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Climatic Variability and U.S. Migration from Rural Mexico

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Climatic Variability and U.S. Migration from Rural Mexico

Abstract: In rural areas of many developing countries, natural resource dependency is a day-to-day reality for many rural households. Changes in weather and climate patterns, therefore, hold tremendous potential to impact livelihoods through their interaction with structural factors that affect capital availability. When environmentally-based livelihood options are constrained, migration becomes a significant, adaptive livelihood strategy. We ask: *Is emigration from rural Mexico to the U.S. associated with recent patterns of precipitation, net of other socio-economic factors shaping migration patterns?* Using data from the Mexican Migration Project, U.S. emigration from rural communities is modeled as related to community, household and climate factors. The results suggest that households subjected to drought conditions are far more likely to send a migrant compared to those subjected to wet conditions, but only in communities with strong migration histories. The results have policy implications emphasizing diversification of rural Mexican livelihoods in the face of contemporary climate change. (150 words)

Climatic Variability and U.S. Migration from Rural Mexico

Increasing climatic variability associated with climate change will most likely increase the frequency and severity of natural disasters such as hurricanes (Trenberth et al. 2007) and more prolonged, lower-intensity events such as droughts (Kundzewicz 2007). Both of these phenomena might alter patterns of human migration (e.g. Gutmann and Field 2010; McLeman and Smit 2006), an issue that has increasingly garnered attention among the public as well as policy and academic realms (Hartmann 2010; Renaud et al. 2011) Even so, little peer-reviewed scholarship exists on the specific connection between (longer-term, lower intensity) climatic variability and migration, particularly in the context of Mexico-U.S. migration (for an exception, see Feng et al. 2010).

While most scholars argue that climate change will likely increase mobility within a nation's borders rather than create a wave of international "climate refugees" (e.g., Bardsley and Hugo 2011; Hartmann 2010; Hugo 1996), the association between climatic variability and migration distance has been shown to be contingent on factors such as household socioeconomic status (Gray 2009). Further, whether people move within or across national boundaries as a response to economic and, we argue, climatic shocks/variation is also contingent to the prior establishment of internal or international migrant networks out of a given locale (Lindstrom and Lauster 2001).

Take the case of Mexico - U.S. migration, one of the largest and longest-sustained international flows of people in the world (Massey and Sana 2003) and the main source of both legal and undocumented migration into the U.S. (Hoefler, Rytina and Campbell 2007; Martin and Midgley 2010; Passel and Cohn 2011). Rural areas have historically been an integral part of this

stream and continue to have a large representation (Durand, Massey, and Zenteno 2001; Hamilton and Villarreal 2011; Riosmena and Massey *forthcoming*).¹ In addition, a strong association has been identified between migrant networks and migration in the Mexican setting (Massey and Espinosa 1997; Massey and Riosmena 2010; Palloni et al. 2001), particularly in rural areas (Fussell and Massey 2004; Massey, Goldring, and Durand 1994; Massey and Zenteno 1999). As such, one would expect climatic variability to have an impact on international migration, particularly in drier places with highly-entrenched international migrant networks such as Central-Western Mexico, the historical heartland of U.S.-bound migration (Durand et al. 2001; Durand and Massey 2003). Prior (international) migration experience within the household decreases the uncertainty surrounding and costs associated with subsequent migration, thereby facilitating mobility (e.g., Massey and Espinosa 1997). As such, we anticipate such familiarity with migration should further facilitate movement in the context of climatic variability.

In this paper we test the association between long-term variation in rainfall and U.S.-bound migration from both the historical and other sending regions using data from 66 rural communities surveyed by the Mexican Migration Project (MMP). Although substantial research has examined the social, economic, and policy drivers of Mexican migration to the U.S. (e.g. Angelucci, *forthcoming*; Binational Study on Migration 1998; Cohen 2004; Hanson, Robertson, and Spilimbergo 2002; Hamilton and Villarreal 2011; Jones 1995; Kana'iaupuni 2000; Lindstrom and Lauster 2001; Massey et al. 1987; Massey, Goldring, and Durand 1994; Massey and Espinosa 1997; Massey, Durand, and Malone 2002; Massey and Riosmena 2010), far less is known about the association between climate variability and the likelihood of U.S.-bound migration. An association between migration and environment conditions is logical, particularly

in rural sending areas, due to spatial variation of climate-related livelihood impacts (see Nevins 2007).

Prior studies examining the effects of natural disasters (Saldaña-Zorrilla and Sandberg 2009) and of declining crop yields (Feng, Krueger, and Oppenheimer 2010) on the likelihood of migration have modeled migration at the municipal or state levels. We model these decisions at a finer spatial scale, the household – a particularly relevant unit of analysis (e.g., see rationale in Stark and Bloom 1985; Massey et al. 1994) -- while also considering the role of migrant networks and the prior migration experience of the household in mediating this association.

PREVIOUS RESEARCH

We contribute to the literature on natural resources and rural livelihoods, to the literature viewing migration as an adaptive livelihood strategy, particularly among vulnerable households, and to the New Economics of Labor Migration framework. These three bodies of scholarship are briefly reviewed below, with specific reference to the Mexican setting as available within existing work.

Natural resources and human capital allocation in the context of rural and *ejido* livelihoods

We use the conceptual framework of Rural Livelihoods (IFAD 2010) which has shaped a wide variety of analytical endeavors including exploration of health behaviors (Rugalema 2000), food security (Bank 2005) and household diversification strategies (Yaro 2006). The framework classifies various “capital assets” that shape livelihood options, including human (e.g., labor), financial (e.g., savings), physical (e.g., automobiles), social (e.g., support networks), and natural capital (e.g., wild foods and fuels). The relative availability of various assets is shaped by individual and household actions as well as broader socioeconomic-political structures and

processes (Bebbington 1999). In turn, the availability of different forms of capital shapes livelihood strategies which may include how households allocate human capital across space (e.g., labor migration, see Collinson et al. 2006a, 2006b) or how they make use of natural capital (e.g., making resource-based crafts for market, Pereira, Shackleton and Shackleton 2006). The livelihoods approach has thus proven a valuable tool in highlighting the diversity and dynamism of the choices and activities in which rural households engage to meet household needs (Winters et al. 2002).

