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Assessment of climate drivers of migration and neglected infectious disease risk in Latin American and Caribbean migrants

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An abstract of

A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University

in partial fulfillment of the requirements for the degree of
Master of Public Health
in Global Epidemiology

2022

Abstract

Assessment of climate drivers of migration and neglected infectious disease risk in Latin American and Caribbean migrants

By Clary Herrera

Introduction

Climate change-related factors have led to an increase in migration from Latin America and the Caribbean (LAC) to the United States. Climate change has both influenced the agricultural and socioeconomic infrastructure of LAC countries and is leading to emergence and reemergence of waterborne, helminth transmitted, and vector borne infectious diseases. This pilot study aimed to identify climate-related drivers of migration and to describe the burden of climate-sensitive neglected infectious diseases (NTD) in immigrants arriving in the US. The objective is to help understand the role of climate change in decisions to immigrate from Latin America and the Caribbean to the Atlanta-metro area.

Methods

First generation migrants from LAC countries living in the Atlanta-metro area were recruited through a local clinic, varied community services, and places of employment between May and December 2021, and were invited to enroll into this cross-sectional study. Participants completed a survey concerning demographics, socioeconomics, living conditions in their country of origin and living conditions in Atlanta, and motivations for migration. Blood and stool samples were collected to identify Chagas and soil-transmitted helminths, and exposed skin exams were performed to screen for leprosy and leishmaniasis. Descriptive analysis, including means and frequencies, were performed using SAS. A multivariable logistic regression analysis of this dataset looked at the association between a climate-driven motivation to migrate and geographic and socioeconomic factors.

Results

Sixty participants were enrolled with survey data available for 57 participants. Eleven LAC countries were represented, with most migrants originating from Central America (n=32; 56%) and Mexico (n=13; 23%). Forty-two participants claimed to have perceived a climate change in their country of origin, and direct climate drivers (e.g., floods, drought, etc.) were identified by 12 participants (21.4%). The primary climate and environmental factors were water scarcity (29.4%) and land loss, hurricanes, and climate change (11.8%). Infectious diseases screening found one (2.5%) positive Chagas case out of 40 blood samples. Food insecurity, agriculture work, and Central American countries were associated with climate-driven migration, odds ratios (aOR) of 6.3 (95% CI 1.1, 35.5), 5.7 (95% CI 0.7, 43.8), and 0.4 (95% CI 0.1, 2.1), respectively.

Conclusions

While most participants did not directly identify climate change as a reason for migration, our study reveals many factors such as food insecurity, agricultural occupations, and region of origin that may underlie to climate-motivated migration. The potential role of climate change in infectious disease transmission in LAC populations warrants additional study and improved surveillance, including studies in LAC countries, and screenings for newly arrived immigrants that focus on region-specific NTDs.

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Acknowledgements

I would like to extend my genuine gratitude to my faculty advisor, Dr. Uriel Kitron, for his generous partnership and time committed to helping my project and thesis progress. Additionally, my deep thanks to my field advisor, Dr. Jessica K. Fairley, for her mentorship of my thesis project. Her consistent guidance and expertise offered throughout the analytical component of my thesis were tremendously valuable. Finally, a sincere thank you to my committee member, Dr. Rebecca Philipsborn, for her constant encouragement throughout this process.

Thank you to each member of the AGREC study team: Morgan Lane, Alexis Nkusi, Emaline Laney, Amitha Sampath, Cassandra White, Uriel Kitron, Rebecca Philipsborn, and Jessica K. Fairley, to the incredible team at the COSMO Clinic and Center for Pan Asian Community Services, and the Atlanta Global Research and Education Collaborative Grant without whom this thesis project would not be possible.

I am deeply grateful for the Emory Coverdell Fellows program which provided the opportunity to pursue my MPH at this incredible institution. Lastly, I give my deepest gratitude to my parents, Clara and Luis Herrera, who have unconditionally supported me through each season of my life and have always been my greatest champions.

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Introduction

Background on migration

Over the last 4 decades, the migration of Latin American and Caribbean (LAC) populations into the United States has increased substantially; in 2017, approximately 19 million people born in LAC countries were living in the US, compared to 6.2 million in 1990 [1]. Migrants have opted to leave their homes for a variety of motives including safety and security concerns due to conflict, economic pressure, and environmental factors that could be related to climate change [2, 3]. Previous research has indicated that political and socioeconomic factors are primary drivers for global migration. The Internal Displacement Monitoring Centre reported that nearly 237,600 people in the Latin American and Caribbean region were displaced due to conflict and violence in 2020 [4]. For instance, El Salvador recently faced its "deadliest day" in 30 years with 62 murders occurring on Saturday, March 26, 2022 [5]. Less studied but becoming increasingly recognized as a driver for migration is the role of climate change and climate change-related factors in peoples' decision to migrate, specifically in Latin America and Caribbean populations [6, 7].

Background on Climate Change

The National Aeronautics and Space Administration defines climate change as " a long-term change in the average weather patterns that have come to define Earth's local, regional and global climates" [8]. Latin America and the Caribbean have experienced an increase in frequency of extreme weather events such as monsoons and hurricanes. The region has similarly begun to encounter long-term climate changes such as recurring floods (increased rainfall), droughts, and water shortages. In addition, Central America has experienced a rise

in extreme weather events in the form of hurricanes due to the El Niño Southern Oscillation. In Caribbean countries, El Nino is contributing to sea-level rising due to the increase in surface water temperatures while in South America, El Nino is compounding fresh-water scarcity [9]. In 2020 alone, climate-related events consisting of 3 distinct hurricanes displaced approximately 2,130,906 individuals across 13 distinct Latin American and Caribbean nations [4].

