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# Climate Change as Migration Driver from Rural and Urban Mexico

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## Abstract

Studies investigating migration as a response to climate variability have largely focused on rural locations to the exclusion of urban areas. This lack of urban focus is unfortunate given the sheer numbers of urban residents and continuing high levels of urbanization. To begin filling this empirical gap, this study investigates climate change impacts on U.S.-bound migration from rural and urban Mexico, 1986–1999. We employ geostatistical interpolation methods to construct two climate change indices, capturing warm and wet spell duration, based on daily temperature and precipitation readings for 214 weather stations across Mexico. In combination with detailed migration histories obtained from the Mexican Migration Project, we model the influence of climate change on household-level migration from 68 rural and 49 urban municipalities. Results from multilevel event-history models reveal that a temperature warming and excessive precipitation significantly increased international migration during the study period. However, climate change impacts on international migration is only observed for rural areas. Interactions reveal a causal pathway in which temperature (but not precipitation) influences migration patterns through employment in the agricultural sector. As such, climate-related international migration may decline with continued urbanization and the resulting reductions in direct dependence of households on rural agriculture.

### Keywords

Climate change; climate migration; environment; international migration; rural livelihoods; urban livelihoods; Mexico

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## 1. Introduction

Climate change is an issue of global magnitude that will impact human populations through, for example, increases in frequency and intensity of storms, floods, and heat waves, as well as more gradual changes involving sea-level rise and desertification (IPCC 2013, 2014). Particularly poor, less developed countries (LDCs) will likely suffer most from climate change due to a less adequate infrastructure such as irrigation, combined with limited financial capital to develop technological protection including sea walls (cf., Gutmann and Field 2010).

When climate change negatively impacts livelihoods, households may employ *in situ* (in place) adaptation strategies to meet basic needs (Bardsley and Hugo 2010; Davis and Lopez-Carr 2010). *In situ* strategies include selling assets, using formal and informal credit, reducing nonessential expenditures, and/or drawing on social networks and public programs for assistance (Gray and Mueller 2012). However, households may also send a member elsewhere as an *ex situ* strategy to diversify income sources through remittances. As such, migration functions as an informal insurance mechanism. This mechanism is most effective when the household member is sent to a destination where environmental and market conditions are largely uncorrelated with those at the origin (Massey et al. 1993; Stark and Bloom 1985). This diversification strategy may be useful in times of climate stress (Black et al. 2011). In addition, remittances not only benefit the migrant family but positively impact community development through various multiplier effects (Taylor et al. 1996).

Evidence from around the world suggests that environmental factors influence migration patterns (e.g., Bohra-Mishra et al. 2014; Gray and Bilsborrow 2013; Hunter et al. 2013, 2015; Mueller et al. 2014). However, studies frequently find that the climate-migration association varies by location characteristics (e.g., Nawrotzki et al. 2013), access to social networks (Hunter et al. 2013), and demographic factors such as gender (Gray 2010). Yet, this body of research, and the generalizations emerging from collective results, have a decidedly rural focus. In fact, there is no published study available (to our knowledge) that contrasts climate migration from rural and urban areas. This lack of research is unfortunate, given continuing high levels of urbanization (Ravallion et al. 2007). About 54% of the world's population currently lives in urban areas (UNPD 2014) and in future decades the population of LDCs will be predominantly urban (Seto et al. 2012).

Understanding the implications of climate variability and change for urban migration is of tremendous policy importance given the high levels of global population in urban regions (c.f., Adamo 2010). In this letter, we report research results contrasting climate migration responses from rural and urban areas in Mexico, with a focus on international migration. Bringing physical climate science into social science, we employ two measures of climate extremes, the warm spell duration index (*WSDI*) and the wet spell duration index (*CWD*) formalized by the Expert Team on Climate Change Detection and Indices (ETCCDI) (Peterson and Manton 2008).

## 2. Mexico as a Setting for Research on Climate and Migration

Mexico provides an excellent case for the study of international climate migration dynamics due to a long history of migration. Longstanding international labor migration between Mexico and the U.S. has led to the establishment of strong transnational migrant networks (see supplement S1 for a detailed account of the history of Mexico-U.S. migration). Such networks operate as migrant corridors and may strongly facilitate climate-related migration (Bardsley and Hugo 2010).

We conceptually consider migration a household-based strategy for income diversification to guard against the adverse influence of environmental and economic impacts (Massey et al. 1993; Stark and Bloom 1985). Yet, we argue that climate variability and change influence livelihoods differently in rural and urban areas. In rural areas of Mexico, households depend heavily on agricultural production for sustenance and income generation (Conde et al. 2006; de Janvry and Sadoulet 2001; Wiggins et al. 2002). This reliance on agriculture combined with a lack of technological infrastructure (e.g., limited irrigation) makes rural Mexican households highly vulnerable to climatic shifts (Eakin and Appendini 2008; Endfield 2007; Schroth et al. 2009).