Within the Sustainable Livelihoods framework, natural capital holds a prominent position among the diversity of household capitals. Indeed, in rural regions of developing nations, proximate natural resources are often essential in meeting basic living requirements (e.g. Hunter, Twine and Patterson 2007; Nunan 2010) and in Mexico, land and water resources are especially central to rural livelihoods. For instance, using data from four communities, Wiggins et al. (2002) found that 78% of households farmed, predominantly maize and beans.ⁱⁱ Although not the main income source for smallholders (on average, 14% of total household income), agriculture was central to sustenance and to diversification of livelihoods. De Janvry and Sadoulet (2001) also document that rural Mexican livelihoods represent a mixture of farm and off-farm income, with agricultural contributions to household income ranging from 23 to 67% depending on the size of land holdings. Given the importance of natural capital within livelihoods, environmental change has immediate and direct impacts on the health and well-being (Koziell and Saunders 2001) since it shapes vulnerability through impacts on agricultural productivity (Eakin 2005; Feng et al. 2010).

Key to examination of natural capital within Mexico is understanding *ejidos* -- rural communities which collectively possess rights to land and whose resident members (*ejidatarios*)

are entitled to work a plot of their own (Wiggins et al. 2002). *Ejidors*, created through land transfers starting in the 1930s, contain approximately 60% of the rural population (de Janvry and Sadoulet 2001). Though market liberalization reforms during the 1990s allowed *ejidatarios* to attain private individual titles and thus have the capacity to sell their lands, very few have actually sold them (Barnes 2009).

Given the nature of *ejidos*, it is not surprising that their residents are even more dependent on natural capital than the rural households described by Wiggins et al. (2002). In Winters, Davis and Corral's (2002) examination of a nationally representative sample of Mexican *ejido* households, fully 93.7% participated in crop production while agricultural activities as a whole (crops, livestock and agricultural employment) made up over half (55%) of total rural household income.

Recent work suggests that contemporary efforts to provide *ejido* households with a certificate of land ownership are associated with an increase in emigration to the U.S., thereby inferring that more secure access to this form of natural capital provides a foundation from which to engage in the relatively-expensive livelihood diversification strategy of international migration (Valsecchi 2010). As such, our modeling strategy includes land ownership type at the household scale.

Yet other forces beyond the household clearly also shape livelihood strategies. Winters and colleagues (2002:141) note that livelihood decision-making "is conditioned on the context in which the household operates – influenced through natural forces, markets, state activity and societal institutions", which may shape access to water resources (e.g., irrigation systems and the lack thereof). In this way, environmental change acts in concert with political and economic forces to shape livelihood strategies. We describe some of these major forces in the Mexican

context in below, after discussing how households may use migration as an adaptation strategy consistent with the notion of rural livelihood diversification.

Migration as adaptation to rural livelihood vulnerability

Application of the Rural Livelihoods framework to the problem at hand is further informed by social science research on vulnerability and adaptation. Vulnerability is defined as “the degree to which a system, subsystem, or a system component is likely to experience harm due to exposure to a hazard either as a perturbation or stress/stressor” (Turner et al. 2003). As explained by Leichenko and O’Brien (2002:2), “within the context of climate studies, conceptualization of vulnerability has mostly focused on marginality, susceptibility, adaptability, fragility, and risk.” Using these factors, vulnerability mapping helps identify regions particularly vulnerable to climate shifts (Fussell and Klein 2006; Hahn, Riederer and Foster 2009; Ionescu et al. 2009; Polsky, Neff and Yarnal et al. 2007). High levels of natural capital dependence contribute to climate vulnerability (Thomas and Twyman 2006) and regions in which residents depend on rain-fed agriculture (such as 76% of our study sample) are especially vulnerable (Reid and Vogel 2006). However, note that while the physical geography of a place may increase its exposure to (lower- or higher-intensity) weather events (i.e., it may increase its susceptibility to become vulnerable), social institutions, markets, and networks are key in determining the eventual vulnerability of a system (Leichenko and O’Brien 2002).

Livelihood diversification is the process by which households reduce vulnerability as they seek to ensure well-being (Ellis 2000). Such *adaptation* may occur in response to climate vulnerability, with adaptation defined as “adjustments to a system in response to actual or expected climate stimuli, their effects, or their impacts” (Leichenko and O’Brien 2006). A focus

on agriculturally-dependent rural households is logical in that, considering vulnerability and adaptive capacity, Adger, Paavola and Huq (2006:2) state

“the world’s changing climate and our responses to it threaten to exacerbate precisely those trends and pressures that cause present insecurities and that are likely to lead to increased insecurity in the future. The old, young, poor, and those dependent on climate-sensitive resources, including all of the world’s farmers and fishers, are at greatest risk.”

In addition to being an adaptation strategy used by households in the face of institutional (e.g., market) failure (discussed next), migration is a particular adaptation strategy used by households in the face of environmental strain (Bilsborrow 1992; de Sherbinin et al. 2008; McLeman and Hunter 2010; McLeman and Smit 2005; Njock and Westlund 2010; Nunan 2010). When households are faced with a lack of livelihood options, often due to cumulative processes of environmental degradation (Zweifler, Gold and Thomas 1994), they may strategically diversify their human capital allocation, with some household members migrating to seek opportunity elsewhere (Bilsborrow 2002; Snegstrom 2009; McLeman and Hunter 2010). In this way, changes in proximate natural capital shape household decisions about use of human capital.

There is evidence that this is the case in a variety of rural areas of the world. Massey, Axinn and Ghimire (2010) find that environmental factors play a role in migration in Nepal, particularly short-distance moves. Meze-Hausken (2000) evaluates historical experience gained from drought-induced migration in Ethiopia, finding that families with more survival strategies tended to resist distress-migration longer. In Burkina Faso, Henry and colleagues (Henry, Schoumaker and Beauchemin 2004) demonstrate that residents of drier regions are more likely to engage in both temporary and permanent migrations to other rural areas, as compared to residents of high-precipitation regions. Findley (1994) explored the migratory implications of Mali drought and found that the severe drought of 1983-1985 was associated with a dramatic

increase in migration of women and children, and also an increase in short-term cyclical migration.

With the above work as a foundation, a spate of new research has recently emerged on the migration-environment association. Overwhelmingly, the recent additions provide evidence of lack of, and variability in, natural capital acting as a “push” factor in outmigration, in concert with other influences. As an example, bringing the livelihoods framework to rural migration-environment issues in China, Qin (2010) finds that rural out-migration is a strategy that lowers dependence on natural capital, specifically agriculture and other proximate natural resources used for subsistence. Lower natural capital in the form of smaller fish catches also intensifies livelihood vulnerability in East Africa, resulting in the migration of fisherfolk (Njock and Westlund 2010; Nunan 2010).

