control as well for level of food insecurity and revise if a climate shock occurs, deepens their situation and how this affects their decision to migrate.

As Baez, Mueller & Niu (2017) and Baez, Caruso, Mueller & Niu (2017) discussed, it will be of interest to understand within Guatemala if younger individuals are more likely to migrate from rural to urban areas when confronted with prolonged droughts and heatwaves.

Future research should also attempt to detail the climate shock impact to agricultural occupations in intermunicipal migration considering the wealth of individuals before migration.

7 References

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Appendix A

Table 5: Population distribution by department and area type, 2018

Departament	Area	
	Urban	Rural
Guatemala	91.2%	8.8%
El Progreso	51.8%	48.2%
Sacatepequez	88.5%	11.5%
Chimaltenango	54.1%	45.9%
Escuintla	61.2%	38.8%
Santa Rosa	46.4%	53.6%
Solola	61.6%	38.4%
Totonicapan	49.0%	51.0%
Quetzaltenango	61.5%	38.5%
Suchitepequez	48.0%	52.0%
Retalhuleu	57.3%	42.7%
San Marcos	25.4%	74.6%
Huehuetenango	28.0%	72.0%
Quiche	32.3%	67.7%
Baja Verapaz	40.2%	59.8%
Alta Verapaz	31.3%	68.7%
Peten	40.5%	59.5%
Izabal	41.0%	59.0%
Zacapa	44.2%	55.8%
Chiquimula	37.4%	62.6%
Jalapa	63.0%	37.0%
Jutiapa	51.1%	48.9%
Total	**53.9%**	**46.1%**

Notes: Alta Verapaz, Izabal and Peten are the departments on the northern part of Guatemala.

Source: Own construction with information from INE (2018)

Table 6: Population dependent on agricultural – related activities, by department

GDC	Area		Total
	Urban	Rural	
Guatemala	12,775	13,673	26,448
El Progreso	2,226	7,871	10,097
Sacatepequez	15,125	2,732	17,857
Chimaltenango	10,454	12,246	22,700
Escuintla	5,206	7,388	12,594
Santa Rosa	5,897	16,128	22,025
Solola	5,687	4,248	9,935
Totonicapan	2,729	5,692	8,421
Quetzaltenango	10,860	13,520	24,380
Suchitepequez	3,622	2,958	6,580
Retalhuleu	4,545	5,541	10,086

GDC	Area		Total
	Urban	Rural	
San Marcos	6,913	34,490	41,403
Huehuetenango	12,236	71,871	84,107
Quiche	11,696	48,132	59,828
Baja Verapaz	7,679	20,858	28,537
Alta Verapaz	17,439	68,605	86,044
Peten	10,654	43,073	53,727
Izabal	3,619	16,682	20,301
Total	**149,362**	**149,362**	**149,362**

Source: Own construction with information from INE (2018)

Table 7: Population dependent on agricultural – related activities, in the GDC.

GDC	Area		Total
	Urban	Rural	
Baja Verapaz	7,679	20,858	28,537
Chimaltenango	10,454	12,246	22,700
Chiquimula	6,858	19,368	26,226
El Progreso	2,226	7,871	10,097
Guatemala	12,775	13,673	26,448
Huehuetenango	12,236	71,871	84,107
Jalapa	17,805	19,257	37,062
Jutiapa	13,569	27,983	41,552
Quiche	11,696	48,132	59,828
Totonicapan	2,729	5,692	8,421
Zacapa	3,164	8,964	12,128
Total	**101,191**	**255,915**	**357,106**

Source: Own construction with information from INE (2018)

Table 8: Population moderately to severely food insecure in the GDC, 2011.

GDC	Population moderately to severely food insecure in the GDC
Baja Verapaz	40.3%
Chimaltenango	51.2%
Chiquimula	47.0%
El Progreso	37.4%
Guatemala	29.1%
Huehuetenango	33.5%
Jalapa	39.9%
Jutiapa	51.3%
Quiche	49.9%
Totonicapan	52.0%
Zacapa	40.0%

Source: Own construction with information from INE (2011)

Table 9: Climate conditions and projections for Guatemala.

