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Socioeconomic Inequality, Climate Strain, and International Migration from Rural Mexico

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SOCIOECONOMIC INEQUALITY, CLIMATE STRAIN, AND INTERNATIONAL MIGRATION FROM RURAL MEXICO

by

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Socioeconomic Inequality, Climate Strain, and International Migration from Rural Mexico

Thesis directed by Professor Lori Hunter

Climate change is challenging rural livelihoods across the globe and migration is one potential adaptation strategy. However, migration is a difficult endeavor that requires substantial social and financial resources. This suggests that the use of migration as adaptation to climate change is likely a stratified process. In this way, climate change has the potential to reinforce existing inequalities and trap resource poor households in place. Mexico provides the ideal case study to investigate the intersection of climate, migration, and inequality given the strong history of international migration, vulnerability to climate impacts, and high levels of income inequality. Using multilevel discrete-time event-history methods, this study examines the association between climate strain and international migration across rural contexts characterized by low, average, and high socioeconomic marginalization between 1986-2013. This period encompasses the height and decline of Mexico-US migration, as well as large changes to the Mexican economy and agricultural sector which negatively impacted many rural households. Results suggest that precipitation deficits in prior corn growing seasons increase the likelihood of migration from households in average socioeconomic settings, while hot spells increase the probability of migration from households in highly marginalized contexts. Households that sent migrants were more likely to report agricultural employment compared to non-migrants in both settings. Finally, migrant households in the average marginalization group were more likely to own property, while social capital was predictive of migration in high marginalization contexts as migrant households were more likely to have familial ties to US migrants.

ACKNOWLEDGMENTS

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INTRODUCTION

Climate change disproportionately burdens poor nations and poor people and is reshaping rural livelihoods across the globe (Yamin, Rahman, and Huq 2005). Migration is one strategy that households may use in response to climate strain, but migration is costly and requires significant social and financial capital. Therefore, climate change has the potential to exacerbate existing inequalities as those who can relocate from challenging environments may do so, effectively "trapping" the poorest of the poor in place. Given that inequality is a primary focus of sociology, a sociological lens is useful for research at the intersection of climate, migration, and inequality. In fact, in a recent review of literature on the environmental dimensions of human migration, Hunter and colleagues called on sociologists to ensure that the discipline "not be left behind" since sociology has much to contribute both theoretically and empirically to climate-migration scholarship (Hunter, Luna, and Norton 2015, 392).

Extant migration research suggests that middle-income populations are most likely to become migrants given that they have both the motivation and the means to seek opportunities elsewhere (Massey, Goldring, and Durand 1994), and this finding is also observed in previous climate-migration research from settings as varied as Bangladesh and Mali (Etzold et al. 2016; Findley 1994). Findings at the national-scale also illustrate that both internal and international migration was more common in response to warmer temperatures for those in middle-income countries compared to lower-income countries (Cattaneo and Peri 2016).

Mexico, the focus of this paper, provides an ideal case study for the examination of climate, migration, and inequality for several reasons. First, Mexico has a long history of international migration to the United States (Massey and Sana 2003). Second, Mexico is highly vulnerable to climate impacts and global climate models project more temperature extremes and rainfall shortages for much of the country (Christensen et al. 2013; Collins et al. 2013). In addition, the economic restructuring and agricultural reforms that began in the 1980s have hurt many rural Mexican livelihoods, as farmers have lost considerable access to credit, price supports, and technical assistance from the government (Appendini 2001). As such, migration may help rural households adapt to these economic and climatic challenges. However, climate change may further limit access to international migration opportunities for marginalized groups, leaving those unable to relocate left to endure the negative impacts of climate change. A better understanding of inequality in climate-related migration from Mexico is also necessary given that the country has the second highest income inequality among OECD (i.e. Organization for Economic Cooperation and Development) nations (OECD 2016).

Using demographic data from the Mexican Migration Project (MMP161), climate records from IPUMS-Terra (Kugler et al. 2015; MPC 2013), and marginalization indices from Cortes and Vargas (2011), I build on existing research by exploring differences in international migration across rural settings that vary in their scale of socioeconomic marginalization. This paper takes a sociological perspective to advance the broader literature on climate-migration by considering how these existing inequalities interact with exogenous shocks such as precipitation deficits and increased temperatures to restrict international migration as a coping strategy to particular households, in particular places, with the adequate and accessible capital to send a migrant during challenging times. This work is important as migration as adaptation to climate strain, an important coping strategy for rural livelihoods, may not be an option for the most vulnerable populations.

BACKGROUND

Rural Livelihoods and Climate Vulnerability

In most rural settings, the household is the most basic unit where decisions are made. A household is often described as a group of individuals bound by social and economic interdependencies (Ellis 2000). In order to survive and prosper, rural households pursue livelihood strategies (e.g., herding, farming, off-farm employment) according to the assets that they have most available. According to the livelihoods approach (discussed below) all rural households hold some form of wealth which may fall into five broad categories that include natural, physical, social, human, and financial capital. In this way, households may draw on any number of these assets to withstand economic or environmental challenges to their livelihoods. However, the amount of household capital and the availability of livelihood strategies are shaped by many macro-level social, political, and economic forces.

Between the 1960s and 1970s rural Mexicans were relatively well supported by state programs that focused on improving the livelihoods of rural smallholders. Perhaps the best example is that of the Mexican Food System (i.e. Sistem Alimentario Mexicano) which provided price guarantees for agriculture, access to credit, and extension advice to rural farmers as the state worked to boost production and self-sufficiency (Austin and Esteva 1987). However, the debt crisis in 1982 led to the Mexican government abandoning the program and focusing on neoliberal policies in the process of overhauling the Mexican economy. For rural smallholders, this meant that the national budget for agriculture was reduced significantly across the 1980s and the previous price supports guaranteed to farmers were revoked (Ochoa and Lorey 1994). Instead, the state, and the agricultural bank BANRURAL focused efforts on meeting the needs of farms that were deemed “economically viable” in the global marketplace, which excluded most rural smallholders (Myhre 1998). In this way, rural farmers lost access to crop insurance programs, government credits, subsidized inputs, and technical assistance in the agricultural reforms forwarded by the administration of President Salinas in the early 1990s (Appendini 2001).

Rural livelihoods were further challenged by economic restructuring as Mexico entered the North American Free Trade Agreement (NAFTA) with Canada and the United States in 1994. This agreement reduced the price of white corn grown in Mexico as it competes with prices set by producers of yellow corn in the US (Nadal 1999). Between 2000 and 2006, President Fox began to confront mounting frustration in rural Mexico with the Law for Rural Sustainable Development. The law was aimed at providing greater certainty for farmers, increasing competitiveness in production chains, and developing regional markets through commercialization. However, the benefits from increased funding to the Ministry of Agriculture and the focus on commercialization went to the large-scale producers of corn, not rural smallholders (Appendini 2014). Nonetheless, due to the social and cultural significance of corn in Mexico, many rural farmers have sought to overcome the low prices by doubling down and intensifying production (Groenewald and Van den Berg 2012). Corn production was also indirectly encouraged through the program PROCAMPO which provided payments to farmers based on the size of land under cultivation (Appendini 2005).

In addition to the challenges faced by rural smallholders as a result of state policies and economic restructuring, livelihoods are also strained by climatic impacts such as drought and high temperatures.

Historically, Mexico has experienced relatively stable rainfall and temperature patterns, but contemporary climate change is altering these trends (IPCC 2013). For example, between

1960 and 2003, Mexico experienced a 0.6 degree Celsius increase in mean annual temperature, with 1.1-3.0 degree increases expected by 2060 (McSweeney, New, and Lizcano 2008). These changes have exacerbated existing climate vulnerabilities in Mexico, especially in rural areas where agricultural production provides as much as two-thirds of household income (de Janvry and Sadoulet 2001). Farming is central to rural livelihoods more broadly, with 78 percent of households engaging in farming to some degree (Wiggins et al. 2002). Agricultural production is often small-scale, with households lacking technology, such as irrigation, to mitigate climate strain such as rainfall deficits (Carr, Lopez, Bilsborrow 2009; Endfield 2007). Dependence on rainfed agriculture is widespread, as estimates suggest that less than 25 percent of cropped land is irrigated (World Bank 2009).

This reliance on rainfed agriculture is problematic in the context of climate change, as documented by the impacts of past climate challenges (Boyd and Ibarraran 2009; Eakin 2005; Koziell and Saunders 2001), with 80 to 90 percent of crop losses between 1980 and 2000 connected to weather-related disasters (Appendini and Liverman 1994; Saldana-Zorrilla and Sandberg 2009). Corn, the primary staple within Mexico (Eakin 2000), is extremely sensitive to high temperatures during development (Schoper, Lambert, and Vasilas 1987). Therefore, temperature extremes have negative impacts on production and profit (Mueller, Gray, Kosec 2014). Evidence also demonstrates that rainfall patterns have changed such that annual farming cycles are less reliable, with the rainy season beginning later than usual. Farmers have increasingly struggled to complete the annual agricultural cycle and harvest before the start of the cold season (Schmidt-Verkerk 2010). This unpredictable climate and reduction in crop yields provides more reasons for rural Mexicans to emigrate in search of alternative, diverse livelihood strategies (Alscher 2010; Feng and Oppenheimer 2012).

Migration as a Livelihood Strategy

Research considering the environmental dimensions of human migration largely began in response to alarmist claims of "environmental refugees," which predicted 50 to 200 million people being displaced by climate change by 2050 (Myers 2002). Subsequent scholarship from social scientists has documented how these projections were far too high as environmental factors influence migration on a continuum, from slow-onset stresses to rapid-onset natural disasters (Hugo 1996). Additionally, social science has demonstrated that environmental factors interact with numerous micro- (e.g., age, education), meso- (e.g., social networks), and macro-level (e.g., population structure, historical climate conditions) phenomenon to shape migration (see Black et al. 2011).