Bringing our attention to Mexico, Eakin (2005) argues that understanding farmers’ range of livelihood choices, and limits to their adaptive capacity, is important in understanding rural vulnerabilities to climate change (see also Liverman 2010). Indeed, environmental trends clearly shape household coping capacity since agricultural yields are impacted by climate factors (Luers et al. 2003). Related research, has shown that off-farm employment and migration appear to stabilize household livelihoods through diversification and reduced environmental reliance (De Janvry and Sadoulet 2001; Wiggins et al. 2002). Such livelihood diversification is also important to insure against income risks arising from crop price fluctuations (Massey et al. 1993; Stark and Bloom 1985). (Migration also seems to be used as a livelihood strategy in Mexico, as we describe in the next section).

Rural livelihood diversification in the context of vulnerability to climatic variability and institutional failure may have become particularly relevant in recent times given economic

restructuring and changes in the Mexican political economy, disproportionately (negatively) affecting the countryside. Studies have documented the negative implications of the nation's global economic integration for Mexico's smallholder farmers (Eakin 2005). After decades of public investment and supportive, protective agricultural policies spurring agricultural growth, liberalization of the agricultural sector and food policy during the Salinas de Gortari administration (1988-1994) brought dramatic and longstanding changes to the countryside, which further concentrated poverty in rural places as agricultural employment diminished considerably as commodity prices evinced a downward trend (e.g. Nevins 2007; Zepeda et al. 2009). These changes, paired with increases in foreign direct investment and employment in (*maquiladora*) manufacturing helped exacerbate urban-rural and North-South inequality in the country (Hanson 2003; Polaski 2004; Zepeda et al. 2009), further stimulating internal (and international) migration (Lozano-Ascencio, Robert, and Bean 1999). Informed by these trends, not captured by our community SES measures, we include both state and year fixed effects in the models presented below to control for space-varying-time fixed and space-fixed-time-varying unobserved characteristics respectively.

The New Economics of Labor Migration in the context of rural vulnerability and adaptation

The previous account of migration in the context of vulnerability and rural livelihood diversification suggests that migration is a potential diversification/adaptation strategy to overcome vulnerability related to shocks in access to natural capital by allocating part of the household's human capital endowments in another (foreign) labor market. This notion is consistent with the New Economics of Labor Migration (NELM), a theory frequently used to

explain the motivations of Mexico-U.S. migrants (Lindstrom 1996; Lindstrom and Lauster 2001; Massey and Espinosa 1997; Massey et al. 1994; Taylor 1999; Taylor and Lopez-Feldman 2010). The NELM posits that migration is a livelihood diversification strategy aimed to minimize the risks and costs associated with the inexistence, failure, or malfunctioning of credit, capital, and insurance markets (Stark and Bloom 1985). In rural contexts, (increasing) climatic variability may exacerbate the vulnerability associated with market malfunction. Most notably, severe commodity price fluctuation, potentially caused by climatic variability through its impact on productivity (Eakin 2005), in a context with no availability of affordable crop insurance mechanisms may motivate rural households to allocate part of their labor supply in an urban or foreign labor market (Massey et al. 1993).

Destination choice in turn depends on relative labor market conditions and on the extent to which places of potential destination are linked to sending areas through migrant networks, especially when a member of the household has prior experience in a potential destination. In general, labor market conditions negatively associated or uncorrelated with those of economic conditions in sending areas should yield higher benefits to migration. People may migrate internationally not only because of higher wages in destination countries but also as urban economies (particularly in areas with high primary-sector dependence) may also be affected by economic shocks (and climatic variability), thus making international movement more sensible than internal movement, at least for those with connections to international labor markets. In the Mexican context, people further migrate domestically or internationally depending on pre-existing connections to domestic (urban areas) or U.S. locales, resulting in the relative specialization of communities in one or the other type of migration (Lindstrom and Lauster 1996).

Overall, existing science in several arenas -- natural resources, livelihoods, vulnerability and migration as adaptation, the New Economics of Labor Migration -- forms an important foundation for bringing examination of migration-environment associations to rural Mexico. Such is especially the case given the important social, economic and political aspects of Mexican migration to the U.S., as reviewed next.

Mexico-U.S. migration patterns and processes

Mexican migration to the U.S. has a long history. Sustained, massive movement of labor migrants dates back to recruitment efforts by U.S. employers in the early 20th Century (Cardoso 1980; Foerster 1925; Gamio 1930). Migration streams plummeted during the Great Depression (Balderrama and Rodriguez 2006; Hoffman 1974) but emerged again in 1942 due to a bi-national labor accord with Mexico, the Bracero Program (Calavita 1992). The Bracero Program survived its original purpose of providing emergency farm labor but was discontinued in 1964 as part of broader civil rights and immigration reform. Despite the end of the program, immigration from Mexico continued, both legally and undocumented, in a somewhat circular fashion (Cornelius 1992; Massey et al. 2002). Considerable increases in migration streams occurred in the 1990s and for most of the first decade of the 21st Century (Martin and Midgley 2010; Passel and Cohn 2011) as emigration from Mexico increased (Bean et al. 2001; Hill and Wong 2005) and (short-term) return migration rates plummeted (Massey et al. 2002; Riosmena 2004).

Historically, much of the Mexico-U.S. migration flows have come from rural areas in Central-Western Mexico. Although the geography of these migration flows was some of a historical accident derived from the location of the main rail road lines (Cardoso 1980) coupled with low population levels in the border region, it perpetuated and gained strength over the years

(Durand et al. 2001; Durand and Massey 2003). This regional concentration for much of the history of the flows is no accident but relates to the buildup of strong translocal connections between sending and destination communities (Massey et al. 1987). Social capital in the form of migration networks can decrease costs associated with migration by providing information and assistance that decrease the risks and costs of border-crossing and unemployment upon arrival. In fact, having familial and community-wide connections with migrants in the U.S. is one of the best predictors of U.S.-bound migration in Mexico (Massey and Espinosa 1997; Phillips and Massey 2000; Massey and Riosmena 2010), particularly from rural areas (Fussell and Massey 2003; Massey et al. 1994; Massey and Zenteno 1999). Therefore, migrant networks help to perpetuate emigration in communities once they reach substantial levels (Lindstrom and Lopez-Ramirez 2010; Massey 1990; Massey et al. 1994; Massey and Zenteno 1999; McKenzie and Rapoport, 2007). An individual's prior experience is also strongly associated with the likelihood of (subsequent) migration (Massey and Espinosa 1997).

Although these networks have traditionally been concentrated in the Central-Western region, a nontrivial portion of migrants has always and increasingly come from less traditional sending regions South and East of Mexico city, as communities within built their own engines of social capital (e.g., Cohen 2004; Durand and Massey 2003; Cornelius 2009; Rosas 2008; Smith 2006). As these areas are disproportionately rural, the particular speed of this network build-up and diffusion over rural communities in less traditional sending regions may in turn be associated with the deep restructuring that the Mexican countryside experienced in the last two decades (Nevins 2007; Riosmena and Massey *forthcoming*), briefly described in a previous section.