Climate Change Risk Factors

These climate change related phenomena not only motivate people to move to the United States, but also present risk factors for the emergence or reemergence of specific infectious diseases [10, 11]. An evaluation by Mark Booth at Newcastle University, explained that most of humanity is at-risk to illnesses that are affected by environmental factors; this includes infections that are waterborne, vector borne, and transmitted through helminths (soil), many of which are considered neglected tropical diseases (NTDs) [12]. According to a review conducted by Parry et al, Latin America has a neglected tropical disease burden of 135 per 100,000 Disability-Adjusted-Life-Years (DALYs); the most prominent diseases being Chagas, dengue, and ascariasis [13, 14]. A 2014 study concentrating on Latin American migrants in Los Angeles, California conducted one of largest known Chagas screenings to date; the study found a prevalence of 1.2% for Chagas in the area with Salvadoran migrants contributing largely to the statistic [15]. This finding was consistent with the Centers for Disease Control and Prevention (CDC) report of 1.3% prevalence of cases in the US among Latin American immigrants [16].

Researchers have studied the proximal and distal influences of country of origin, agriculture, and socioeconomic conditions as risk factors for climate-driven migration. For

example, Theide's study focused on the type of climatic change, the demographic socioeconomic characteristics, and the distance or direction of migration [17]. Climate change-related risk factors can be divided into two categories: proximal or distal. Proximal factors are those that directly affect the decision to move while distal factors are those that indirectly affect this decision [18]. Changes in environment and weather across geography (country of origin, urbanicity) and socioeconomics (occupation and food security) have been identified as main risk factors resulting in LAC migration to the US [12]. Environmental and climate changes can affect agriculture in terms of occupations; agriculture includes activities such as forestry, hunting, and fishing, as well as cultivation of crops and livestock production. The agricultural sector in Latin America and the Caribbean accounts for approximately 5 to 18% of the gross domestic product of 20 different countries in the region [19]. The socioeconomic state of LAC has historically prompted migration for many; according to the United States Agency for International Development (USAID), Latin American and Caribbean countries are facing slowing economies and the highest, global rates of income inequality [20].

Study Rationalization

Most of the current literature considering climate and migration from LAC to the US consists of reviews and modelling. Mitra and Rodriguez-Fernandez express that in this limited research conducted to date, inconsistencies in statistics and data collection and classification limit findings and their applicability in assessing health in LAC countries [21]. Many rely on secondary sources of data. For example, Thiede et al employed census data from 25 distinct South American countries to assess patterns in temperature and rainfall which affected interprovincial migration. Their outcomes found extreme monthly (acute)

temperatures to have the greatest effect on migration specifically towards urban areas [17]. These models also do not include the perspective of the individuals choosing to migrate. There is a lack of research that considers the lived experience of those individuals choosing to migrate, their reasons for migration from LAC countries to the Southeast region, and the role of climate change in this decision.

The aim of this exploratory pilot study and analysis is to understand the role of climate change in decisions to immigrate to the Atlanta-metro area from Latin America and the Caribbean. This study is one arm of a mixed methods interdisciplinary approach. We used cross-sectional data, comprised of a qualitative intake survey, an in-depth interview, and clinical information, to evaluate the direct and indirect factors related to climate change in the country of origin which impacted the decision to immigrate, as well as the prevalence of climate-sensitive neglected tropical diseases, e.g., dengue, Chagas, and hookworm. Study data were collected from the Atlanta Global Research and Education Collaborative (AGREC) Grant Study in collaboration with the Center for Pan Asian Community Services (CPACS) COSMO clinic. The interdisciplinary study team comprised members with expertise in immigrant medicine, anthropology, public health, infectious diseases, and environmental sciences, including team members directly serving the health needs of the community. We hypothesized that climate change has played a role in the decision by the Latin American and Caribbean population in Atlanta to migrate, and that there is an infectious disease burden of climate-sensitive diseases that has yet to be quantified in this population. By understanding the role and risk factor that climate change presents for migration and migrant communities recently arrived in the U.S., health care facilities will be better able to

accurately diagnose and treat climate-related illnesses and provide better services for Latin American and Caribbean populations.

METHODS

Study Design and Population

This pilot study used a cross-sectional design aimed towards better understanding and quantifying the role and risks of climate change as an impetus for migration, specifically for Atlanta-area migrant communities originating from Latin America and the Caribbean. We recruited men, women, and children between May 2021 and December 2021 who were first-generation immigrants in the metro-Atlanta area and associated with the Cosmo Health Center (CHC), the associated Center for Pan Asian Community Services (CPACS), a local afterschool program, and a landscaping company. Participants were recruited during a routine visit to the clinic, when picking up food at the associated food bank, and through word-of-mouth from the afterschool program director and company manager. This study was approved by the Emory University and Georgia State University Institutional Review Boards (IRBs).