Given the complexity of these interactions across spatial and temporal scales, findings often vary between research settings and as related to the environmental measures under study. For example, in Guatemala, land tenure is one factor that appears to keep people in place, as the lack of available land and insecure land tenure serve as key drivers in the decision to migrate (Lopez-Carr 2012). Other research indicates the importance of household wealth within migration decision-making. Research on Mali's severe drought in the 1980s demonstrates that poor households were limited to short-distance migration for shorter time-periods (Findley 1994). Further, in Bangladesh, the poorest households are not able to use migration as adaptation to challenging environmental conditions, despite it being a common coping strategy for seasonal flooding (Gray and Mueller 2012).

Inequalities in Migration

The examples above also serve to illustrate how migration can provide a pathway for some households to mitigate climate stressors, while others may not have the resources to send a migrant as a livelihood strategy. Such inequalities occur at multiple scales, including between households, regions and even on a global scale. In fact, some scholars argue that international migration itself is a “visible reflection of global inequalities” (Faist 2016, 324). Considering the socioeconomic dimensions of climate-migration is vital as previous research documents that climate strain is most predictive of migration among middle-income households (Etzold et al. 2016) and from middle-income countries (Cattaneo and Peri 2016).

History suggests that the most vulnerable populations struggle to migrate in the face of climate strain. For example, during the extreme 1930s drought in the Great Plains of North America, commonly referred to as the “Dust Bowl,” the landless poor were disproportionately burdened (McLeman et al. 2008). Moreover, such households often could not migrate and, thus, were left entrenched in poverty in Dust Bowl states. A similar dynamic appears in contemporary Bangladesh where household capital, including social networks, shape strategies used to cope with rainfall variability. Migration is most often used as a strategy for relatively middle-class households since those better off can adapt *in situ* (e.g., liquidating assets, diversifying crops), while the poorest of households remain trapped with little ability to afford migration as a livelihood option (Etzold et al. 2016). Finally, in Mexico, Schmidt (2016) illustrates how access to migration networks is not uniformly distributed. While some cultural contexts encourage migration (Kandel and Massey 2002), there are also ties that keep people in place. For women, this may be children or obligations to care for elderly parents, all of which limit migration opportunities (Schmidt 2016). As such, Schmidt (2016) argues that those with an already limited ability to migrate due to social or cultural factors could be further cut off from migration networks as a result of climate change.

Using survey data from rural Mexico, the present study builds on this work by examining the climate-migration relationship across rural settings that differ in their level of socioeconomic marginalization.

Mexico-U.S. Migration

Mexico provides an ideal setting in which to study inequalities in climate-migration given the magnitude and historical tradition of Mexico-U.S. migration (Massey and Sana 2003). This migration stream dates to the early 1900s, when Mexicans began providing labor to farms and for railroad construction projects (Durand and Arias 2000). Migration increased dramatically following the creation of the Bracero Program in 1942, a labor agreement formed to address shortages on U.S farms during World War II (Calavita 2010), and continued to rise well into the 1990s (Martin and Midgley 2010; Passel and Cohn 2011). The 1986 Immigration Reform and Control Act (IRCA) altered migration stream dynamics with strict penalties for the hiring of undocumented immigrants, in addition to providing increased funding for border protections. Contrary to the IRCA policy goals, undocumented migration continued due to the established migrant networks and labor demand in U.S. destinations (Kandel and Parrado 2005). Instead, it was the circularity of the migration stream that was impacted, as more undocumented migrants settled in the United States due to these enhanced border security measures (Massey and Riosmena 2010).

Today, migration between Mexico and the U.S. is currently the lowest since the 1990s (Gonzalez-Barrera 2015). The Great Recession and the slow economic recovery are often cited for the recent net-negative migration flow, but others have attributed the decrease to demographic changes (i.e., declining fertility) in Mexico as well (Villarreal 2014). Despite these recent trends, Mexico remains the single largest source of immigrants to the United States

(Lopez and Bialik 2017), so a better understanding of all the forces behind this migration stream remains important.

Climate-related International Migration from Mexico

Across the globe, research suggests that internal migration is a more common response to environmental change as compared with international migration (Black et al. 2011; Findlay 2011). That said, international migration appears more of an option in regions with strong international migration networks and traditions, such as Mexico (Bardsley and Hugo 2010; Fussell and Massey 2004). Indeed, prior research finds that climate is more predictive of international migration from rural Mexico, the focus of this study, as opposed to domestic movements (Nawrotzki et al. 2016).

Previous scholarship on climate-related migration from Mexico has illustrated the importance of social and environmental characteristics of sending communities. Between 1995-1999, rainfall deficits were predictive of international migration for only those in dry Mexican states (Nawrotzki, Riosmena, and Hunter 2013). The history of migration in Mexican communities is also relevant as the association between drought and migration was highest for households in communities with strong social networks, as those in non-traditional sending areas exhibited reductions in outmigration following drought between 1987-2005 (Hunter, Murray, and Riosmena 2013). To test the influence of social networks in origin on climate-related migration, Nawrotzki et al. (2015c) examined differences between first and last international migration trips. The first migration trip is integral in developing social ties and capital flows between origin and destination (Massey 1987), with the probability of a later trip increasing substantially following the initial migration (Curran and Rivero-Fuentes 2003). This finding was observed at the household level, as climate measures were more predictive of the first international migration trip (Nawrotzki et al. 2015c).

Recent work continues to demonstrate the importance of contextual characteristics in communities of origin, as Riosmena, Nawrotzki, and Hunter (2018) find that international migration following temperature increases and precipitation declines is restricted to places with low vulnerability. Moreover, increased outmigration following severe precipitation declines between 1995-2010 were observed only for communities with higher migration intensities (i.e. social networks) and lower marginalization levels. The current study builds on the aforementioned work to explore whether the climate-migration relationship differs across socioeconomic contexts, as average to high marginalized areas may be more vulnerable to climate strain.

Most existing research on the climate-migration relationship in Mexico has focused on migration associated with variation in rainfall (Barrios Puente, Perez, and Gitter 2016; Hunter, Murray, and Riosmena 2013; Leyk et al. 2017; Nawrotzki, Riosmena, and Hunter 2013) and temperature (Nawrotzki and DeWaard 2016; Nawrotzki et al. 2015c), using various measures of climate and migration. Studies using census data are limited to climate reference periods, as the data indicates only whether an individual (or household) migrated during the five years prior to the census. Using 1988-1993 as the comparison, Nawrotzki, Riosmena, and Hunter (2013) examine the influence of state-level precipitation deficits on household emigration to the United States between 1994 and 1999, finding that precipitation deficits *increased* migration from historically dry areas during this period. Conversely, Riosmena, Nawrotzki, and Hunter (2018) used six-year climate lags (using finer-scale municipal climate data) preceding the 2000 and 2010 censuses, respectively, demonstrating that outmigration was *reduced* following severe bouts of hot or dry conditions. These conflicting findings may be attributed to differences in the scale of climate measures, as the former utilized state-level predictors, while the latter employed municipal measures. In addition to various scales of climate data, extant research has often employed different specifications of climate strain. While studies using census data have compared precipitation or temperature to a reference period as discussed above, other work has examined migration using alternative measures of climate such as the duration of high temperatures and the number of days with heavy precipitation in prior years (Nawrotzki and DeWaard 2016). Using these measures and survey data between 1986-1999, Nawrotzki and DeWaard (2016) investigate the timing of migration, showing that the risk of migration was highest three years after the climate shock. The present study expands on this understanding by exploring a variety of precipitation and temperature predictors that capture annual strain, as well as exposure during important months in the agricultural calendar (e.g., corn growing season).

The current study asks three research questions to examine climate-migration across low, average, and high levels of socioeconomic marginalization:

1. Does the climate-migration relationship differ *across* socioeconomic contexts in rural Mexico?
2. Do heat and drought alter the likelihood that households in marginalized settings will send a migrant to the United States?
3. Are agricultural households more likely to send a migrant following climate strain as compared to those not working in agriculture?

THEORETICAL FRAMEWORKS

This study draws on three theories to create the conceptual framework that grounds subsequent analyses.

New Economics of Labor Migration

The foundation of the conceptual framework is the New Economics of Labor Migration (NELM) theory. Since Mexican livelihood strategies are often generated through household processes rather than at the individual level (Cohen 2004; Massey et al. 1993), the NELM framework has proven useful for integrating environmental factors into migration decision-making in this setting. According to NELM, households may choose to send a migrant elsewhere to maximize household income and minimize risks associated with crop failures and market fluctuations (Massey et al. 1993; Stark and Bloom 1985). In this way, households diversify income sources, an important strategy for rural dwellers that have little access to formal insurance markets (Lucas and Stark 1985). Remittances from a migrant can serve as an ex ante risk mitigation strategy as households may send a migrant to help mitigate potential losses from future crop failure or climate strain. Alternatively, remittances may take the form of an ex post means of coping following challenging environmental exposures (Gray 2010; Halliday 2006).

Although useful, the NELM framework is limited in some ways specifically related to this project. For example, NELM does not adequately account for how contextual characteristics may facilitate or limit households' ability to send migrants. For instance, as noted above, sending a migrant as a livelihood strategy may be concentrated among households in middle-income settings that are both sensitive to the climate and economic stressors but also have the available resources to draw on. Further, NELM does not adequately account for other *in situ* adaptation strategies that may differ in availability according to socioeconomic conditions in sending communities. To better integrate these processes, this study also draws on the Sustainable Livelihoods Framework (SLF).

Sustainable Livelihoods Framework

Migration is but one of a variety of livelihood options that households may employ in response to exogenous shocks, and the SLF is used here to better situate migration within this portfolio of livelihood options at the household scale (de Sherbinin et al. 2008; Ellis 2000; Scoones 1998). For example, households may pursue *in situ* coping strategies such as reducing household expenditures or switching to alternative crops. These strategies are shaped by the capital that households have available to them, which include natural capital (e.g., natural resources, local environmental characteristics), social capital (e.g., networks, group memberships, access to institutions), human capital (e.g., health, formal/informal education), physical capital (e.g., land, tools, infrastructure), and financial capital (e.g., cash savings, remittances, credit). Of course, households differ in levels of capital, and therefore, their options to adapt *in situ*. Livelihood strategies are also connected to local contexts. For example, in some settings, such as poor regions with little history of migration, relocation may be a coping strategy of last resort, as households instead pursue other livelihood diversification opportunities. Additionally, households may attempt to adapt *in situ* first, and send a migrant only if these available strategies are unsuccessful. That said, in contexts with limited *in situ* adaptation options or strong migration networks, migration may be the preferred coping mechanism.