As also mentioned in the outset, there is little work on how rural Mexican households might respond to natural capital shocks (i.e., climatic variability) using (U.S.-bound) migration

as an adaptation strategy. Yet, we draw on three studies that have more or less directly looked at the issue. Seminal work by Munshi (2003) using an earlier version of the MMP sample in rural areas of the historical region, used precipitation patterns as an instrumental variable to predict the size of the international migrant network available to people in rural sending communities. The focus of that project was examination of the effect of networks on the wages of Mexican migrants in the United States and, indeed, networks exhibit a positive effect on employment and wages. We build upon this work by modeling household-level migration directly as a function of rainfall variability on a broader sample of communities, including some located outside the historical region. As this strategy brings back the potential problem that rainfall variability could be spuriously correlated with migration (e.g., through its effects on the local economy), we also control for community characteristics and state and year fixed effects.

While other work has looked at the association between climatic shocks and migration in Mexico, existing research examines migration at coarser scale than the household. Using the 2000 Mexican Census, Saldaña-Zorilla and Sandberg (2009) found that local susceptibility to natural disasters is associated with the municipal out-migration rate. Here, susceptibility (and the “push” to migrate) included absence of credit and associated declines in income. Further, using data from the 2000 Census and the 2005 Population Count, Feng et al. (2010) found a negative association between crop yields (as a proxy of the confluence of climatic shifts and structural conditions) and state-level U.S. migration rates. Specifically, their modeling exercise suggests a 10% reduction in crop yields would lead an additional 12% of the Mexican population to emigrate.

Yet municipal- and state-level analyses may be subject to the ecological fallacy and, at any rate, they do not allow for adequate control of household-level factors shaping migration

decision-making (e.g. Hondagneu-Sotelo 1994; Lindstrom 1996; Massey, Goldring, and Durand 1994; Massey and Espinosa 1997; Stark and Bloom 1985). We build upon this work by performing a more precise examination of how emigration from rural Mexico associated with recent patterns of precipitation, net of other socio-economic and political factors shaping emigration patterns. Making use of the Rural Livelihoods framework, we include natural capital among the more typical predictors of migration – human, financial, physical, and social capitals. Given differences in migration and development trajectories (and climatic conditions) across different Mexican regions, we stratify our analysis between historical and less traditional sending regions. Further, given that prior migration experience in the household is also an indicator of both migration-specific human and social capital (Massey and Espinosa 1997), we also assess if the likelihood of emigration in the context of environmental strain varies according to these levels. We explain the operationalization of terms next.

DATA

We use data from the Mexican Migration Project (MMP), a bi-national research initiative based at Princeton University and the University of Guadalajara. Every year since 1987, the MMP selects between 4 and 6 Mexican communities and interviews a simple random sample of approximately 200 households in each community. Given the focus on rural livelihoods, our sample is restricted to non-urban communities. As we include state-level rainfall data and in order to ensure representation and variation in state-level variables over time, which would enable us to utilize state fixed effects in our regression specification (see Munshi 2003), only states in which more than one community has been surveyed are included in our sample (see

Appendix A). With this restriction, our working sample includes 23,686 households in 66 communities located in 12 states surveyed from the year of 1987 to 2005.

As migration has consistently varied by region within Mexico we have further disaggregated our data into two key categories. Communities located in the "historical region" represent central-western states that have historically contributed most of the emigrant flow (Durand and Massey 2003). In our data, 74% of households are located within this region, namely in the states of Zacatecas, Guanajuato, Jalisco, Michoacán, San Luis Potosí, Aguascalientes, and Colima. The remainder communities located in "all other regions" are located in the states of Chihuahua in the Border region; Puebla, Guerrero, and Oaxaca in the Central region; and Veracruz in the Southeast (for a full regional classification, see Durand and Massey 2003).

The MMP questionnaire collects basic socio-demographic and retrospective migration questions about all members of the household at the time of the survey. Data are also collected on all children of the household head regardless of their place of residence. Among these questions, respondents report the dates and duration (if applicable) of the first and last U.S. trip for all people listed in the household roster. Our dependent variable reflects emigration to the U.S. by any individual age 15+ in the household roster within three years prior to the survey (that is, during the survey year and two years prior). This is a relatively common phenomenon, with approximately 21% of households sending a migrant to the US during this three-year window. As expected, there are large differences between the emigration rates from historical and non-historical sending communities in our sample: whereas 25% of households in the historical region sent a migrant to the United States in the 3-year window of observation, only 11% of households in other regions did so (see Table 1).

-TABLE 1 ABOUT HERE-

Central to this project is the inclusion of variables reflecting the availability of natural capital as shaped by (variability in) rainfall levels. As such, our main predictor variables represent deviations from long-term average rainfall at the state level. We follow the lead of a large body of climate science through use of a 30-year mean as “climate normal” and for assessment of climatic variability (NCDC 2011). We define drought years as those in which the state-level rainfall measurement was a standard deviation below the 30-year mean. Inversely, we define a wet or rainy year as that in which rainfall levels were one standard deviation above the state’s historical average. We find substantial variation in precipitation regimes in our sample, with an overall mean of 23% of households subjected to drought during the survey year. In addition 13% of our sample had a drought the year prior to the survey year while 3.6% experienced a drought in both years. On the other hand, approximately 28% of households experienced rainy conditions during the survey year, while 23% had a rainy year the year prior; 7% experienced rainy conditions during both years. Overall, households located in communities outside of the historical region are subject to both more droughts (28% vs. 22%) and rainy years (33% vs. 27%) than those within it, despite the fact that our calculations are relative to long-run (quasi-)local conditions (i.e., the drought is not only an artifact of lower rainfall levels in the region). Note that the effect of our natural capital indicator may not only be a function of the physical susceptibility of a place, but of the way this interacts with structural conditions.

At the household level, we include measures reflecting access to the variety of capitals outlined in the Rural Livelihoods framework and central to household strategies. These include

human capital (e.g., household composition, educational levels), financial capital (e.g., business ownership), physical capital (e.g. land and livestock ownership, possessions), and social capital (e.g., prior trips to the US, a measure of both migration-specific human and social capital).