Eligibility criteria:

To be eligible to participate in the study, individuals must have originated from Latin America or the Caribbean and be 3 years old or older. Pregnant women were eligible to participate. For children, informed consent was provided by a parent or legal guardian and assent required for children aged 6 years old and up as per IRB guidelines. Exclusion criteria included those who were younger than 3 years old, originated from outside Latin America or the Caribbean, were unable or unwilling to provide informed consent, or were incarcerated. Participation was voluntary, and informed consent, surveys, and subsequent interviews were carried out in English, Spanish, or Portuguese depending on the language proficiency and preference of the participant. Questions regarding the immigration legal

status of the participants were averted as a precaution out of consideration for the vulnerability of this community.

Data collection activities:

After providing informed consent, a comprehensive survey was administered over the phone (in English, Spanish or Portuguese depending on the language proficiency and preference of the participant) or in person. The survey consisted of 46 questions which were asked in stepwise, multiple choice, select-all-that-apply, and open response formats. Questions inquired about characteristics and demographics of each person considering three different points in time: in their country of origin (prior to migration), as a recent arrival in the US, and current situation. Questions on climate-change related environmental determinants of health were included. For example, participants were asked about the natural environment of their home of origin, whether it was mountainous, near a body of water, or had a variety of biting insects/mosquitos (Appendix 1). Each of these could be linked to climate change effects or susceptibility for infectious disease. Participants were asked clinical background information concerning a prior diagnosis of specific climate-sensitive neglected tropical diseases such as dengue, Chagas, hookworm, amoeba, chikungunya, malaria, typhoid, and giardia. Lastly, participants were asked about the circumstances that motivated their decision to immigrate to the US.

Following the survey, participants attended a clinical study visit at the COSMO Clinic; the infectious burden of climate-sensitive neglected tropical diseases was quantified with stool and blood samples and targeted medical questions. The visit commenced by collecting customary nutritional status indicators such as weight-for-age, height-for-age, and body mass index (BMI) for children, and weight, height, and BMI for adults. Blood samples were

collected using a venipuncture. Samples were analyzed by a third-party laboratory, LabCorp, for identification of Chagas antibodies signifying chronic disease. Blood samples were also used to screen for anemia using a complete blood count (CBC) test. Stool samples were collected for the detection for the soil-transmitted helminths. Samples underwent parasitologic assessment for ova and parasites as well as strongyloides' antibodies from serum. Measurements of lead levels were included as an indicator of specific exposures related to the environment in both adults and children. All specimens were sent to the laboratories used by the health clinic and recorded in the health record to guide appropriate care and management of any positive results.

After the initial survey and clinical visit, participants were offered the opportunity to participate in an in-depth interview (IDI). A maximum of 20 such interviews were conducted with the first 20 adult participants who consented to participate. These interviews were administered in-person or via a secure, end-to-end encrypted platform, such as WhatsApp or Web Ex. The IDI consisted of 41 open-ended questions addressing their motivations to move to the US and specifically to Atlanta, and to better understand the role of climate in their migration. The analyses of these IDIs are not included in this manuscript.

Variables:

The outcome variable for this study was climate-driven migration. We derived this variable by aggregating all reasons for migration that are directly associated with climate: floods, hurricanes, earthquakes, monsoons, land change, land loss, water scarcity, climate change, and other weather. To explore factors associated with climate associated migration we dichotomized our covariates; therefore, the key independent variable was food insecurity,

which was categorized into 2 levels: food secure or food insecure, with the hypothesis that food insecurity prior to migration was linked with a climate as a driver of migration. Food security was identified by those that reported they "frequently, often, or sometimes" ran out of food and could not afford more or those that cut or skipped meals in the 12 months prior to migration, compared to those who never experienced a food insufficiency. Secondary exposures were region of origin which was separated in 4 categories: South America, Central America, Caribbean, and Mexico. Due to the high frequency of participants from Central America (El Salvador, Guatemala, Honduras), this variable was dichotomized further into Central America and non-Central America. Lastly, occupation was included as an additional secondary variable, with the hypothesis that people working in select occupations may be more susceptible to climate change associated negative impact. Occupation was dichotomized to agricultural work and non-agricultural work based on the occupation reported in their country of origin prior to migration.

Statistical Methods:

After performing basic descriptive statistics, we examined bivariate associations between climate-driven migration and each of the independent variables using the chi-square test for nominal covariates and the t-test for age, a continuous variable. Logistic regression models were developed to calculate adjusted odds ratios (aOR) and the corresponding 95% confidence intervals (CI) reflecting the associations of the main independent variable of interest (climate-driven migration) and covariates (food security, occupation, region) controlling for gender and age. A p-value <0.05 was considered statistically significant. Since the sample size for this pilot study was small, model diagnostics were limited. We tested for interaction between the main exposure (food insecurity) and covariates

(occupation, region of origin, gender), and then used a chunk test with maximum likelihood ratios to determine no significant interaction in our model. Lastly, using the Akaike Information Criterion (AIC), we determined the best fitting model: $Logit\ [P(Y=1)] = \beta_0 + \beta_1 FD\_insecurity + \gamma_1 Occupation + \gamma_2 Continent + \gamma_3 Gender.$ Confounding was assessed using the backward stepwise approach where covariates were removed if they were not found to be statistically associated with the outcome and did not change the point estimate of the primary exposure by more than 10%.