Vulnerability and Adaptive Capacity

While households may respond to climate strain as a collective unit, their need and ability to adapt is connected to their local context, as well as individual factors. Therefore, this study draws on the work of McLeman and Smit (2006) and later McLeman (2014) to highlight how vulnerability to climate strain is a function of many social, economic, and geographic factors that vary by setting and by social group.

Vulnerability is often described as the potential for harm or loss due to an event. McLeman and Smit expand this traditional definition and posit that vulnerability is a function of the *likelihood* of an exposure occurring and the *capacity* of communities to cope with the event (McLeman and Smit 2006, 34). McLeman (2014) builds on this to suggest that vulnerability is shaped by exposure, adaptive capacity, and *sensitivity*. This is an important addition as populations may be more or less exposed to challenging climates based on geographic location, which in turn alters their sensitivity to the given exposure. For example, historically dry places are likely exposed to drought more frequently than those in humid regions. As such, the same exposure may be felt much differently across populations due to the underlying sensitivity of a given place. Whereas households in dry areas may develop strategies to deal with occasional drought, those in humid regions may not (McLeman 2014, 155). McLeman (2014) illustrates these connections with the equation, $M=f(E, S, (A-M))$, as migration in response to challenging climates is a function of the exposure, sensitivity, and adaptation options outside of migration (A-M). Thus, the equation acknowledges that migration is just one way in which households may adapt to climate impacts. Further, it follows that the likelihood of migration is increased with heightened exposure and sensitivity, and is reduced by the adaptive capacity of households or communities. But, McLeman (2014) notes, adaptation strategies are inherently limited by the meso- and macro-level factors of place such as institutions, gender norms, social network strength, and financial markets.

Taken together, the NELM framework situates the migration decision within households and the SLF expands this understanding to incorporate various forms of capital used within livelihood decision-making. Finally, McLeman (2014) demonstrates that vulnerability to climate strain differs by exposure, sensitivity, and the available adaptation strategies outside of migration. Using insights from all three frameworks, the current study examines the relationship between climate strain and migration across rural Mexican contexts that vary in their level of marginalization.

DATA, MEASURES, AND ANALYTIC STRATEGY

Data

This study draws on three data sources. First, demographic information, including migration histories, are provided by the Mexican Migration Project (MMP), a collaborative effort between Princeton University and the University of Guadalajara. The MMP offers detailed information from a sample of Mexican communities, with three to five communities surveyed annually since 1982, now totaling 161 across the years 1982-2016. An ethnosurvey approach is used that combines ethnographic fieldwork and survey sampling design to collect qualitative and quantitative data for the randomly sampled households. The full MMP161 dataset used here contains information representing 27,113 households and 169,945 individuals.

Climate data reflecting rainfall and temperature patterns are generated from data provided by IPUMS-Terra at the Minnesota Population Center. Originally raster data compiled by the University of East Anglia’s Climate Research Unit, these data have been pre-processed into a municipal level dataset by IPUMS-Terra (Harris et al. 2014; Kugler et al. 2015; MPC 2013). In this study, the climate measures (details below) originate from monthly precipitation and temperature maximum measures, 1961-2013. For each month, municipality precipitation was recorded in millimeters and temperature was recorded as the average daily high temperature.

Taken together, the precipitation and temperature data allow for the creation of climate predictors that capture precipitation deficits and temperature extremes, both of which are detrimental to agricultural production and rural livelihoods more broadly.

Finally, this study makes use of Cortes and Vargas (2011) marginalization indices. These data represent a standardized measure of socioeconomic marginalization for all Mexican municipalities. The scores reflect the percentage of municipal population that 1) are illiterate; 2) lack primary schooling; 3) live in dwellings without sewage or dedicated in-home toilet; 4) without electricity; 5) without piped water; 6) with dirt floors; 7) are overcrowded; 8) living in localities with fewer than 5,000 inhabitants; 9) making less than twice the minimum wage. Using these time-varying standardized measures, I computed an average marginalization score for each municipality in the MMP and households were subsequently categorized as residing in communities with low, average, or high socioeconomic marginalization during the study window. The tertile approach is used here in order to compare the likelihood of migration from households located in contexts at the socioeconomic extremes (i.e. low and high marginalization), to those in more average settings. Figure 1 displays the geographical location of municipalities by marginalization category.

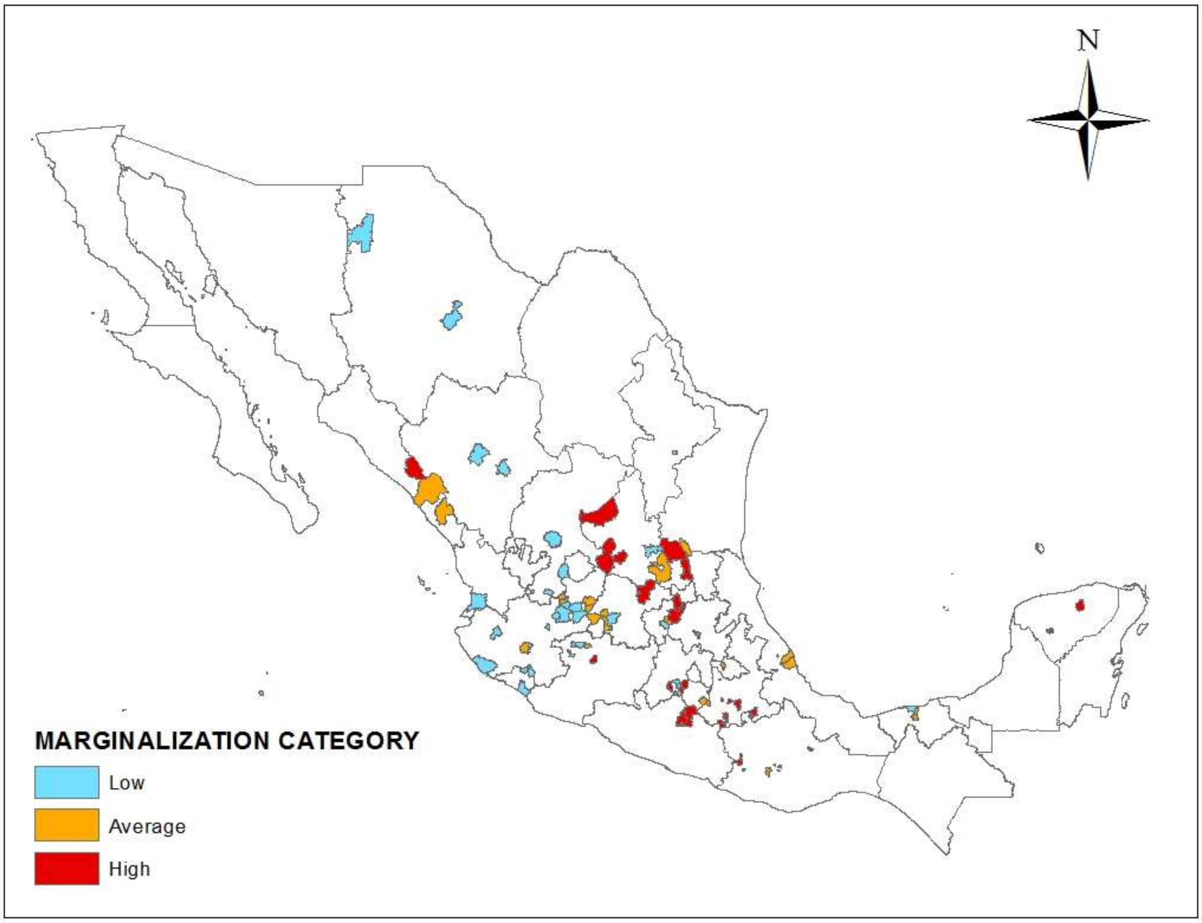

Figure 1. Geographical location of MMP municipalities by marginalization category

Dependent Variables

The MMP defines migration as a move for work, job search, or to establish new residence, and therefore excludes short-term visits to family or friends. The present study focuses on the timing of the household's first international migration to avoid the confounding nature of repeat migrations within a household, as the likelihood of migration is increased drastically following the first trip (Curran and Rivero-Fuentes 2003). Therefore, the outcome is simply represented as a binary indicator (1=first international migration).

Figure 2 displays the baseline hazard of first international migration between 1986-2013 as estimated with the MMP data used in this study. Although MMP data are not representative of the nation as a whole, the hazard does track with larger Mexico-US migration trends with the peak in 2000 and lessening rates between 2001-2013.