Regarding human capital, the average household has almost 5 members, 40% of which are in the labor force (reflecting the presence of children). 86% of household heads are employed; heads have on average 5 years of formal schooling. Differences in human capital across regions are small, with households located out of the historical region being smaller (4.6 vs. 5.0 members) and with heads with slightly higher levels of schooling (5.6 vs. 4.9 years). Overall the amenities owned by households in and out of the historical region are similar, with a sample average of 7.5 out of 11 possible amenities.ⁱⁱⁱ

On average, 26% of households engage in farming and 22% own a business, with 6% having both a farm and a business. Of those who own land, approximately 16% have their primary holding in either communal or *ejido* land. As previously noted, households whose primary landholding is *ejido* territory tend to be more constrained in livelihood options due to incomplete property rights, lessening their financial and physical capital and decreasing their ability to access formal credit markets relative to households with private property. This, in turn, could increase their likelihood of migration relative to private households in the context of climatic shocks, particularly given their higher dependence on natural capital. As expected, households located out of the historical region are more likely to engage in farming (32% vs. 22% in the historical region) and somewhat more likely to be located in *ejido* or communal lands (22% vs. 14%). In turn, also as expected, households in the historical region tend to have higher levels of migration-specific social capital, measures as the number of prior U.S. trips of the household head (1.9 in the historical region vs. 0.4 in all others).

The household and individual level data were supplemented with information collected by the MMP at the community and municipal scales. These data include information reflecting households' access to livelihood diversification options. Prior work has shown that migration is associated with local economic conditions that are particularly indicative of opportunities for remunerated work for women (Kana'iaupuni 2000; Lindstrom 1996; Riosmena 2009). As such, we use female labor force participation rates and the proportion of the female labor force in manufacturing. We also measure the municipality's dependence on agriculture (in terms of the proportion of males in the labor force devoted to these activities). Finally, we also include a measure of community-level social capital, known as the migration prevalence ratio (see Fussell and Massey 2003; Lindstrom and Lopez-Ramirez 2010; Massey et al. 1994), indicating the strength of broader migrant networks. Note that communities located outside the historical regions have lower livelihood diversification opportunities given their lower female labor force participation rates (but a slightly higher female participation in manufacturing) and a much higher dependence on agriculture (77% vs. 38%). Further, the migration prevalence of these communities is much lower than those in the historical region, where 24% of individuals 15 and over in the community had been to the United States in 1980, compared to only 4.9% in less traditional communities.

METHODS

We first simply graph aggregated migration and precipitation trends across time, by state, to descriptively examine their association. Importantly, we present migration trends only after the high levels of migration motivated by the 1986 Immigration and Reform Control Act (IRCA), which provided amnesty to approximately 2.3 million seasonal and undocumented Mexican

workers in the US. We also present separate graphs for historical and non-historical migration-sending regions. Rainfall trends were calculated as the percentage of rain in the recent year in comparison to maximum of the sample timeframe. Similarly, migration prevalence represents the number of adults reported in the MMP, retrospectively, as having left in each year and the trend line is formed by calculating the percentage of migration prevalence in the current year in comparison to the maximum within the sample timeframe.

Since the MMP is a repeated cross-sectional survey that includes retrospective questions, we use information from the retrospective questions to generate a pseudo-panel across time for each household. We then develop event history multivariate models predicting the migration a household member during the aforementioned 3-year window given that migration is rooted in household decision processes (e.g., Hondagneu-Sotelo 1994; Stark and Bloom 1985). Specifically, we model the likelihood that at least one household member emigrates to the U.S. in the three years prior to the survey as a function of community level, household-level and environmental factors. We opted for a three-year recall window for three reasons: 1) to minimize potential memory biases (Auriat 1991; Belli 1998; Smith and Thomas 2003); 2) to increase the representativeness of the analyses by avoiding going too far back in time, when the experience of people emigrating out of the community is lost; and 3) to maximize the number of covariates available for modeling purposes as many of the community and household characteristics are measured only at the time of the survey (e.g., our household amenity index; as such, we assumed they remained stable during the 3-year window). These static measurements, therefore, limited our ability to utilize retrospective information too far back in time due to the obvious temporal mismatch.

As our outcome of interest is a time-dependent event, which has a probability of occurrence derived from a censored distribution, we employ discrete-time event survival analysis techniques. Following Allison (1982), we do this by fitting a logistic regression modeling the likelihood of U.S. migration while considering the exposure to the risk of emigration of each unit of analysis (see also Singer and Willett 2003). To do so, we estimate the model on a set of pseudo-observations, in this case household-years of exposure before household member's emigration during the three-year window. To control for the changing economic conditions in Mexico we employ both state and year fixed effects. As data from each MMP community comes from a simple random sample, pooling communities in any analysis implies the clustering of households within communities. Thus, we estimate robust standard errors accordingly.

RESULTS

First, Figures 1 and 2 present trend lines for sampled Mexican communities in regions with strong historical migration streams and those without. The figures clearly hint at an association between rainfall patterns and emigration. For example, in historical regions (Figure 1), the relatively dry year of 1989 was associated with relatively high levels of outmigration from study communities while migration declined following increases in rain during the early 1990s. Migration began a consistent decline after a peak rainfall year in 1994. In non-historical regions (Figure 2), increases in rainfall starting 1995 combine with declining relative levels of migration while relative migration again increases during a period of low rainfall around the year 2000.

-FIGURES 1-2 ABOUT HERE-

The findings from our multivariate model shed additional light and are, for the most part, consistent with many of the studies mentioned in the background section. Table 2 presents results of our discrete-time event history models, stratifying analyses by communities located in and out of the historical region. Within each of these, we run two models. Model I is an additive specification in which we assess the association between migration and precipitation in each region while controlling for other relevant factors as previously discussed. In Model II we include an interaction between the prior U.S. migration experience of the household head and rainfall variables, to further test the notion of the relevance of migration-specific social and capital as a facilitator of (climate-induced) international migration (Massey 1990).

Many of the standard migration predictors behave similarly across both models and within both historical and Non-historical regions. For example, human capital variables suggest households with more educated heads are less likely to send an international migrant, perhaps due to the fact that they face more favorable local opportunities to diversify livelihoods. Financial capital, employment of head and business ownership are associated with lower emigration probabilities, again likely due to existing diversification strategies (Massey and Espinosa 1997; Riosmena 2009). On the other hand, a higher index of household amenities is associated with a higher likelihood of migration. Further, *ejido* or communal land ownership are associated with a higher probability of migration (as posited by Valsecchi 2010), suggesting migration may be a more important livelihood diversification strategy under these land tenure systems. Likewise, human and social capital gained by the household head through prior migration is indeed associated with a higher likelihood of emigration.