Parameter	Current Conditions (since 1960s)	Projected Changes to 2030
Temperature	● Increases in maximum temperature by 0.2°C and in minimum temperature by 0.3°C per decade. ● Increase in the number of hot days by 2.5% and the number of hot nights by 1.7% per decade[9].	● Mean temperatures are projected to increase by 0.9°C to 1.0°C by 2030, with the greatest warming occurring in March, toward the end of the dry season. The largest increases are expected in the north, Caribbean coast, east, and southern coast. ● Monthly maximum daily temperatures are projected to increase by 1.3°C to 1.5°C. ● Annual number of hot days and hot nights are projected to increase. ● More frequent and prolonged heatwaves.
Drought	● Increase frequency and intensity of El Niño events, leading to frequent and severe droughts in the Dry Corridor.	● More frequent and prolonged droughts. ● Decreases in summer precipitation, largely in central highlands, west, and eastern regions. ● Expansion of semi-arid climate regions.
Extreme Events	● Increase in average annual rainfall by 13% to 27%, with the largest increases in the north and the Pacific Coast. ● Irregular start of rainy season and more intense rain in short periods of time.	● Increased incidence and intensity of extreme rainfall events and floods. ● Increased incidence of heavy rainfall events followed by dry days.

Source: Climate Risks to Food Security in Food for Peace Geographies: Guatemala. USAID (2020).

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[9] According to USAD (2020), a hot day is where the maximum temperature exceeds 35°C and a hot night is where the minimum temperature exceed 20°C.

Table 10: People dependent on agricultural-related activities who reported being recent migrant/non-migrant.

GDC	Non-migrant		Migrant	
	Urban	Rural	Urban	Rural
Baja Verapaz	97.8%	98.9%	1.9%	2.5%
Chimaltenango	98.0%	98.9%	1.0%	1.0%
Chiquimula	98.4%	98.2%	1.2%	4.0%
El Progreso	98.3%	98.8%	1.1%	2.5%
Guatemala	96.5%	98.2%	2.8%	1.3%
Huehuetenango	98.5%	98.8%	1.1%	5.0%
Jalapa	98.8%	98.5%	1.0%	1.4%
Jutiapa	98.6%	98.4%	1.0%	2.8%
Quiche	98.7%	98.5%	0.5%	4.2%
Totonicapan	98.9%	98.7%	0.8%	1.5%
Zacapa	97.3%	97.8%	2.1%	2.7%
Average	**98.2%**	**98.5%**	**1.3%**	**2.6%**

Source: Own construction with information from INE (2018)

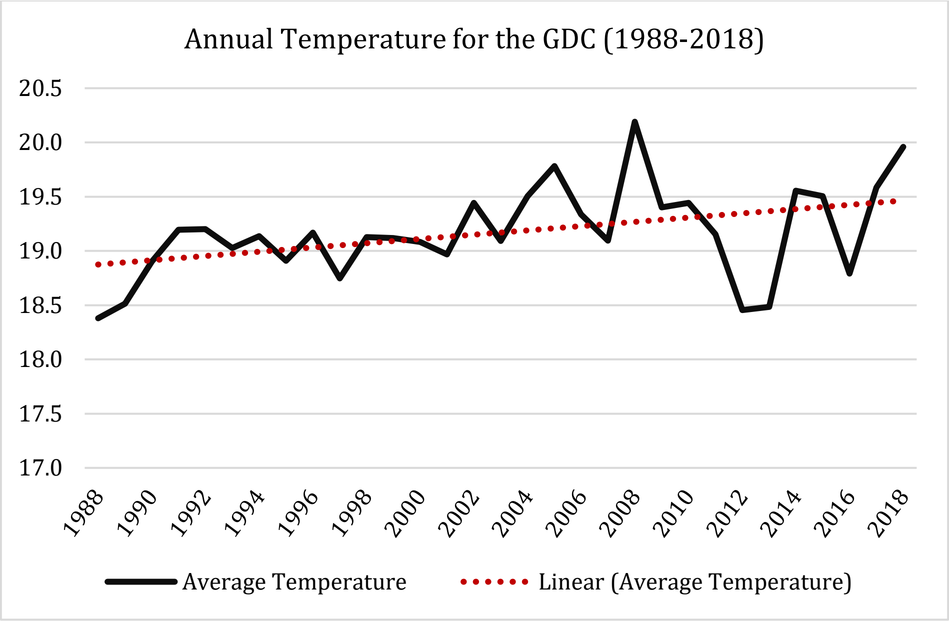
Table 11: People that migrated between 2002 to 2018 by gender and who depended on agricultural-related activities.

GDC	Male		Female		Total
	Urban	Rural	Urban	Rural	
Baja Verapaz	1.5%	0.7%	0.4%	0.2%	1.1%
Chimaltenango	0.8%	0.6%	0.1%	0.1%	0.8%
Chiquimula	1.2%	1.4%	0.3%	0.4%	1.7%
El Progreso	0.6%	0.4%	0.2%	0.1%	0.6%
Guatemala	3.4%	1.5%	1.8%	0.8%	3.7%
Huehuetenango	3.4%	2.6%	0.8%	0.6%	3.4%
Jalapa	0.3%	0.4%	0.1%	0.1%	0.5%
Jutiapa	0.6%	0.9%	0.2%	0.3%	1.1%
Quiche	0.9%	1.7%	0.2%	0.3%	1.9%
Totonicapan	1.5%	1.4%	0.3%	0.3%	1.8%
Zacapa	1.3%	0.6%	0.5%	0.2%	1.1%
Average	**1.4%**	**1.1%**	**0.5%**	**0.3%**	**1.6%**

Notes: These proportions are own calculations based on information from the 2018 Population Census.