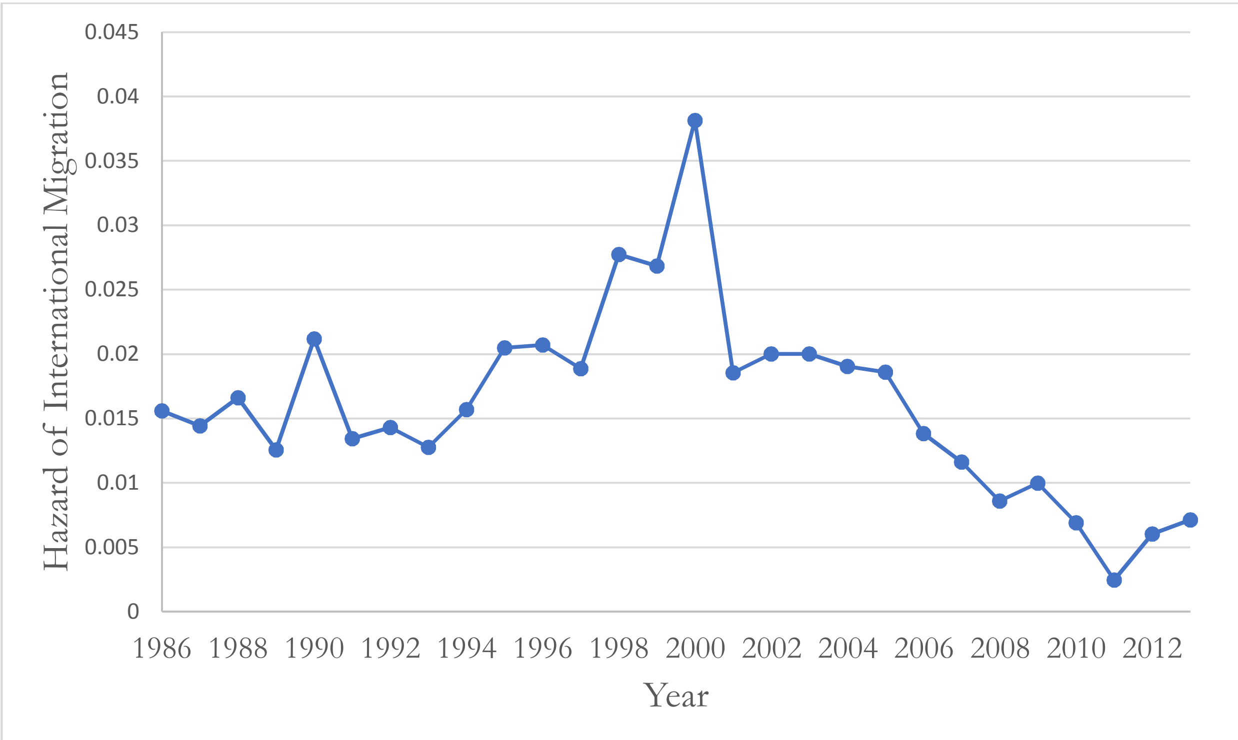

Figure 2. Baseline hazard of international migration, MMP data 1986-2013

Climate Predictor Variables

Measures of climate strain reflect the number of months in a given period that were below (precipitation) or above (temperature) one-standard deviation from the 30-year monthly normal (1961-1990), as climate science has determined the 30-year normal to be a useful benchmark in identifying climate variability. Based on prior work which suggests a two- (Hunter, Murray, and Riosmena 2013) to three-year lag (Nawrotzki and DeWaard 2016) between climate shocks and migration from Mexico, this study combines the number of months in the prior three years that exceed the one standard deviation threshold.

Table 1. Description of the predictors and controls in the current study

Variable Name	Description
Climate Predictors	
Precip. Predictors	
Drought months, annual	# below 1 SD of 30-year monthly precipitation normal
Drought months, highest rainfall	# below 1 SD of 30-year monthly precipitation normal for July & August
Drought months, rainy season	# below 1 SD of 30-year monthly precipitation normal for June-Sept.
Drought months, corn growing season	# below 1 SD of 30-year monthly precipitation normal for June-Oct.
Temp. Predictors	
Heat months, annual	# above 1 SD of the 30-year monthly high temperature normal
Heat months, warmest months	# above 1 SD of the 30-year monthly high temperature normal for April-Sept.
Heat months, corn growing season	# above 1 SD of the 30-year monthly high temperature normal for June-Oct.
Household Controls	
Human Capital	
Years of Education	Total years of education of the household head
Children in the household	Number of children under the age of 18 present in the household
Occupation: Blue collar	Indicator of whether the household head was employed in a blue collar occupation
Agricultural Employment	Indicator of whether the household head was employed in agriculture during study window
Social Capital	
Female	Indicates whether the household head was a female
Married	Marital status of the household head
Physical Capital	
Land ownership	Binary indicator of land ownership in the household-year
Property ownership	Binary indicator of property ownership in the household-year
Financial Capital	
Business owner	Binary indicator of business ownership in the household-year
Community & Municipality Controls	
Social Capital	
Migration prevalence	Annual international migration prevalence in the community
Natural Capital	
30-year Precipitation Normal	30-year (1961-1990) monthly precipitation normal at the municipal level
30-year High Temperature Normal	30-year (1961-1990) monthly high temperature normal at the municipal level
Koppen Climate: Dry	Dry Koppen category includes municipalities classified as very-dry, dry, and semi-dry
Koppen Climate: Warm	Warm Koppen category includes municipalities classified as very-warm, warm, and semi-warm
Degree of Marginalization	
Marginalization score	Average of Cortes & Vargas (2011) marginalization indices for each municipality, 1990-2010

Table Notes:

HH and Community Data from Mexican Migration Project (MMP161), available from http://mmp.opr.princeton.edu

Climate Data from: IPUMS-Terra, available from https://www.terrapop.org

Marginalization data from Cortés, F. and Vargas, D., 2011. Marginación en México a través del tiempo: a propósito del índice de Conapo. Estudios Sociológicos, pp.361-387.

Koppen climate classifications from Köppen, W. P., & Geiger, R. (1923). Klimakarte der erde. Gotha: Justus Perthes.

Four different specifications are tested to assess exposure to climate strain beyond just annual measures in order to focus in on periods important to the agricultural calendar. Thus, I investigate precipitation deficits during the highest rainfall months of July and August (Barrios Puente, Perez, and Gitter 2016), the rainy season of June-September (Fuentes-Franco et al. 2015), and the corn growing season of June-October (Sacks et al. 2010). For temperature, the predictors measure temperature extremes in the warmest months of April-September (Marty 1992) and the corn growing season of June-October (Sacks et al. 2010), as compared to the historical normal for each month. These alternative measures are relevant both theoretically and empirically as climate strain is primarily associated with migration through an agricultural pathway (Nawrotzki and Bakhtsiyarava 2017).

Controls

To best isolate the relationship between climate and migration, a variety of known migration correlates are also included in the models. For example, education is an important predictor of migration, especially within the Mexico-US migration stream. Mexico-U.S. migrants tend to have lower levels of education, although demand in labor sectors that employ those with lower education has declined since the recession (Villarreal 2014). Other controls for human capital include the number of children under the age of 18 in the household, as young adults may migrate in order to send remittance money back home. Further, measures of employment were included, one indicating whether a household head engaged in blue-collar (e.g., manufacturing, construction) or agricultural work during the study window as these households may be most sensitive to climate strain. For social capital, this study accounts for the self-reported gender of the household head and whether the household head was married in a given year. Together, these represent important measures of social capital as marriage expands the social network available to a household, and women have social and cultural obligations that may limit migration opportunities (Schmidt 2016).

Analytic Strategy

A multi-level, discrete time, event history approach is used to model migration while allowing for time-varying predictors. As such, the data are organized with each row representing a year at which a household was "at risk" of sending a migrant ("household year"). Households begin to be represented within the database when they are formed (i.e., year of marriage) and the household head is at least 15 years of age. Households then leave the risk set following either an international migration, when the head turns 65 years of age, or at their survey year (since this is the final year for which information about that specific household is known). The database representing each year of household migration "risk" begins at 1986 due to the changes to the migration system in Mexico following IRCA. Also excluded are urban areas given the focus on the agricultural pathway between climate and migration. Rural areas are defined as those with less than 15,000 people to capture areas heavily dependent on primary sector activities, and in line with recent work from Riosmena, Nawrotzki, and Hunter (2018).

To investigate the association between climate strain and migration across socioeconomic contexts, Cortes and Vargas (2011) indices (i.e., time-varying standardized measures of marginalization described above) were used to create an average value for municipal marginalization across the study period. Using this average marginalization score, municipalities were characterized using a tertile approach to signify low, average, or high socioeconomic marginalization during the study period.

Discrete-time survival methods are appropriate to account for interval-censoring given the fact that households are clustered in communities which share the same survey and censor year (Rabe-Hesketh and Skrondal 2008, 747). Further, MMP data provides the year of migration, not the month or day, thereby precluding the use of models with more specificity (i.e., continuous-time) than migration within an annual period. Multilevel models are used to account for the clustered nature of the data, with households nested in municipalities. Multilevel models are particularly suited for the study of climate-migration as data are often at various scales, with migration measured at the individual or household level, while climate data are available at the community, municipality, or state-level (Nawrotzki and DeWaard 2018).

In all, the odds of international migration (*m*) for any member in household i, in municipality *j,* during period k, (m_{ijk}), is modeled using a logit link function such that $\sigma_{ijk} = log_e(\frac{m_{ijk}}{1-m_{ijk}})$.

$$\sigma_{ijk} = \beta_0 + \beta_1(Precip_{jk}) + \beta_2(Temp_{jk}) + \sum_n^y \beta_n(x_z) + \mu_j + \nu_k$$

In the equation above, β_0 represents the intercept, or baseline probability of a household sending a migrant to the United States. The coefficients β_1 and β_2 reflect the expected difference in the odds of international migration associated with a 1 unit increase in the number of drought and heat months in the 3 years prior, respectively. $\sum_n^y \beta_n(x_z)$ indicates a suite of household and municipal measures that may influence the probability of migration, with the expected difference indicated by the generic β_n coefficient. These include controls for human, social, physical, financial, and natural capital that operate at the household and municipal levels indicated by the generic x_z term. The multilevel model features random-intercepts for municipalities, μ_j, to account for households' clustering within municipalities as well as year fixed effects, ν_k, to control for time-varying factors not captured in the model.

RESULTS

Table 2 begins to explore the descriptive differences in household capital, as well as the social and environmental characteristics of communities across the three marginalization categories. Focusing first on the climate predictors during the corn growing season, households in the low marginalization group experienced an average of 2.45 drought months, compared to 2.29 and 2.31 in average and high marginalization settings, respectively. Households in the high marginalization setting experienced an average of almost four heat months during prior corn growing seasons, while the mean was 3.67 in low marginalization, and 3.82 for average communities.

Measures of human capital also differed across groups. For example, 76 percent of households in regions of average marginalization were engaged in blue-collar work, compared to 71 percent for those in the low-marginalization setting. Agricultural employment was also more common in the average and high categories, at 58 and 48 percent of households, respectively. Social capital at the household level was more consistent across settings, as marriage was nearly universal, with the means in each group above 90 percent. However, physical capital was higher in households from the average and high marginalization settings, with 25 percent of households owning land, compared to just 13 percent in the low marginalization group. Further, 64 percent of households owned property in the average and high categories.