The inclusion of natural capital measures in the models yield intriguing findings. In Model I in Panel A, drought during the year of analysis is associated with $100 \cdot 100 \cdot [\exp\{0.41\}]$

– 1] = 51% higher odds of emigrating to the United States among households located in the historical region. Further, a drought in the year prior is associated with $100 \cdot [\exp\{0.53\} - 1] = 70\%$ higher odds of migration to the United States among these. Although having a two-year consecutive drought is associated with higher emigration, this effect is not statistically significant. On the other hand, rainy years are associated with a lower likelihood of emigration out of the historical region. More specifically, having two consecutive years of rainfall levels one standard deviation above the 30-year mean is associated with a 38% decrease in U.S.-bound migration out of households located in central-western Mexico during the three-year window.

-TABLE 2 ABOUT HERE-

Our most basic expectations about the relationship between precipitation and migration held true in the historical region. This is, however, not the case for less traditional sending areas as shown in Model I in Panel B: a drought in the current/prior year is associated with an actual *decrease* in the likelihood of U.S.-bound migration while the effect of wet years is not significant. As we hypothesized, U.S.-bound migration seems to be a more logical and easily accessed strategy in places with a longer history of migration even after controlling for the prior migration experience of the household head and the community migration prevalence. Further, the negative effects of drought on migration could refer to higher income constraints in communities outside the historical region, many of which have lower levels of livelihood diversification given their higher prevalence of farming (particularly in *ejido* lands) and which also have considerably lower levels of migration-specific social capital during these negative environmental shocks.

The results of Model II further highlight the importance of migration-specific human and social capital as a mediator to use U.S.-bound migration as an adaptation strategy to shifts in natural capital, again especially in the historical region. In these models, we include an interaction between the prior U.S. migration experience of the household head and rainfall variables. In the historical region (Panel A), households where the head has prior U.S. experience have $100 \cdot (\exp\{0.27\} - 1) = 31\%$ higher odds of sending a migrant to the U.S. during a drought year relative to a household (in the same region) where the head has no prior U.S. experience. Note, however, that the main effects of drought year and lagged drought are cut by 50% and 35% respectively (becoming non-significant in the case of the former) after introducing the interaction with prior U.S. experience of the head. This implies that most of the additional effect of a drought on emigration takes place in households where the head has prior migration experience. This suggests not only that migration may be an adaptation strategy only in households and places with more established translocal connections with the United States, but also that it may be used as a *temporary* livelihood diversification strategy (as a larger number of prior U.S. trips precisely implies a degree of circularity, at least in the historical region, e.g., Massey 1985; Massey et al. 1987; Riosmena 2005: Chapter 3).

Overall, these relationships are the opposite in less traditional sending regions (Panel B, Model II). Households where the head has some U.S. migration experience in the past are generally less likely to emigrate to the U.S. in years of both drought and precipitation abundance. However, in a lagged drought year heads have 67% higher odds of going to the United States during the year after a drought relative to households where the head has no prior U.S. experience. Either way, note that this implies that even people with prior migration experience are considerably less likely to go to the United States during a drought ($-2.41 - 0.56 = -2.97$), the

year after a drought ($-1.23 + 0.51 = -0.72$), or during a wet year ($-0.28 - 0.79 = -1.07$) than in years of “normal” rainfall throughout less traditional sending states. As such, prior relevant migration-specific human and social capital does not seem to operate in the same way in these areas as in the historical region.

DISCUSSION AND CONCLUSIONS

Human migration is a complex social process contingent on origin- and destination-based factors of which climate variability may be an important one. As suggested by prior work in contexts as varied as Mali, Ethiopia, Nepal and Burkina Faso (Findley 1994; Henry et al. 2004; Massey et al. 2010; Meze-Hausken 2000), the research presented here finds an association between rainfall patterns and U.S.-bound migration from rural Mexican households, with dry (wet) years associated with a higher (lower) likelihood of migration building on prior work on environmental shocks and migration (Saldaña-Zorrilla and Sander 2009) and (environmental shocks to) crop yields and migration (Feng et al. 2010). As supported by previous work that shows the significance of being able to access social capital to support migration endeavors (Massey and Espinosa 1997; Massey and Riosmena 2010; Palloni et al. 2001), especially from rural areas (Fussell and Massey 2004; Massey and Zenteno 1999), we find that environmental factors act more substantially on households with migration history and within regions characterized by particularly strong historical emigration flows.

In rural Mexico, as in rural regions across the world’s less developed nations, environmental change has direct impacts on health and well-being of residents since natural resources are often central to income generation activities and/or essential in meeting basic living requirements (Koziell and Saunders 2001). Given this resource dependence, changes in weather

and climate patterns hold tremendous potential to impact livelihoods and, in the face of a decline in livelihood options, migration becomes a significant adaptive livelihood strategy (e.g., Adger 2006; McLeman and Smit 2006). Although in general these moves tend to be of shorter distance and mostly within national borders (Gray 2009; Massey et al. 2010), international migration does seem to be a likely adaptation strategy for households in places with strong ties to the United States, particularly if these ties exist in the household itself.

Current climate models for Latin America project mean warming from 1 to 6°C, and a net increase in the number of people experiencing water stress within the region (IPCC 2007). Specific to Mexico's most valuable agricultural export, coffee, Gay et al. (2006) project climate change may yield a 34% reduction in production in Veracruz, potentially making coffee no longer an economically viable livelihood strategy (see also Nevins 2007; Zepeda et al. 2009).^{iv} Clearly environmental change holds important potential to impact rural Mexicans' livelihood strategies, and thereby influence migration patterns. Indeed, our results find a prominent association between emigration from rural central-western Mexico and recent patterns of precipitation, net of other socio-economic and political factors shaping migration patterns.

However, the spatially-uneven association between climatic variability and migration should also be taken into account when assessing the future prospects of "climate-induced" migration. For instance, coffee production is mostly concentrated in Southeastern Mexico (Nevins 2007), a place in which our rainfall variability variable was not consistently associated with a higher likelihood of U.S.-bound migration (but could indeed be associated with internal migration). As such and given the pace of urbanization in Mexico and the steady shift in the spatial distribution of U.S. migrants away from the historical region and towards South and Southeastern Mexico (Durand and Massey 2003), results from projections of potential "climate

refugees” from Mexico to the United States (Feng et al. 2010) should be taken with caution, as they assume environmental forces work in similar ways across space. Although both physical susceptibility (to natural disasters) and social vulnerability related to the organized social response in the face of environmental strains may be both more problematic in rural and coastal areas of Southern Mexico (Saldaña-Zorrilla and Sander 2009), U.S. migration may not be the main adaptation strategy for most of these households and communities in the future, but indeed potentially for those with a longer migration tradition within less traditional regions of migration (Nevins 2007).