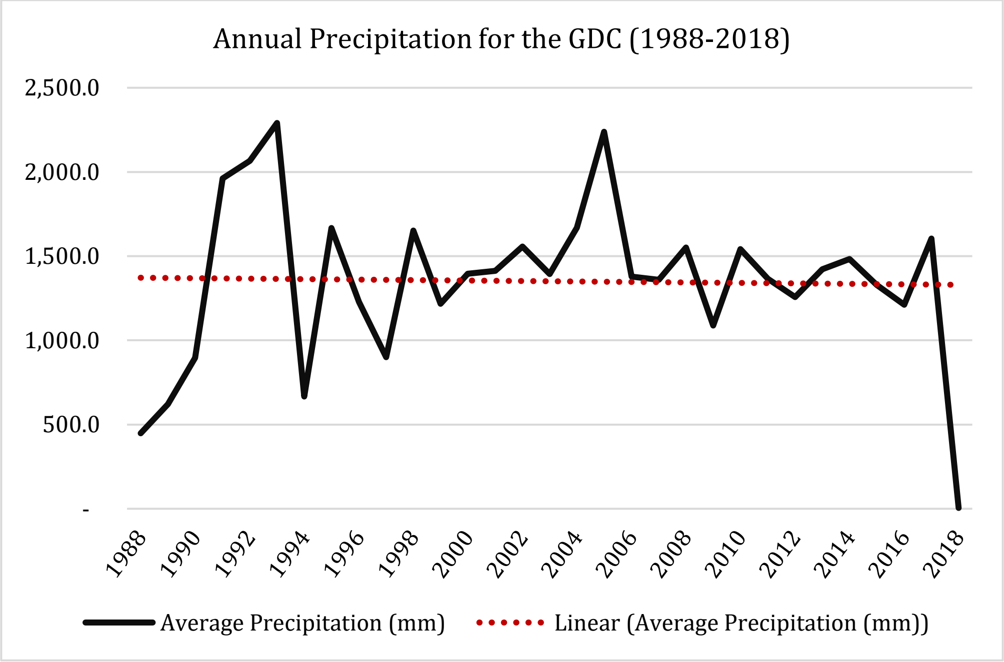
Source: Own construction with information from INE (2018)

Figure 10: Annual Temperature for the municipalities in the GDC (1988-2018)



Source: Own construction with information from NASA Power 8 Release

Figure 11: Annual Precipitation for the GDC (1988-2018)



Source: Own construction with information from NASA Power 8 Release.

Table 12: Average range of temperature and precipitation for the GDC (1988-2018)

Year	Temperature		Precipitation (mm)	
	Max	Min	Max	Min
1988	24.4	19.5	123.4	2.1
1989	22.9	18.3	112.5	2.3
1990	23.8	19.1	232.7	5.8
1991	24.3	18.1	280.4	1.3
1992	22.0	18.8	330.0	10.5
1993	22.9	18.3	403.9	4.4
1994	23.9	19.7	66.7	2.8
1995	23.3	19.1	302.9	1.6
1996	22.7	19.0	181.0	4.7
1997	23.6	19.8	187.0	6.2
1998	25.0	18.0	336.6	0.8
1999	23.0	17.5	214.4	9.4
2000	23.0	17.8	234.6	4.8
2001	23.0	19.0	276.0	7.3
2002	23.1	19.0	358.9	4.2
2003	23.7	17.9	259.6	6.4
2004	22.9	18.1	320.7	5.7
2005	23.9	18.7	382.6	2.4
2006	22.6	18.6	228.1	6.3
2007	23.6	18.3	292.7	8.3
2008	23.2	17.7	349.1	6.9
2009	23.2	18.7	194.7	4.7
2010	23.8	16.6	335.6	3.4
2011	23.4	18.1	308.2	7.9
2012	22.5	18.5	280.6	11.8
2013	24.0	19.0	240.5	8.0
2014	23.3	18.1	290.5	8.9
2015	23.5	19.4	234.7	11.3
2016	24.4	19.4	196.3	7.6
2017	23.4	18.3	252.1	7.0
2018	22.6	18.5	10.0	0.2

Source: Own construction with information from NASA Power 8 Release