RESULTS

Of the 60 individuals enrolled in the study, 57 (95%) completed an initial interview, 40 (66.7%) completed a clinic visit, and 20 (33.3%) participated in an in-depth interview. In three instances, the participants were able to attend a clinic visit prior to completing the initial interview and before completing the questionnaire; two stool samples were not returned to the clinic and one participant (pregnant) did not consent to the full blood sampling. The main justifications for non-participation (incomplete initial interviews or unattended clinic visits) were nonresponse, refusal, and other reasons including difficulty of scheduling due to primarily work schedule of participants not corresponding with clinic hours, or to lack of transportation.

The results of descriptive analyses comparing the distributions of participant characteristics across LAC countries are presented in Table 1. Approximately 80.7% (n=46) of study participants were self-identified women, 73.7% (n=42) had lived in either urban or semi-urban settings in their country of origin, and 43.9% (n=25) first arrived in the US 15 or more years ago. Participants were from 11 distinct LAC countries: Brazil, Colombia, Dominican Republic, El Salvador, Guatemala, Honduras, Mexico, Paraguay, Peru, Puerto Rico, and Venezuela. Countries were categorized into 4 subregions: 3.5% from the Caribbean, 56.2% from Central America, 17.5% from South America, and 22.8% from Mexico. Climate-related reasons for immigrating to the US were claimed by 21.1% (n=12) of participants. Of the 12 individuals who reported a climate-driven motivation, 2 are from El Salvador (16.7%), 3 from Guatemala (25.0%), 1 from Honduras (8.3%), 1 from Venezuela (8.3%), and 5 from Mexico (41.7%).

Twelve participants reported 17 total climate-driven reasons for migration (Table 2). The most frequent climate-driven causes were water scarcity (41.7%), hurricane (16.7%), land loss (16.7%) and climate change (16.7%). Other reported drivers of migration, classified as non-climate-driven, were reported by 100% of participants. The most common purposes for non-climate-driven migration were work (59.6%), unification with friends/family (47.4%), safety/security (43.9%), education (35.1%), and poverty (35.1%) (Table 3). Lastly, participants reported past diagnoses of 28 cases of specific, climate-sensitive neglected infectious disease in Table 4; most widely reported was chikungunya (32.1%) followed by hookworm (17.9%), other (17.9%), and dengue (10.7%).

Results of the bivariate analysis determined food insecurity as our key independent variable with odds of climate-driven migration 6.8 times higher (95% CI 1.3, 34.9) than those who did not report food insecurity. This analysis also revealed region of origin (Central America vs other LAC region), occupation (agricultural work vs non-agricultural work), and gender (woman vs man) to be covariates of interest. Crude odds ratios (cOR) for the covariates are as follows: Region of origin cOR=0.7 (95% CI 0.2, 2.6), Occupation cOR=4.7 (95% CI 0.8, 27.0), and Gender cOR=0.3 (95% CI 0.04, 2.8) as indicated in Table 5.

The preliminary multivariable logistic regression model included the outcome, climate-driven migration, and the associated covariates: food insecurity, occupation agriculture, region Central America, gender, and age (a continuous variable). Using a reverse stepwise approach, age was determined to not be a confounder as it did not change the outcome by more than 10%. The final multivariable logistic regression model included the variables: food insecurity, occupation, gender, and region of origin. Results of this analysis among

participants who reported food insecurity revealed the odds of a climate-driven migration was 6.3 times higher than in those who did not report food insecurity (95% CI 1.1, 35.5; p-value=.04) (Table 5). A second prominent finding was strong association between agriculture as an occupation and climate-driven migration, although it did not reach statistical significance. The odds of climate-driven migration among those who worked in agriculture was 5.7 times higher than that of those who worked in other occupations such as traditional, domestic work, business, students, or unemployed (95% CI 0.7, 43.8: p-value= 0.9). "Unemployed" included those reporting not having a form of employment prior to immigrating; this was predominantly made up of those who were children at the time of migration. This finding was bolstered by results of our in-depth interviews; for example, a Salvadoran woman was motivated to migrate to the US due to climate change (flooding) inhibiting her ability to work as a shrimp farmer.

Results of the clinical study visit revealed the following outcomes (Table 6): Out of 39 blood samples, one participant had confirmed anemia by abnormal hemoglobin levels. Of the 33 returned stool samples, none were found to have helminths, although non-pathogenic protozoa and ova were found in 3 samples. As our data consisted of only 39 blood samples, we adjusted our expectation to potentially not detecting any Chagas cases; however, we discovered 2 out of 39 *suspected* Chagas cases via blood sample analysis. Of the two suspected cases, one was confirmed by follow-up tests. This was a noteworthy finding because it established a 2.5% prevalence for our study, higher than the CDC estimated prevalence. Neither of the two participants reported having been diagnosed or treated for Chagas prior to entering the study, so the research team newly diagnosed this neglected infectious disease in this participant.

DISCUSSION & CONCLUSION

Delineating and describing the interrelated factors that prompt migration is complex [22]. To the best of our knowledge, this study is the first of its kind to be conducted in the Southeastern region of the United States with the aim of collecting data directly from individuals who have migrated about climate-driven and non-climate-driven exposures, such as poverty and security concerns, which induce migration.