Table 2. Descriptive statistics by socioeconomic marginalization category

	Low Marg.		Average Marg.		High Marg.	
	Mean	SD	Mean	SD	Mean	SD
Climate Predictors						
Precip. Predictors						
Drought months, annual	3.42	2.04	3.42	1.88	3.68	2.28
Drought months, highest rainfall	1.11	0.97	0.83	0.86	0.90	1.07
Drought months, rainy season	2.08	1.35	1.83	1.24	1.85	1.58
Drought months, corn growing season	2.45	1.48	2.29	1.37	2.31	1.65
Temp. Predictors						
Heat months, annual	9.35	4.97	9.70	4.32	9.21	5.51
Heat months, warmest months	4.98	3.04	5.07	2.88	4.85	3.50
Heat months, corn growing season	3.67	2.46	3.82	2.19	3.99	2.88
Household Level						
Human Capital						
Years of Education	6.38	4.41	5.69	4.40	6.03	4.37
Children in the household	2.33	1.90	2.45	2.00	2.39	1.83
Occupation: Blue collar	0.71	0.45	0.76	0.43	0.72	0.45
Agricultural Employment	0.40	0.49	0.53	0.50	0.48	0.50
Social Capital						
Female	0.16	0.36	0.13	0.34	0.16	0.37
Married	0.91	0.28	0.92	0.27	0.91	0.29
Physical Capital						
Land ownership	0.13	0.34	0.25	0.43	0.25	0.43
Property ownership	0.58	0.49	0.64	0.48	0.64	0.48
Financial Capital						
Business owner	0.03	0.18	0.04	0.20	0.04	0.21
Community & Municipality Level						
Social Capital						
Migration prevalence	15.77	11.13	9.40	8.66	14.01	11.32
Natural Capital						
30-year Precipitation Normal	889.87	368.70	1019.33	399.19	934.72	336.35
30-year Max Temperature Normal	26.54	2.49	26.99	2.41	28.82	2.50
Dry Climate (Koppen)	0.21	0.40	0.12	0.32	0.17	0.37
Warm Climate (Koppen)	0.21	0.41	0.50	0.50	0.70	0.46
Marginalization Measures						
Marginalization score	-0.94	0.24	-0.34	0.14	0.30	0.33
% illiterate	9.91	3.28	14.45	3.68	20.33	4.63
% without primary school	37.57	7.99	43.79	7.32	51.27	6.22
% without sewage/toilet	11.91	5.35	21.43	7.32	37.89	9.99
% without electricity	4.94	3.41	6.13	3.62	11.87	10.95
% without piped water	10.96	7.18	14.36	12.71	24.19	14.00
% overcrowded dwellings	45.87	6.49	53.44	7.39	60.43	6.94
% with dirt floors	10.72	7.08	21.14	9.35	28.97	12.36
% less than 5,000 inhabitants	53.17	27.12	72.68	23.24	90.66	13.89
% making < twice min. wage	56.26	7.14	69.48	5.49	76.16	6.78

Table Notes:
Climate predictors indicate the number of months exceeding 1 SD threshold in prior three years
Descriptives generated based on the censor year (year of migration or survey year)
HH and Community Data from Mexican Migration Project (MMP161), available from http://mmp.opr.princeton.edu
Climate Data from: IPUMS-Terra, available from https://www.terrapop.org
Marginalization data from Cortés, F. and Vargas, D., 2011. Marginación en México a través del tiempo: a propósito del índice de Conapo. Estudios Sociológicos, pp.361-387.
Koppen climate classifications from Köppen, W. P., & Geiger, R. (1923). Klimakarte der erde. Gotha: Justus Perthes.

Community and municipal level measures reported in Table 2 also highlight distinct social and environmental contexts as well. In the more advantaged group, the mean migration prevalence was 15.77 and just 9.40 in average marginalization communities. Additionally, the 30-year temperature normal for communities in the highest marginalization group was 28.82 degrees Celsius, almost 2 degrees higher than those in more advantaged communities. The Koppen climate classifications also suggest that the high marginalization communities were in warm areas of Mexico as 70 percent of communities are in municipalities characterized by historically warm climates. Conversely, communities in the average marginalization setting are predominately humid. The 30-year precipitation normal suggests that the average annual precipitation in these municipalities was 1019.33 mm/year, and only 12 percent of communities reside in municipalities characterized as historically dry.

There were also large disparities in the socioeconomic measures that make up the marginalization indices, which supports the idea that these communities reside in distinct socioeconomic contexts. To highlight a few, households in the high marginalization group reside in communities with 76.16 percent of the population making less than two times the minimum wage, compared to 56.26 percent in the low marginalization group. Additionally, municipalities in the high marginalization group have an average illiterate population of 20.33 percent, whereas it is only 9.91 percent in communities in the low marginalization setting. Finally, the mean percentage of those without piped water in highly marginalized municipalities was 24.19, compared to 14.36 in the average-, and 10.96 percent in the low-marginalization setting.

To build on this descriptive foundation, Table 3 reports the odds of migration across each setting from separate models using the four climate measure specifications. High temperatures and the warm historical climate conditions may explain why heat was consistently predictive of international migration for households in the high marginalization group. Moreover, each additional heat month increased the odds of migration by 3 percent when using the annual measure, and 6 percent when focusing in on periods important to agriculture such as the corn growing season. On the other hand, drought was predictive of outmigration for households in the average marginalization setting, which may also reflect sensitivity due to historical conditions as these communities were largely situated in humid regions of Mexico. Indeed, each additional drought month during the rainy season increased migration by 8 percent, with 12 percent increases following drought months during the corn growing season. Interestingly, heat months reduced the likelihood of household migration in this setting. Finally, only the annual drought measure, which was marginally significant (OR=1.04, $p<0.1$), was predictive of migration for households in the low marginalization group.

Table 3. Odds of U.S. migration between 1986-2013 using various climate predictor specifications

	Low Marginalization		Average Marginalization		High Marginalization	
	Drought	Heat	Drought	Heat	Drought	Heat
Climate Predictors						
A. Annual measure	1.04*	1.00	1.03	0.98*	1.00	1.03***
B. Highest rain/heat months	1.01	1.03	0.95	0.95**	1.00	1.06***
C. Rainy season/warmest months	1.00	1.03	1.08**	0.94***	1.00	1.06***
D. Corn growing season	1.00	1.03	1.12***	0.91***	0.99	1.06***

Table Notes:
*p<0.1 **p<0.05 ***p<0.01
Coefficients reflect odds ratios while controlling for HH and municipal characteristics from Table 1
Predictors A: Annual drought and heat months
Predictors B: Highest rainfall months (July/August) & warmest months (April-September)
Predictors C: Rainy season (June-September) & warmest months (April-September)
Predictors D: Drought/heat shock during corn growing season (June-October)

Table 4 reports the full models using climate strain during the corn growing season to show the relative influence of the controls across each context. Consistent with past research, education was negatively selective across all three settings, with each additional year of education reducing the odds of migration by 4 percent in low and average settings, and 2 percent for households in the high marginalization group. Children in the household was predictive of migration for those in the low and high marginalization settings, while blue-collar employment was predictive of migration regardless of socioeconomic context. Further, agricultural employment increased the odds of migration for those in the high marginalization group, but not for households in the average context. These differences were explored by interacting the climate measures with agricultural employment, discussed below. Property ownership proved important for households in the average group, whereas business ownership and financial capital increased the likelihood of migration for households in the high marginalization context. Finally, migration prevalence in communities of origin increased the odds of migration across all settings, highlighting the importance of social networks.

Table 4. Odds of U.S. migration from random intercept logistic regression models using corn growing season predictors

	Low Marg.	Average Marg.	High Marg.
Climate Predictors			
Drought months, corn growing season	1.00	1.12 ***	0.99
	(0.03)	(0.04)	(0.03)
Heat months, corn growing season	1.03	0.91 ***	1.06 ***
	(0.02)	(0.03)	(0.02)
Household Level			
Human Capital			
Years of Education	0.96 ***	0.96 ***	0.98 ***
	(0.01)	(0.01)	(0.01)
Children in the household	1.06 ***	1.02	1.06 ***
	(0.02)	(0.02)	(0.02)
Occupation: Blue collar	1.30 ***	1.71 ***	1.48 ***
	(0.13)	(0.18)	(0.16)
Agricultural Employment	1.15 *	0.75 ***	1.23 **
	(0.10)	(0.07)	(0.11)
Social Capital			
Female	1.13	0.87	1.10
	(0.16)	(0.13)	(0.15)
Married	0.97	0.69 **	0.80
	(0.15)	(0.10)	(0.12)
Physical Capital			
Land ownership	1.04	1.14	0.89
	(0.11)	(0.10)	(0.08)
Property ownership	1.17 **	1.19 **	1.01
	(0.09)	(0.09)	(0.08)
Financial Capital			
Business owner	1.13	1.24	1.61 ***
	(0.22)	(0.19)	(0.27)
Community & Municipality Level			
Social Capital			
Migration prevalence	1.04 ***	1.05 ***	1.04 ***
	(0.00)	(0.01)	(0.01)
Natural Capital			
Koppen Classification: Dry	1.42 **	1.06	1.64 **
	(0.22)	(0.29)	(0.40)
Koppen Classification: Warm	1.14	1.16	0.76
	(0.18)	(0.24)	(0.17)
Intercept	0.01 ***	0.02 ***	0.14 **
	(0.00)	(0.02)	(0.16)
Model Characteristics			
Year Fixed Effects	Yes	Yes	Yes
N(HH-years)	40,189	39,155	39,569
N(Municipalities)	32	25	29
Log-Likelihood	-4018.48	-4087.27	-3999.81
Variance (Municipality)	0.09	0.19	0.22
BIC	8492.83	8608.13	8454.80

Table Notes:
*p<0.1 **p<0.05 ***p<0.01
SE in parentheses
Climate predictors indicate the number of months exceeding 1 SD threshold in prior three years
Coefficients reflect odds ratios

Among rural households, those employed directly in agriculture are likely most sensitive to climate strain during prior growing seasons. Therefore, I interact agricultural employment and climate strain during the corn growing season. Table 5 and Figure 3 illustrate that drought during the corn growing season increases the odds of migration for households in the average marginalization setting. This relationship is depicted on the left panel of Figure 3, as agricultural households have a lower probability of migration initially, but with increased climate strain they become more likely to send a migrant.