The work outlined here presents many directions for future research through expansion of both social and environmental dimensions. On the social dimensions, disaggregation of migration streams by gender and by destination (to examine internal and international migration) would be additionally instructive. On the environmental dimension, integration of additional aspects of environmental change including temperature fluctuations and shifts in vegetation coverage would also represent logical extensions. Of course, the “pull” of desirable natural attributes could also be examined; Within the U.S., a state-level association exists between climate and migration with desirable weather attributes (warmer temperatures, less humidity) associated with positive net migration (Poston et al. 2009). In Ghana, regions with greater access to natural capital experience higher levels of in-migration (Van der Gesest, Vrieling and Dietz 2010).

Regardless, the work presented here offers important initial insight to an important and real factor influencing migration decisions, environmental factors of particular relevance to resource-dependent rural communities, which is too often ignored in demographic scholarship. Indeed, the public and policy realms are paying increasing attention to the potential for

environmental change to alter patterns of human migration, and academic research along these lines is increasingly emerging (see Adamo and Izazola 2010). With regard to Mexico, the barrage of political pressure in the U.S. to deal with emigration might benefit from shifting focus to origin areas where social, political, economic and environmental pressures converge to shape household-decision making. In rural regions with well-established U.S. migrant networks, the present study suggests reduction of proximate natural capital may enhance the likelihood of households tapping into migration's livelihood potential. Certainly such evidence suggests that the environmental dimensions of livelihood strategies, including emigration, deserve additional, focused research attention.

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Table 1. Means (and Standard Deviations) of Dependent Variable and Covariates in the Analysis

	All communities		Historical Region		All Other Regions	
	Mean	(S.D.)	Mean	(S.D.)	Mean	(S.D.)
Outcome of interest						
Proportion households sending a migrant	0.206	(0.404)	0.245	(0.430)	0.106	(0.308)
State-level climatic variability (natural capital shifts)						
Current year a drought year	0.233	(0.423)	0.223	(0.416)	0.280	(0.449)
Last year a drought year	0.131	(0.338)	0.280	(0.449)	0.170	(0.375)
Two drought years in a row	0.036	(0.186)	0.098	(0.298)	0.000	(0.000)
Current year a rainy year	0.279	(0.449)	0.270	(0.444)	0.327	(0.469)
Last year a rainy year	0.226	(0.418)	0.215	(0.411)	0.301	(0.459)
Two rainy years in a row	0.068	(0.251)	0.078	(0.268)	0.091	(0.288)
Household's human capital						
No. of household members	4.9	(2.4)	5.0	(2.5)	4.6	(2.1)
Proportion of household in labor force	0.397	(0.234)	0.397	(0.236)	0.394	(0.225)
Household head is employed	0.855	(0.352)	0.851	(0.356)	0.864	(0.343)
Schooling years, household head	5.0	(4.4)	4.9	(4.4)	5.6	(4.3)
Household's financial and physical capital						
Household engaged in farming	0.263	(0.440)	0.215	(0.411)	0.316	(0.465)
Household owns a business	0.221	(0.415)	0.215	(0.411)	0.231	(0.422)
Household has both a Farm and Business	0.062	(0.241)	0.048	(0.215)	0.093	(0.291)
Primary property is in community/ <i>ejido</i> land	0.157	(0.364)	0.135	(0.342)	0.217	(0.412)
Amenities in HH (out of 11)	7.5	(2.4)	7.6	(2.3)	7.2	(2.5)
Household's migration-specific social capital						
Household head's prior no. of U.S. trips	1.5	(3.8)	1.9	(4.3)	0.4	(1.5)
Municipal-level socioeconomic levels, community-level migration-specific social capital						
Female labor force participation	0.131	(0.053)	0.131	(0.045)	0.133	(0.070)
Female labor force in manufacturing	0.206	(0.151)	0.196	(0.151)	0.234	(0.149)
Male labor force in agriculture	0.500	(0.190)	0.465	(0.155)	0.585	(0.240)
Community Migration Prevalence in 1980	0.185	(0.152)	0.237	(0.144)	0.049	(0.050)
Sample Size	23,686		17,613		6,073	

Table 2. Discrete Time Logit Predicting the Likelihood of Household Sending a Migrant

	A. Historical Region				B. All Other Regions			
	I		II		I		II	
	β	SE	β	SE	β	SE	β	SE
Household's human capital								
% of HH members in labor force	0.62***	(0.14)	0.64***	(0.14)	0.42	(0.37)	0.36	(0.37)
HH Head is employed	-0.16	(0.13)	-0.18	(0.13)	-0.63**	(0.24)	-0.61**	(0.24)
Life Cycle - young children only	1.27***	(0.20)	1.27***	(0.19)	2.10*	(0.92)	2.17*	(0.92)
Life Cycle - young and teenage children	1.61***	(0.21)	1.62***	(0.21)	2.58**	(0.90)	2.63**	(0.91)
Life Cycle - teenage children only	0.65+	(0.34)	0.65*	(0.33)	1.54	(1.05)	1.62	(1.06)
Life Cycle - all children are adults	1.49***	(0.24)	1.50***	(0.24)	1.74*	(0.88)	1.79*	(0.89)
HH head education	-0.06***	(0.01)	-0.06***	(0.01)	-0.07***	(0.02)	-0.07***	(0.02)
HH head age	-0.01**	(0.00)	-0.01**	(0.00)	-0.02*	(0.01)	-0.02**	(0.01)
Spouses education	-0.05***	(0.01)	-0.05***	(0.01)	-0.07*	(0.03)	-0.06*	(0.03)
% daughters in family	-0.63***	(0.17)	-0.61***	(0.17)	-0.53	(0.41)	-0.58	(0.39)
Household's financial and physical capital								
Primary land is community or Ejido	0.40**	(0.14)	0.41**	(0.14)	0.23	(0.26)	0.22	(0.27)
% of amenities out of 11	1.32***	(0.30)	1.31***	(0.30)	1.59***	(0.34)	1.71***	(0.40)
Number of types of livestock	0.13***	(0.03)	0.13***	(0.03)	-0.01	(0.10)	-0.03	(0.10)
HH owns a business	-0.38***	(0.09)	-0.39***	(0.09)	-0.11	(0.18)	-0.06	(0.16)
HH Engages in farming	-0.14	(0.10)	-0.16+	(0.10)	0.11	(0.19)	0.14	(0.19)
Household's migration-specific social capital								
HH Head total US trips (prior to survey)	0.20***	(0.02)	0.18***	(0.02)	0.46***	(0.10)	0.59**	(0.18)
1980 Migration Prevalence								
	1.08*	(0.50)	0.86+	(0.49)	6.05	(9.98)	5.89	(10.16)
State-level climatic variability (natural capital shifts)								
Current year = drought	0.41+	(0.23)	0.27	(0.24)	-2.43***	(0.29)	-2.41***	(0.31)
Last year = drought	0.53**	(0.17)	0.34+	(0.19)	-1.19+	(0.63)	-1.23+	(0.70)
Last two years = drought	0.07	(0.46)	0.26	(0.49)
Current year = wet	-0.21	(0.17)	-0.40*	(0.18)	-0.66	(0.57)	-0.28	(0.65)
Last year = wet	0.19	(0.18)	-0.07	(0.20)	0.14	(0.56)	0.47	(0.65)
Last two years = wet	-0.48*	(0.22)	-0.22	(0.28)	0.43	(0.50)	0.26	(0.63)
HH head has been to US & drought year			0.27*	(0.12)			-0.56*	(0.27)
HH head has been to US & drought last year			0.39***	(0.11)			0.51**	(0.18)
HH head has been to US & drought last two years			-0.37	(0.26)			.	.
HH head has been to US & wet year			0.35**	(0.11)			-0.79+	(0.44)
HH head has been to US & wet last year			0.48**	(0.15)			-0.58	(0.39)
HH head has been to US & wet last two years			-0.52*	(0.22)			-0.03	(0.53)
Intercept	-3.86***	(0.87)	-3.76***	(0.85)	-3.60***	(0.94)	-3.86***	(1.07)
Observations			17,613				6,073	