Though recent modelling studies have suggested that Central American and Mexican countries are experiencing an increase in climate-driven migration, current literature suggests that most migration from the region can be attributed to poverty and security concerns. These factors are not wholly distinct but, rather, interrelated. Poverty and security concerns can both impede a country and community's ability to adapt to climate change, while climate change can further enhance poverty and security concerns. Raliegh's study of migration literature points to poverty in developing nations preventing and/or reducing the ability of a country to take action against environmental or climate changes which, in turn, tend to exacerbate over time [3]. These environmental effects may cause involuntary or voluntary migration through displacement caused by subsequent "climate-related disasters and chronic climate change hazards"[23]; those being displaced are known as climate migrants or climate refugees [24]. The International Organization for Migration has predicted that by 2050 there will be over 200 million climate-migrants [25].

In the context of agriculture, food insecurity and occupation/unemployment have been recognized as "push factors" that force migration [22, 26]. The Pan American Health Organization reported in 2020 alone there was a 30% increase in food insecurity or hunger in LAC countries: the highest increase affecting 7 million people in the Caribbean [27].

These facts and studies concur with our finding of food security as the primary factor associated with climate-related migration. Food insecurity and unemployment are precursors to hunger and poverty, both of which have been found by Marks (2016) to precede safety/security concerns, at the community and national levels [28]. Our findings identified security, safety, poverty, and work to have been selected by a minimum 20 participants. These first-hand accounts provide a basis for an ongoing study of the interconnectedness and compounding effects of these factors for climate migrants.

Our study findings uphold many of the reviews and models that have considered climate change migration associated with climate change from the Latin American and Caribbean region. Our analysis demonstrated an association between climate-driven migration and region of origin, and specifically large differences between those migrating from Central America vs the other LAC regions (South America, the Caribbean, and Mexico). Balsari et al (2020) identified Central America as one of the top four regions with populations at-risk for negative climate change effects and migration; this is primarily due to more frequent droughts and water scarcity in the "dry corridor" which includes El Salvador, Guatemala, Honduras, and Nicaragua [29]. Meanwhile South American migration may be more attributed to extreme weather events/patterns such as hurricanes, as well as, water scarcity [9]. Although the South American participants in our study did not report climate as reasons for migration, we may not have detected such an association due to the low number of South American participants in our study. Future research that will scale-up and widen the scope to incorporate more individuals from South American and Caribbean countries as well as include individuals who have not migrated from these regions, would

allow for more meaningful comparisons among the factors leading to climate-driven migration across regions of LAC.

Only a few research studies have collected and explored the association in LAC, and the majority that focus on migration to the USA are limited to migration from Mexico, likely due to proximity. In a study employing geostatistical interpolation methods to explore associations between the daily temperature/precipitation, migration histories, and household demographic data, researchers found that peoples' *first* move from rural Mexico was the result of an immediate threat to survival directly related to climate change, in this case flooding due to increased precipitation [30]. A second study of the association between rainfall and Mexico-US migration found that drought following a rainfall deficit made a family more likely to send a migrant; however, this association was predominantly found in Mexican regions which had strong, existing social networks in the US demonstrating the impact of social networks on the relationship between climate change and migration in Mexico [31].

Climate affects infectious disease burden in LAC countries, specifically in regions with increased rainfall and flooding or drought, as well as areas of intense urbanization, where denser populations are concentrated in smaller areas [32]. LAC countries are also affected by vector borne infections and parasitic diseases, given the warm climate and conditions conducive to vector proliferation and exposure to parasites, resulting in enhanced transmission of arborviruses such as dengue and chikungunya [33, 34] and exposure to water and soil-transmitted helminths. Consequently, immigrants from LAC countries are more likely to arrive infected by a climate-sensitive infectious disease that may not be

diagnosed. Medone found in a South American study of Venezuela and Argentina that *Triatoma infestans,* the Chagas vector, will be able to withstand higher temperatures at higher latitudes due to insect adaption by 2050 [35]. In 2015, Pineda et al reported an alert for chikungunya which spread throughout 33 countries including LAC and the US (Florida) [11]. Because we found prevalence of 2.5% in our study and given that the Chagas vector is present in Georgia, there is a potential for future transmission of *Trypanosoma cruzi* in agreement with Pineda and Meymandi (2016, 2017), our study suggests the need for increased screening, surveillance, and treatment of recently arrived immigrants from LAC countries, as well as for increased awareness amongst clinicians caring for immigrant patients. Finally, a Los Angeles Chagas screening study concluded a need for increased surveillance for Chagas in those immigrating to the US from Latin America due to the high prevalence in LA [15].

For some study participants, their study visit was one of few interactions with the healthcare system that they have experienced since moving to the US. To protect study participants due to their potentially sensitive situation in terms of legal status and authorization, the study team did not assess their legal status. However, some participants indicated that their willingness to participate was partly to send a message about the need of better health care services, health policies, and accessibility for LAC migrants. Access to healthcare is a great barrier for LAC migrants in the US. Pega (2021) finds in his meta-analysis that non-migrant workers are 50% more likely to use health services and have better health outcomes compared to migrant workers [36]. This disparity could be attributed to lack of health insurance to afford care, distrust in the healthcare system, limited access, or all of the above. Further study on the current prevalence of NTD

outcomes and health care accessibility in Georgia would help gauge extent of disease burden and identify methods of improving healthcare for migrants.