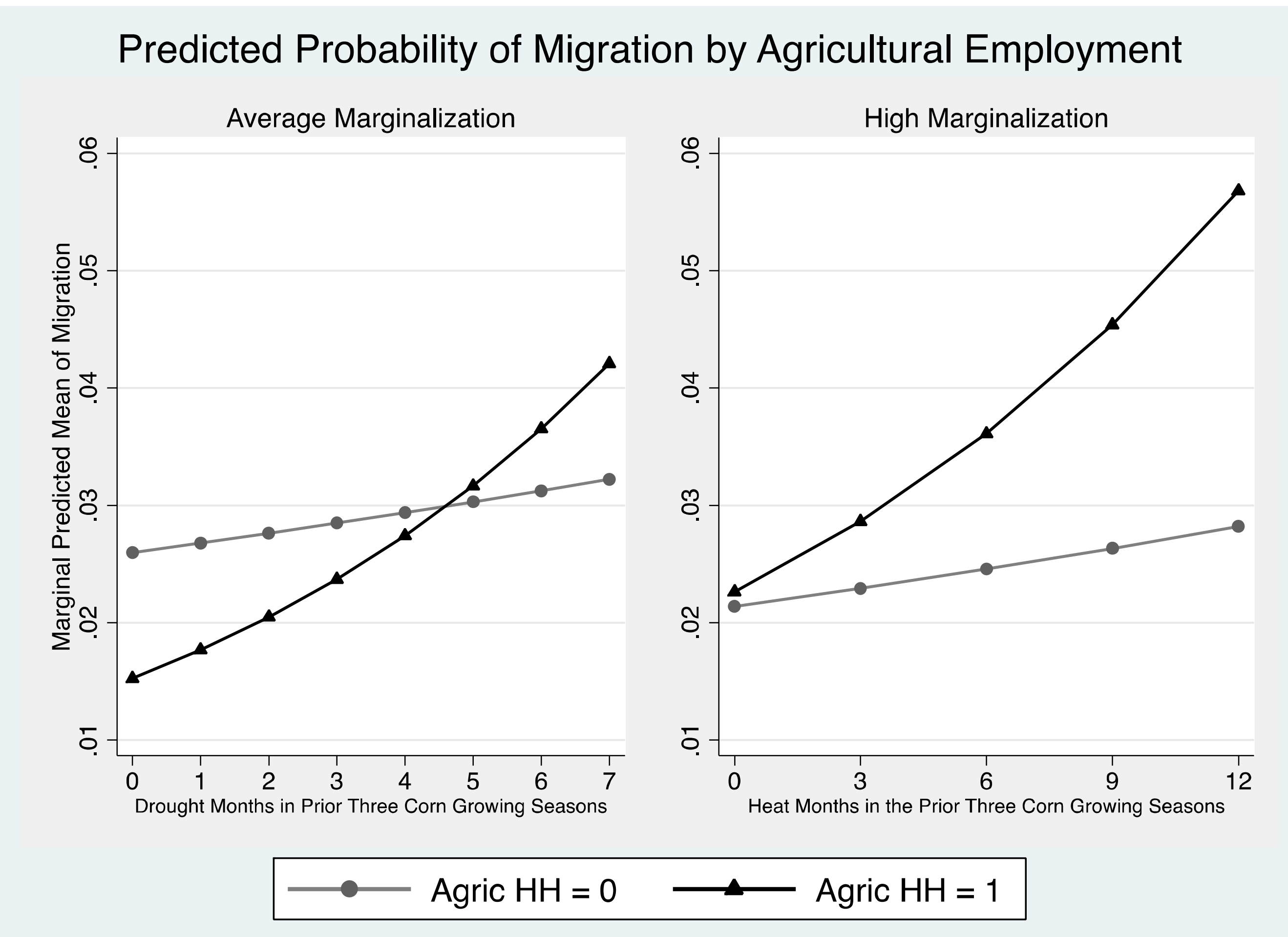

Figure 3. Predicted probability of household migration based on agricultural employment and climate strain. The left side shows the interaction between drought and agricultural employment for households in the average marginalization category. The right side illustrates the interaction between heat months and agricultural employment for households in the high marginalization setting.

Table 5. Main effect and interaction between climate strain and household agricultural employment

	Drought			Heat		
	Low Marg.	Average Marg.	High Marg.	Low Marg.	Average Marg.	High Marg.
Climate Predictor						
Climate, corn growing season	0.98	1.03	0.99	1.02	0.89 ***	1.02
	(0.04)	(0.05)	(0.04)	(0.03)	(0.03)	(0.03)
Household Agricultural Employment						
Agricultural employment	1.15 *	0.73 ***	1.23 **	1.15 *	0.74 ***	1.26 **
	(0.10)	(0.07)	(0.11)	(0.10)	(0.07)	(0.12)
Interaction						
Climate x Agric. Employment	1.04	1.13 **	1.01	1.02	1.05 *	1.06 **
	(0.05)	(0.06)	(0.04)	(0.03)	(0.03)	(0.03)

Table Notes:
*p<0.1 **p<0.05 ***p<0.01
SE in parentheses
Climate predictors indicate the number of months exceeding 1 SD threshold in prior three years
Coefficients reflect odds ratios and all models include HH and municipal controls reported in Table 4

The interaction between heat months and agricultural employment is also statistically significant for those in the high marginalization context, and marginally significant for those in the average setting, which may reflect the fact that corn is sensitive to heat extremes (Keleman, Hellin, and Bellon 2009). The right side of Figure 3 illustrates how households employed in agriculture have a higher likelihood of migration which only increases with additional heat months during the growing season in the high marginalization areas.

To further investigate the characteristics of households that migrate following climate strain within each context, I interact the corn growing season climate predictors with measures of household social and physical capital. Results from these interactions are displayed graphically below, and reported in the appendix. To assess differences in migration probability according to household social capital, a social network measure was created to reflect the number of immediate family members of the household head that had US migration experience prior to the formation of the current household (i.e., marriage of the household head). Figure 4 displays the predicted probability of household migration across heat months for those in the high marginalization setting. Indeed, the probability of migration is increased with additional heat months for households with familial migrant networks, whereas the likelihood of migration did not increase for households lacking family ties to previous migrants.

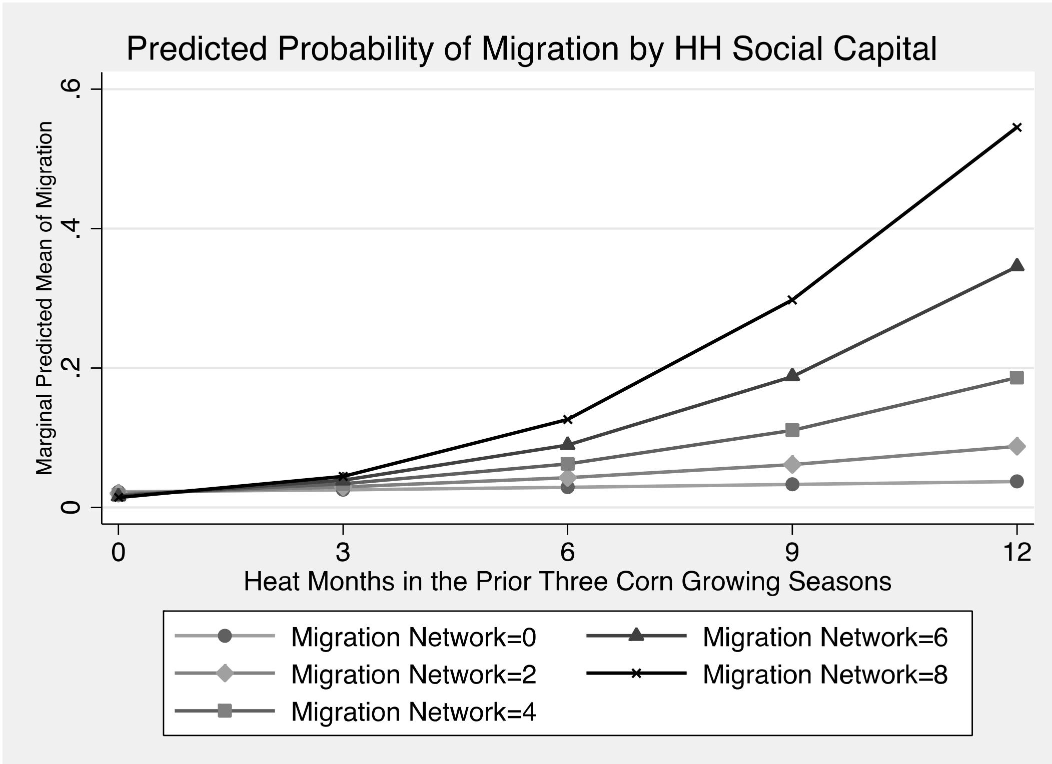

Figure 4. Predicted probability of household migration based on household migration network and heat months for those in high marginalized settings. Migration network represents the number of immediate family members of the household head with prior migration experience.

Given that property ownership was predictive of migration in the full models, interactions between climate strain and property ownership were also tested to show the influence of physical capital on the likelihood of migration within each context. Figure 5 displays the results for the statistically significant interaction for households in the average marginalization setting, with results from all groups available in the appendix. The solid black line indicates that households that own property are more likely to send a migrant with each additional drought month during the corn growing season compared to those that do not. Taken together, these results suggest that it is households with social and physical capital that are more likely to send a migrant in the face of mounting climate strain.