Robust standard errors in parentheses

*** p<0.001, ** p<0.01, * p<0.05, + p<0.10

Additional Controls: Community Female labor force participation, Female and male manufacturing and agriculture concentration, Spouses age and number of trips to the US, and state and year fixed effects

Figure 1:

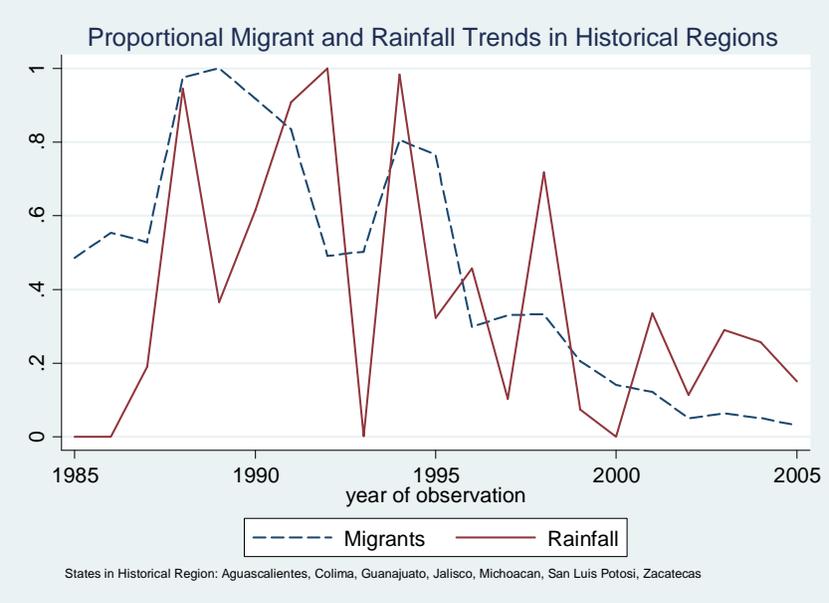
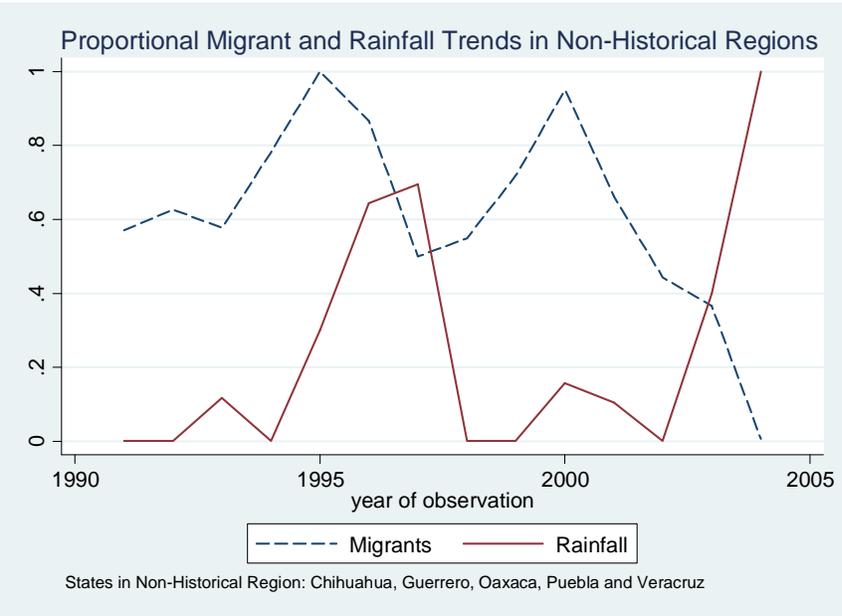


Figure 2:



Appendix A: States, Communities and HH observations in sample

State	Communitites	Historical Region	HH Observations	Percent of Sample
Aguascalientes	2	Y	650	2.69
Colima	3	Y	1,027	4.26
Chihuahua	3	N	1,266	5.25
Guanajuato	12	Y	4,181	17.33
Guerrero	3	N	977	4.05
Jalisco	11	Y	3,613	14.97
Michoacan	6	Y	2,369	9.82
Oaxaca	4	N	1,704	7.06
Puebla	2	N	549	2.27
San Luis Potosi	9	Y	3,176	13.16
Veracruz	6	N	2,023	8.38
Zacatecas	5	Y	2,597	10.76
Total	66	7	24,132	100

ⁱ For instance, Riosmena and Massey (Forthcoming: Table 2) estimate that 40% of Mexico-U.S. migrants in 2001-2006 lived in rural localities, a much higher proportion than the representation among non-migrants at 22%.

ⁱⁱ Burnstein 2007 also notes that corn, in particular, continues to be a mainstay of Mexican rural livelihoods, and its production sustains some 15 million of Mexico's 103 million residents

ⁱⁱⁱ The MMP includes measures of 11 amenities/possessions within study households: running water, electricity, sewage, a stove, a refrigerator, a washing machine, a sewing machine, a radio, a television, a stereo and a telephone.

^{iv} Note, however, that the vast majority of coffee is produced in Mexico's southeast – especially Chiapas and Veracruz -- typically not part of the historical region. As such, climate change-related migration is likely of longer-term concern.