A major limitation of this pilot study was the small sample size and potential bias within this small sample towards Central America and Mexico. The demographics of our study participants reflect the areas of recruitment near COSMO clinic. The demographics of the LAC community in the areas of recruitment (Norcross, Buford, and Tucker, Georgia) similarly reflect higher Central American and Mexican populations. This is consistent with 2019 data that 330,434 out of 526,630 Latin American immigrants, in Georgia, originated from Central America and Mexico [37]. However, this may limit the generalizability of the study findings beyond the Central American and Mexican migrant community. Historically, the LAC population living in the United States has faced challenges with transportation and access to health care [38]. Recruitment and retention were difficult to achieve as the multi-step approach may have been inconvenient for participants or a deterrent for potential participants. A final limitation is the potential for recall bias. Almost 44% of participants migrated 15 or more years prior to the study increasing the likelihood that they may not have been able to recall all climate-related phenomena in their country of origin or the details prompting migration. Future studies would benefit to aim recruitment toward more recently arrived immigrants who can provide accurate reports of climate change and factors influencing migration, and which do not rely on long-term memory.

Our pilot study provides proof-of-concept of the feasibility and added value of a comprehensive protocol built upon a multi-disciplinary mixed methods approach with strong community partnerships in assessing climate change as a driver of migration from

the perspective of immigrants themselves. The study can be a precursor for larger future investigations into the role of climate change as a driver of migration to the US, and the neglected tropical diseases burden which could be associated with their migration. This study can be applied to inclusive population which extended beyond Central America and Mexico. The risk factors of interest derived from this preliminary research can steer future research and the scale-up of this study to explore further the associations that were found.

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Table 1. *Study Population characteristics categorized by country of origin (n=57)*

Participant Characteristics	Central America N=32 (%)	South America N=10 (%)	Caribbean N=2 (%)	Mexico N=13 (%)	Total N=57 (%)
Age, years mean (SD)	38.5 (14.8)	39.8 (17.8)	36.0 (9.9)	44.8 (11.5)	40.1(14.5)
Gender					
Woman	25 (78.1)	7 (70.0)	2 (100)	12 (92.3)	46 (80.7)
Man	7 (21.9)	3 (30.0)	-	1 (7.7)	11 (19.3)
Climate-driven migration					
Yes	6 (18.8)	1 (10.0)	-	5 (38.5)	12 (21.1)
No	26 (81.2)	9 (90.0)	2(100)	8 (61.5)	45 (78.9)
Urbanicity					
Urban/Semi-urban	18 (56.3)	10 (100)	2 (100)	12 (92.3)	42 (73.7)
Rural	14 (43.7)	-	-	1 (7.7)	15 (26.3)
Occupation					
Agriculture	5 (15.6)	-	-	1 (7.7)	6 (10.5)
Traditional	8 (25.0)	3 (30.0)	1 (50.0)	1 (7.7)	13 (22.8)
Business	2 (6.3)	-	-	5 (38.5)	7 (12.3)
Domestic Work	7 (21.9)	1 (10.0)	-	3 (23.1)	11 (19.3)
Student	6 (18.8)	4 (40.0)	1 (50.0)	-	11 (19.3)
NA	4 (12.5)	2 (20.0)	-	3 (23.1)	9 (15.8)
Food Insecurity					
Yes	18 (56.3)	3 (30.0)	1 (50.0)	7 (53.9)	29 (50.9)
No	14 (43.7)	7 (70.0)	1 (50.0)	6 (46.1)	28 (49.1)
Arrival in US					
<5 years ago	6 (18.8)	4 (40.0)	-	3 (23.1)	13 (22.8)
5-10 years ago	8 (25.0)	-	-	1 (7.7)	9 (15.8)
11-15 years ago	4 (12.5)	1 (10.0)	2 (100)	3 (23.1)	10 (17.5)
>15 years ago	14 (43.8)	5 (50.0)	-	6 (46.1)	25 (43.9)
Total	32 (56.2)	10 (17.5)	2 (3.5)	13 (22.8)	

Table 2. *Reported climate-driven drivers for migrations by study participants*

Climate-driven event	**Frequency** N=17 (%)
Drought	1 (5.9)
Flood	1 (5.9)
Hurricane	2 (11.8)
Monsoon	1 (5.9)
Land loss	2 (11.8)
Land change	1 (5.9)
Water scarcity	5 (29.4)
Climate change	2 (11.8)
Earthquake	2 (11.8)

Table 3. *Reported non-climate-driven drivers for migrations by study participants (n=57)*

Non-climate-driven event	**Frequency** N=57 (%)
Work	34 (59.6)
Health	9 (15.8)
Unification	27 (47.4)
Politics	8 (14.0)
Security	25 (43.9)
Conflict	7 (12.3)
Education	20 (35.1)
Poverty	20 (35.1)
Hunger	10 (17.4)
LGBTQ issue	1 (1.8)
IPV issue	1 (1.8)
Gender issue	1 (1.8)
Other reason	7 (12.3)

Abbreviations: LGBTQ= Lesbian, Gay, Trans, Questioning; IPV= Interpersonal Violence

Table 4. *Reported Infectious Illnesses in Study Population*

	Total cases of illness n=28 (%)
Dengue	3 (10.7)
Hookworm	5 (17.9)
Chikungunya	9 (32.1)
Amoeba	2 (7.1)
Malaria	1 (3.6)
Typhoid	2 (7.1)
Giardia	1 (3.6)
Other Illness	5 (17.9)
	28