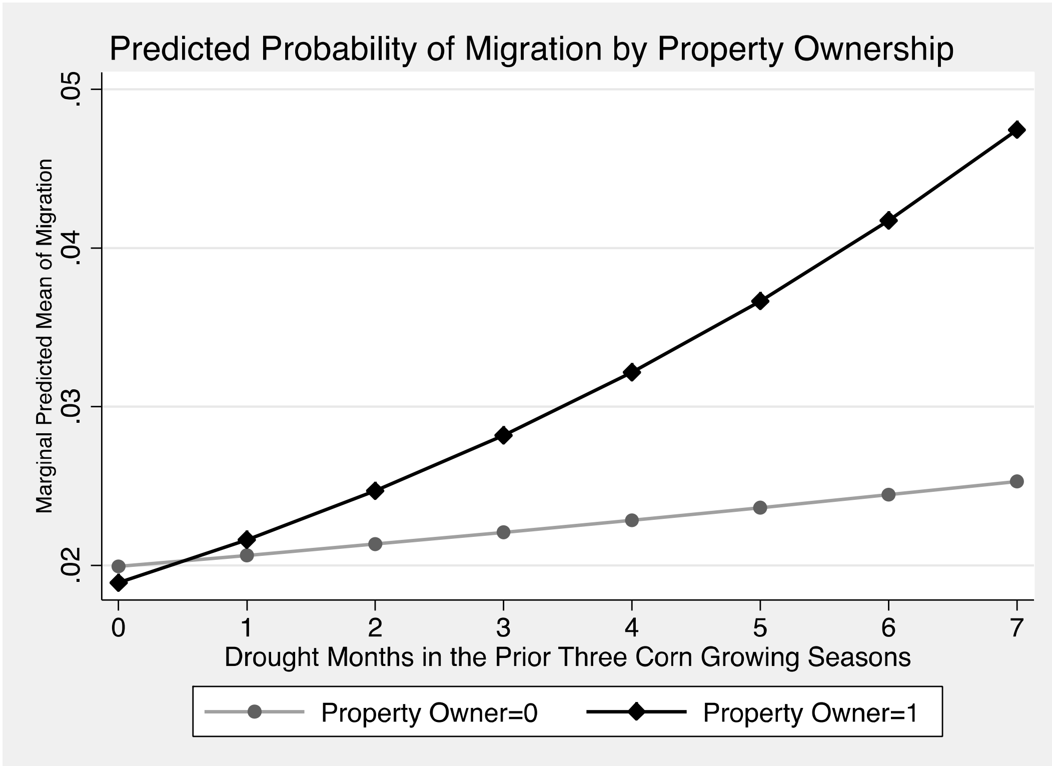

Figure 5. Predicted probability of household migration based on drought months and property ownership for those in average marginalized settings.

DISCUSSION

The first research question asked whether the climate-migration relationship may differ across socioeconomic contexts in rural Mexico, as the descriptive table highlighted several social, environmental, and economic differences between communities in each group. Additionally, the second research question investigated whether the likelihood of migration from marginalized contexts would be altered following climatic strain. Results from this study begin to answer both of these questions as precipitation deficits and heat extremes during prior years did not provide a universal push to migrate for households across all settings. While drought during the rainy months and prior corn growing seasons increased the likelihood of household migration for those in average marginalization contexts, it was heat that was predictive of international migration for those in the high marginalization setting. These differences likely reflect the underlying sensitivity to these forms of climate strain in each community, as outlined by the McLeman (2014) framework above. Moreover, households in the average-marginalization setting largely resided in communities that were characterized by humid historical climate conditions. Therefore, households may be especially sensitive to drought in prior years as 88 percent of communities in this category were in humid regions of the country.

Alternatively, for households in the high marginalization setting, heat extremes were consistently associated with the increased likelihood of migration. Heat may be particularly challenging in this context as Table 2 suggested that the average high temperature was already 2 degrees Celsius above those in the low and average marginalization groups. Further, 70 percent of these communities were in historically warm regions of the country. As such, additional heat months may exceed a threshold whereby livelihoods are challenged and crops are damaged. One recent study from Mexico suggests that extreme heat reduces local employment and demand for wage work and non-farm labor in rural Mexico, which may provide reasons for households to send a migrant to the United States (Jessoe, Manning, and Taylor 2018). This would be in line with NELM theory as households may send a migrant abroad as a livelihood strategy to cope with heat shocks and the contractions in the labor market. Interestingly, in this study, heat months were negatively associated with migration from households in the average marginalization communities which is more in line with findings from Riosmena, Nawrotzki, and Hunter (2018). Nonetheless, it is unclear the degree to which heat extremes may trap households in this context given that they may instead seek domestic off-farm employment, and results from the interaction between heat and agricultural employment (Table 5) illustrates a marginally significant relationship such that additional heat months heighten the likelihood that agricultural households send a migrant abroad. Finally, the likelihood of migration does not appear to be altered for households located in more advantaged settings (i.e., low marginalization) following prior climate conditions, as 7 of the 8 climate measures used in this study were not statistically significant. Taken together, the climate-migration relationship does differ across socioeconomic settings, and the likelihood of migration is altered by prior climate strain for households in the average-high marginalization categories.

This study takes place during a period of massive economic restructuring which negatively impacted rural livelihoods and small-scale agriculture in Mexico. Therefore, question three asked whether climate strain in prior years, especially the corn growing season, would increase the likelihood of migration for households that reported agricultural employment. Through interactions between household agricultural employment and climate strain in prior corn growing seasons, this study finds that agricultural households are more likely to send a migrant as climate pressures mount. For those in the average marginalization setting, agricultural households initially had a lower probability of migration, but with increasing months of drought they become more likely to send a migrant abroad. Further, heat months in prior corn growing seasons were predictive of outmigration for those in the high marginalization setting, and marginally significant for those in the average context. These results likely illustrate the fact that agricultural households are most sensitive to challenging climates.

The current project also explored the influence of household capital within each marginalization group. As the sustainable livelihood framework suggests, rural households draw on various forms of capital to cope with challenging conditions and to mitigate future losses from market failures or climate strain. Therefore, this study tested the relationship between climate strain and household social and physical capital. Results demonstrate that it is households with available social and physical capital that are more likely to send a migrant in the face of challenging conditions. For households in the average marginalization setting, property owners were more likely to send a migrant following drought in the corn growing season, compared to non-property owners. Among households experiencing heat extremes in high marginalization places, social capital distinguished migrants from non-migrants. Moreover, the probability of migration increased with each additional heat month for households that had familial migrant networks, whereas the likelihood of migration was near zero for those without migrants in their extended family. This is consistent with past research in Mexico, as drought increased outmigration for those in sending areas characterized by strong migration networks (Hunter, Murray, Riosmena 2013).

This study is just the first step at understanding climate-migration dynamics across socioeconomic contexts, so it is not without limitations. First, prospective data would be preferred to retrospective migration data, as the MMP does not capture full households that move together. Therefore, these results likely provide an underestimate of the relationship between climate strain and migration in Mexico. Additionally, this study represents households' first international migration between 1986 and 2013. This specification results in the left truncation of households that sent their first migrant before 1986. This analytic decision was made due to the profound changes to the Mexico-US migration stream following IRCA and to investigate more contemporary migration which happened in conjunction with economic restructuring and agricultural reforms. Nonetheless, this requires that interpretation of these results should only pertain to households in rural Mexico that had not sent a migrant prior to 1986. Further, this project cannot speak to the migration dynamics of subsequent moves within a household, as the current study examines only the first migration trip. This specification was made to limit the confounding influence of within-household social network dynamics on subsequent moves as the likelihood of future migration is increased following the first trip (Curran and Rivero-Fuentes 2003). This provides another avenue for future research as these networks could exacerbate existing inequalities.

Future research should also explore the differential timing of migration across socioeconomic contexts. This study employs climate measures that capture strain in the prior three years based on previous research (Nawrotzki and DeWaard 2016), but it could be that households in low-SES areas take even longer to employ migration as a response to challenging environmental conditions. Finally, and perhaps most importantly, subsequent research should consider internal migration across socioeconomic groups in Mexico, as this might provide a less costly and risky adaptation strategy for marginalized populations. In this way, there are likely important differences in destination choice (i.e., internal vs. international) across sending contexts.

CONCLUSION

This paper investigates the role of socioeconomic marginalization and inequality in climate-related migration. I explore this topic by linking demographic and migration data from the Mexican Migration Project (MMP161) to climate data available from the IPUMS-Terra group at the Minnesota Population Center (Kugler et al. 2015; MPC 2013). Using multilevel discrete-time event-history methods this study models the first international migration from rural households in Mexico between 1986-2013. The analysis presented here contributes to the literature in four primary ways.

First, this project extends the existing work in Mexico which documents the importance of social and environmental contextual factors (Hunter, Murray, and Riosmena 2013; Nawrotzki, Riosmena, and Hunter 2013) by examining socioeconomic inequality across place. This is an important contribution as Mexico has the second highest income inequality of any OECD nation (OECD 2016). I draw on marginalization indices from Cortes and Vargas (2011) to classify rural areas as low, average, or high marginalization. This complements the qualitative work from Schmidt (2016) that highlighted inequality in access to migration networks in Mexico and the recent work from Riosmena, Nawrotzki, and Hunter (2018) which finds that outmigration is more common from areas with low vulnerability. Findings from the current study show that climate strain is associated with migration from areas characterized by average-high marginalization. Moreover, by stratifying models according to levels of socioeconomic marginalization, this study is able to illustrate that the climate-migration association does not provide a universal "push" to migrate, as the likelihood of household migration differs across socioeconomic contexts.

Second, this study contributes to the literature on climate-related migration in Mexico by investigating more contemporary migration as much of the existing work analyzed migration during the height of Mexican migration to the US (for review see Simon 2018). While several studies analyze migration after 2000 (Barrios Puente, Perez, and Gitter 2016; Leyk et al. 2017; Riosmena, Nawrotzki, Hunter 2018), they largely use census data which has certain limitations. For example, while census data features larger geographical coverage, they are limited in that the exact timing of migration is unknown. As such, using more recent migration data from the MMP serves as an important addition to existing studies that used MMP data for the years 1986-1999 (Nawrotzki et al. 2015a, b, c; Nawrotzki and DeWaard 2016; Nawrotzki et al. 2016).