Table 5. *Multivariable analysis of the association between climate-driven migration and associated covariates*

Participant characteristics		Crude OR (95% CI)	Adjusted OR (95% CI)
Food Insecurity			
	No	1 (ref)	1 (ref)
	Yes	6.8 (1.3, 34.9)	6.3 (1.1, 35.5)
Region of Origin			
	No	1 (ref)	1 (ref)
	Yes	0.7 (0.2, 2.6)	0.4 (0.1, 2.1)
Occupation			
	No	1 (ref)	1 (ref)
	Yes	4.7 (0.8, 27.0)	5.7 (0.7, 43.8)
Gender			
	Woman	1 (ref)	1 (ref)
	Men	.3 (0.04, 2.8)	.3 (0.02, 3.6)
Age			1.0 (0.9, 1.0)
	Old	1 (ref)	-
	Mid	4.7 (0.9, 24.3)	-
	Young	0.4 (0.04, 3.2)	-

Abbreviations: OR=odds ratio; CI-confidence interval

Table 6. *Results of clinical laboratory testing*

Lab Result	Hemoglobin N=39	Trypanosoma Cruzi Ab IgG N=40	Ova + Parasite N=33
Abnormal	1 (2.6)	2 (5.0)	3 (9.1)
Normal	38 (97.4)	38 (95.0)	30 (90.9)

Appendix 1: Atlanta-area Migrant Communities and Climate Change Initial Survey

Atlanta-area Migrant Communities and Climate Change Initial Survey

Responses to this survey will not go into any of your clinic records. Your answers to these questions will not be published individually, but will be reported in aggregate form (for example, we might report the percentage of people who gave a particular answer to a question).

What language do you prefer for this interview? (This question may already have been answered during the consent process, but if not, the team member will ask it here).

_____

<u>Demographics and Reasons for Moving:</u>

1. **What is your age? _____**

2. **What is your gender identity (check one)?**
   - Female
   - Male
   - Nonbinary
   - Other (write in): _____

3. **What languages do you speak?**

   _____

4. **Where were you born (country/region)?**

   _____

5. **What countries did you live in before moving to the U.S.?**

_____

6. **How much time (years or months) did you spend in each country?**

_____

7. **When did you come to the U.S.? (Check one)**
   - Less than 5 years ago
   - 5-10 years ago
   - 11-15 years ago
   - more than 15 years ago

8. **What were the reasons you decided to move to the U.S.? (Check all that apply):** Some reasons may be about the country or countries where you lived. Others could be the reasons you came to the U.S.

- To find work
- Health reasons
- Joining family
- Religion
- Politics
- Violence/Safety concerns
- War/conflict
- Education
- Drought
- Regular flooding
- Hurricane
- Earthquake
- Monsoons
- Poverty
- Hunger
- Loss of land/home/farm/ crops or livestock
- Gender-related issues
- Discrimination: LGBTQ, racial, or other?
- interpersonal violence
- Land changes (such as deforestation)
- Food security
- Water scarcity
- Climate change
- Other weather events
- Other Reasons (Write In): _____

_____

9. **Before you came to the U.S., did you notice changes to the weather, climate or land from year to year in any of the places you lived?**
    - Yes
    - No

    If yes, did these changes have a negative effect on your life or the lives of others?
    - Yes
    - No

In the US:

10. **Now I have a few questions about your ["your main residence."] Is this place where you live a house, apartment, or other?**
    - Apartment
    - House
    - Condo
    - I am staying with others
    - "doubled up"
    - in a hotel
    - in a car
    - living outside on the street
    - living in an abandoned building
    - I have housing but I am worried about losing it in the future

    10a. Do you [or your spouse or partner] own this [type of residence (house, apartment)], rent it, or other?

    - Own or buying
    - Rent
    - Live here for free
    - Don't know

11. **How many people live with you (including anyone that has lived there for at least 2 months)?**

    _____

12. **Do you have problems with any of the following at your house? (Check all that apply**):

    - mold

- bug or small animal (rat/mouse) infestation
- water damage
- water leaks
- no heat
- no air conditioning
- no smoke detectors
- lead paint
- none of the above

13. I'm going to read you several statements that people have made about their food situation. For these statements, please tell me whether the statement was <u>often</u> true, <u>sometimes</u> true, or <u>never</u> true for (*you/your household*) in the last 12 months OR since you arrived in the US (if less than 12 months)—that is, since last (*name of current month*).

13a. The first statement is, "The food that (I/we) bought just didn't last, and (I/we) didn't have money to get more." Was that <u>often</u>, <u>sometimes</u>, or <u>never</u> true for (you/your household) in the last 12 months OR since you arrived in the US?

- Often true
- Sometimes true
- Never true
- DK or Refused

13b. In the last 12 months since last (*name of current month*) OR since you arrived in the US,, did (*you/you or other adults in your household*) ever cut the size of your meals or skip meals because there wasn't enough money for food?

- Yes
- No (Skip 13c)
- DK (Skip 13c)

13c. [IF YES ABOVE, ASK] How often did this happen—almost every month, some months but not every month, or in only 1 or 2 months?

- Almost every month
- Some months but not every month
- Only 1 or 2 months
- DK

14. Now, I'm going to read these statements again. For these statements, please tell me whether the statement was <u>often</u> true, <u>sometimes</u> true, or <u>never</u> true for (*you/your household*) before you moved to the US.

14a. The first statement is, "The food that (I/we) bought just didn't last, and (*I/we*) didn't have money to get more." Was that <u>often</u>, <u>sometimes</u>, or <u>never</u> true for (*you/your household)* before you arrived in the US?

- Often true
- Sometimes true
- Never true
- DK or Refused

14b. Before you arrived in the US, did (you/you or other adults in your household) ever cut the size of your meals or skip meals because there wasn't enough money for food?

- Yes
- No (Skip 14c)
- DK (Skip 14c)

14c. [IF YES ABOVE, ASK] How often did this happen—almost every month, some months but not every month, or in only 1 or 2 months?

- Almost every month
- Some months but not every month
- Only 1 or 2 months
- DK

15. In the last 12 months (or since you arrived in the US), did you have trouble paying your utility (gas, electricity, water) bills or did the electric, gas, or water company threaten to shut off your services?

- Yes
- No

16. In the last 12 months (or since you arrived in the US), have you had to leave your home, even for a day, because of storms, flooding, fire, or other natural disasters?

- Yes
- No

17. Do you take any medication every day?

- Yes
- No

16a. IF YES: Have you ever run out of your daily medication before you could get more?

- Yes
- No
- Not sure

18. Do you know how to find out about emergency alerts (boil water advisories, air quality alerts, severe weather warnings) in your area?
- Yes
- No

19. Does your household have a plan to protect yourself in the event of a disaster or emergency? This might include how to contact your family members or how to leave your home.
- Yes
- No

20. We are interested in how people are getting along financially these days. The next questions are about income you receive. [*This information will not be reported to anyone and will not affect your care at the clinic*]. Did you do any work for pay in the last twelve months?
- Yes
- No
- DK
- No answer

21. What was your household income over the past 12 months (or since you arrived in the US)?

$ _____

22. How many individuals does that income support?

_____

23. How do you assess the material status of your family? *Pick the most appropriate statement*
- We can easily satisfy our needs
- We can somewhat satisfy our needs
- We can hardly satisfy our needs (make ends meet)

24. What is your highest educational level attained?

_____

25. Do you currently have a job?

- Yes
- No

24a. If YES: What is your job(s)?

_____

26. Have you ever been diagnosed with any of the following infections?

- Dengue
- Zika
- Hookworm
- Chagas
- Leishmaniasis
- Leprosy
- Ascaris
- Whipworm
- Amoeba
- Giardia
- Chikungunya
- Malaria
- Typhoid fever
- Cysticercosis
- Other?

25a. IF YES, were you treated or are you currently in treatment?

- Yes
- No
- Not sure

<u>Before coming to the US:</u>

27. Before you moved to the US, what type of area(s) did you live in (check all that apply)?

- Urban
- Semi-urban / outskirts
- Rural

28. What kind of housing did you live in (check all that apply)?

- Apartment
- Hut
- House

- Shared space / house
- No secure housing

29. What kind of flooring did you have in your housing (check all that apply)?

- Natural floor
  - Earth/Sand
  - Dung
- Rudimentary floor
  - Wood Planks
  - Palm/bamboo
- Finished floor
  - Parquet or polished wood
  - Vinyl or asphalt strips
  - Ceramic tiles
  - Cement
  - Carpet
- Other

30. Would you be willing to share with us which region of the country you came from (where you spent the majority of your time)?

---

31. Can you describe the natural environment where you lived (check all that apply)?

- Near a body of water
- Mountainous
- A lot of mosquitos or other biting insects
- Desert
- Other

32. Was there mining in your area?

a. Yes
b. No
c. Not sure

33. What kind of work did you do prior to coming to the US?

_____

34. Did you have livestock or animals around the home?

- Yes
- No

35. What was the main source of drinking-water for members of your household?

- Piped water
  - Piped into dwelling

        - Piped to yard/plot
        - Piped to neighbor
        - Public tap/standpipe
    - Tube well or borehole
    - Dug well
        - Protected well
        - Unprotected well
    - Water from spring
        - Protected spring
        - Unprotected spring
    - Rainwater
    - Tanker truck
    - Cart with small tank
    - Surface water (river/dam/ lake/pond/stream/canal/ irrigation channel)
    - Bottled water
    - Other

36. Where was that water source located?

- In own dwelling
- In own yard/plot
- Elsewhere

37. What kind of toilet facility did members of your household usually use?

- Flush or pour flush toilet
    - Flush to piped sewer system
    - Flush to septic tank
    - Flush to pit latrine
    - Flush to somewhere else
    - Flush, don't know where
- Pit latrine ventilated
    - Improved pit latrine
    - Pit latrine with slab
    - Pit latrine without slab/open pit
- Composting toilet
- Bucket toilet
- Hanging toilet/hanging latrine
- No facility/bush/field

38. How did your household usually dispose of garbage?

- Collected by formal service provider
- Collected by informal service provider
- Disposed of in designated waste disposal area
- Disposed of within household yard or plot
- Buried or burned
- Disposed of elsewhere

- Don’t know

Thank you so much for your time. . . . if you are interested