The third contribution from this work involves the use of measures that capture climate strain during important agricultural periods throughout the year. In addition to the annual measures of exposure, three predictors were created in consideration of important months to agricultural production. Evidence suggests that migration is a response to climate impacts to agriculture (Nawrotzki and Bakhtsiyarava 2017), and findings highlight the fact that households that report employment in agricultural work were more likely to migrate in response to precipitation deficits and temperature extremes during the corn growing season.

Fourth, this study also contributes to the climate-migration literature in Mexico by incorporating multiple theories to investigate social inequality in the use of migration as adaptation to climate strain. While studies in Mexico often draw on the NELM and/or the sustainable livelihoods framework, I build on these two theories with the addition of McLeman (2014) as places are likely differentially vulnerable and sensitive to climate impacts as a result of their socioeconomic and historical climate conditions.

To conclude, this work is further evidence that the impacts of climate change will not be felt equally across groups within a society, as it is often those that are already socially and economically marginalized that are most vulnerable to climate impacts.

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APPENDIX

Table S1. Odds of U.S. migration from random intercept logistic regression models using annual climate measures

	Low Marg.		Average Marg.		High Marg.	
Climate Predictors						
Drought months, annual	1.04	*	1.03		1.00	
	(0.02)		(0.03)		(0.02)	
Heat months, annual	1.00		0.98	*	1.03	***
	(0.01)		(0.01)		(0.01)	
Household Level						
Human Capital						
Years of Education	0.95	***	0.96	***	0.98	**
	(0.01)		(0.01)		(0.01)	
Children in the household	1.06	***	1.02		1.06	***
	(0.02)		(0.02)		(0.02)	
Occupation: Blue collar	1.30	***	1.70	***	1.48	***
	(0.13)		(0.18)		(0.16)	
Agricultural Employment	1.15	*	0.75	***	1.23	**
	(0.10)		(0.07)		(0.11)	
Social Capital						
Female	1.13		0.86		1.10	
	(0.16)		(0.13)		(0.15)	
Married	0.97		0.68	**	0.80	
	(0.15)		(0.10)		(0.12)	
Physical Capital						
Land ownership	1.04		1.14		0.89	
	(0.11)		(0.10)		(0.08)	
Property ownership	1.17	**	1.18	**	1.01	
	(0.09)		(0.09)		(0.08)	
Financial Capital						
Business owner	1.13		1.25		1.61	***
	(0.22)		(0.19)		(0.27)	
Community & Municipality Level						
Social Capital						
Migration prevalence	1.04	***	1.05	***	1.04	***
	(0.00)		(0.01)		(0.01)	
Natural Capital						
Koppen Climate: Dry	1.44	**	1.00		1.62	**
	(0.23)		(0.27)		(0.40)	
Koppen Climate: Warm	1.11		1.08		0.77	
	(0.18)		(0.22)		(0.17)	
Intercept	0.01	***	0.01	***	0.01	***
	(0.00)		(0.00)		(0.00)	
Model Characteristics						
Year Fixed Effects	Yes		Yes		Yes	
N(HH-years)	40,189		39,155		39,569	
N(Municipalities)	32		25		29	
Log-Likelihood	-4017.65		-4094.45		-3999.74	
Variance (Municipality)	0.10		0.18		0.22	
BIC	8491.16		8622.49		8454.67	

Table Notes:

*p<0.1 **p<0.05 ***p<0.01

SE in parentheses

Climate predictors indicate the number of months exceeding 1 SD threshold in prior three years

Coefficients reflect odds ratios

Table S2. Odds of U.S. migration from random intercept logistic regression models using highest rainfall/warmest heat months

	Low Marg.	Average Marg.	High Marg.
Climate Predictors			
Drought months, highest rainfall	1.01	0.95	1.00
	(0.05)	(0.05)	(0.05)
Heat months, warmest months	1.03	0.95 **	1.06 ***
	(0.02)	(0.02)	(0.02)
Household Level			
Human Capital			
Years of Education	0.96 ***	0.96 ***	0.98 **
	(0.01)	(0.01)	(0.01)
Children in the household	1.06 ***	1.02	1.06 ***
	(0.02)	(0.02)	(0.02)
Occupation: Blue collar	1.30 ***	1.70 ***	1.48 ***
	(0.13)	(0.18)	(0.16)
Agricultural Employment	1.15 *	0.75 ***	1.23 **
	(0.10)	(0.07)	(0.11)
Social Capital			
Female	1.13	0.86	1.10
	(0.16)	(0.13)	(0.15)
Married	0.97	0.68 **	0.80
	(0.15)	(0.10)	(0.12)
Physical Capital			
Land ownership	1.04	1.14	0.89
	(0.11)	(0.10)	(0.08)
Property ownership	1.17 **	1.18 **	1.01
	(0.09)	(0.09)	(0.08)
Financial Capital			
Business owner	1.13	1.26 *	1.60 ***
	(0.22)	(0.19)	(0.27)
Community & Municipality Level			
Social Capital			
Migration prevalence	1.03 ***	1.05 ***	1.04 ***
	(0.00)	(0.01)	(0.01)
Natural Capital			
Koppen Climate: Dry	1.41 **	1.05	1.62 **
	(0.22)	(0.27)	(0.39)
Koppen Climate: Warm	1.15	1.11	0.78
	(0.15)	(0.22)	(0.04)
Intercept	0.01 ***	0.01 ***	0.01 ***
	(0.00)	(0.00)	(0.00)
Model Characteristics			
Year Fixed Effects	Yes	Yes	Yes
N(HH-years)	40,189	39,155	39,569
N(Municipalities)	32	25	29
Log-Likelihood	-4018.33	-4093.17	-4000.17
Variance (Municipality)	0.09	0.17	0.21
BIC	8492.52	8619.93	8455.52

Table Notes:
*p<0.1 **p<0.05 ***p<0.01
SE in parentheses
Climate predictors indicate the number of months exceeding 1 SD threshold in prior three years
Coefficients reflect odds ratios

Table S3. Odds of U.S. migration from random intercept logistic regression models using rainy season/warmest months

	Low Marg.	Average Marg.	High Marg.
Climate Predictors			
Drought months, rainy season	1.00	1.08 **	0.99
	(0.03)	(0.04)	(0.03)
Heat months, warmest months	1.03	0.94 ***	1.06 ***
	(0.02)	(0.02)	(0.02)
Household Level			
Human Capital			
Years of Education	0.96 ***	0.96 ***	0.98 **
	(0.01)	(0.01)	(0.01)
Children in the household	1.06 ***	1.02	1.06 ***
	(0.02)	(0.02)	(0.02)
Occupation: Blue collar	1.30 ***	1.70 ***	1.48 ***
	(0.13)	(0.18)	(0.16)
Agricultural Employment	1.15 *	0.75 ***	1.23 **
	(0.10)	(0.07)	(0.11)
Social Capital			
Female	1.13	0.87	1.10
	(0.16)	(0.13)	(0.15)
Married	0.97	0.68 **	0.80
	(0.15)	(0.10)	(0.12)
Physical Capital			
Land ownership	1.04	1.14	0.89
	(0.11)	(0.10)	(0.08)
Property ownership	1.17 **	1.19 **	1.01
	(0.09)	(0.09)	(0.08)
Financial Capital			
Business owner	1.13	1.25	1.60 ***
	(0.22)	(0.19)	(0.27)
Community & Municipality Level			
Social Capital			
Migration prevalence	1.03 ***	1.05 ***	1.04 ***
	(0.00)	(0.01)	(0.01)
Natural Capital			
Koppen Climate: Dry	1.41 **	1.02	1.62 **
	(0.22)	(0.26)	(0.39)
Koppen Climate: Warm	1.16	1.13	0.78
	(0.18)	(0.23)	(0.17)
Intercept	0.01 ***	0.01 ***	0.01 ***
	(0.00)	(0.00)	(0.00)
Model Characteristics			
Year Fixed Effects	Yes	Yes	Yes
N(HH-years)	40,189	39,155	39,569
N(Municipalities)	32	25	29
Log-Likelihood	-4018.37	-4090.71	-4000.15
Variance (Municipality)	0.09	0.17	0.21
BIC	8492.60	8615.00	8455.49

Table Notes:
*p<0.1 **p<0.05 ***p<0.01
SE in parentheses
Climate predictors indicate the number of months exceeding 1 SD threshold in prior three years
Coefficients reflect odds ratios

Table S4. Main effect and interaction between heat months and household migration network

	Low Marg.	Average Marg.	High Marg.
Climate Predictors			
Heat months, corn growing season	1.03	0.92 ***	1.05 **
	(0.02)	(0.03)	(0.02)
Household Social Capital			
HH-social network	1.05	1.04	1.08 *
	(0.03)	(0.04)	(0.04)
Interaction			
Heat months x HH social network	1.00	0.98	1.05 ***
	(0.01)	(0.02)	(0.01)

Table Notes:
*p<0.1 **p<0.05 ***p<0.01
SE in parentheses
Climate predictors indicate the number of months exceeding 1 SD threshold in prior three years
Coefficients reflect odds ratios and all models include HH and municipal controls reported in Table 4
HH-social network measure reflects a count (0-8) of the number of immediate family members of the HH-head with U.S. migration experience prior to the first migration within a household

Table S5. Main effect and interaction between drought months and property ownership

	Low Marg.	Average Marg.	High Marg.
Climate Predictors			
Drought months, corn growing season	1.00	1.04	0.97
	(0.04)	(0.05)	(0.04)
Household Physical Capital			
Property ownership	1.17 **	1.16 **	1.01
	(0.09)	(0.09)	(0.08)
Interaction			
Drought months x Property ownership	1.00	1.11 **	1.04
	(0.05)	(0.06)	(0.05)

Table Notes:
*p<0.1 **p<0.05 ***p<0.01
SE in parentheses
Climate predictors indicate the number of months exceeding 1 SD threshold in prior three years
Coefficients reflect odds ratios and all models include HH and municipal controls reported in Table 4