In urban areas, however, the livelihood impacts of climate are more complex and often related to extreme events (Revi et al. 2014). For example, flooding may damage wastewater systems (Revi 2008; Romero-Lankao 2010; Willems et al. 2012), transportation infrastructure (Gasper et al. 2011; Koetse and Rietveld 2009), and buildings. These impacts negatively affect job availability and housing quality (CEPAL 2008). In addition, heat waves may result in negative health outcomes (Burkart et al. 2011; Klinenberg 2015; WHO and WMO 2012) and may adversely impact the effectiveness of workers in manual occupations (cf., Kovats and Akhtar 2008). In urban areas, heat waves are often intensified by the urban heat island effect which is due, in part, to daytime absorption and nighttime release of heat by concrete, pavement, and buildings (Adachi et al. 2012; Wilby 2007). In short, while climate variability and change influence rural livelihoods through impacts on the agricultural sector, climate change may affect urban livelihoods through a broad spectrum of impacts to city functions, infrastructure, services, and employment opportunities.

Also important to consider is the connection between rural and urban regions. Adverse climatic conditions in rural areas may influence urban industries and livelihoods in various indirect ways (Boyd and Ibarraran 2009; Wackernagel et al. 2006). For example, urban residents may be employed in the agricultural sector near cities or work in factories processing agricultural outputs (Satterthwaite et al. 2007). In addition, climate variability and change related to agricultural failure in rural areas may decrease food supply and increase urban food prices (Satterthwaite et al. 2007). As such, adverse climatic conditions may directly impact rural livelihoods and at the same time indirectly impact urban livelihoods. Consequently, both rural and urban households may employ migration as a livelihood diversification strategy in the face of climate variability and change (cf., Adamo 2010).

## 3. Data and Methods

To investigate the climate change–migration association for both urban and rural Mexico, we combined sociodemographic data from the Mexican Migration Project (MMP) with climate information from the Global Historical Climatology Network Daily (GHCN-D) data set (Menne et al. 2012). While the MMP provides detailed migration histories and sociodemographic information, the GHCN-D provides daily temperature and precipitation readings for 214 weather stations across Mexico (see S2 for additional detail on the data).

In Mexico, the decision to migrate -- particularly international migration -- is often a household decision and we, therefore, focused our analysis on household-level outmigration (Cohen 2004; Kanaiaupuni 2000). Our sample comprised 14,239 households located in 111 municipalities dispersed across Mexico. We employed geo-statistical interpolation to link spatial climate information to sociodemographic MMP data at the municipality level (see S3 for variable construction). Figure 1 shows the location of the weather stations as well as the 111 MMP municipalities, which are comprised of communities that can be considered either urban or rural. Communities located in a metropolitan area (a state's capital city or other large city) or a city (smaller urban area of 10,000–100,000 inhabitants) are considered urban, while communities located in a town (2,500–10,000 inhabitants) or a village (< 2,500 inhabitants) are considered rural.

The period under investigation is 1986–1999, an excellent timeframe for examination of the potential migratory impacts of future climate change because much of Mexico experienced above normal temperature during the 1990s (Stahle et al. 2009). This climatic pattern resembles projected temperature increases under future climate change scenarios (IPCC 2013; Collins et al. 2013). And on a practical note, the number of Mexican weather stations available within the GHCN-D dropped substantially for more recent years, rendering the spatial interpolation of climate data after 1999 unstable.

For the study of climate-migration dynamics, we used multi-level event history models that account for household clustering within municipalities (see S4 for details on statistical methodology). Our outcome variable was international migration at the household level and we included a suite of important control variables such as indicators of access to migrant networks, occupation status, and socio-economic characteristics such as marital status and assets (Brown and Bean 2006). Community-level factors were also considered such as the level of agricultural employment and access to migrant networks (see supplement S3). We first developed a reliable multivariate base model with these control variables to predict international migration from urban and rural Mexican communities (see S5).

## 4. Results and Discussion

The results of the base model are in line with prior work on Mexican migration, suggesting that international migration from Mexico is influenced by a set of well-known socio-demographic factors. For example, households are more likely to send a migrant when they have good access to migrant networks (Fussell and Massey 2004) or when the household head is an uneducated young male (Fussell 2004). In contrast, the likelihood of sending a migrant is lower when young children are present (Nawrotzki et al. 2013) or when the household owns a business (Massey and Parrado 1998). After testing the robustness of this base model, we added the warm spell duration index (*WSDI*) and the wet spell duration index (*CWD*) jointly, allowing for simultaneous control of temperature and precipitation effects (Auffhammer et al. 2013). Table 1 provides separate estimates of the climate-migration association for rural and urban areas in Mexico, 1986–1999.

The results suggest that longer warm spell durations and wet spell durations lead to higher odds of international migration in the combined model of rural and urban areas (“All”). But the temperature effect is three times as strong as the precipitation effect -- a one standard deviation unit increase in warm spell duration leads to an increase of the odds of international migration by 15% (Odds Ratio [OR]=1.15) while a one standard deviation unit increase in wet spell duration leads to an increase in the odds of an international move by 5% (OR=1.05). This observation is in line with prior work that consistently finds stronger temperature than precipitation effects on migration patterns (Bohra-Mishra et al. 2014; Mueller et al. 2014). An increase in temperature may increase evapotranspiration and lead to drought conditions even if precipitation patterns do not change (Diffenbaugh et al. 2015). In addition, technological responses to precipitation anomalies, such as irrigation, are more readily implemented than technologies to guard against adverse impacts of temperature extremes.

But our central finding is that disaggregating the sample into rural and urban areas reveals that climate change effects only emerge for rural areas. With regard to urban areas, non-significant coefficients suggest that climate effects do not translate into international migration among urban populations. Reasons for the lack of association could include: 1) the indirect effects on urban livelihoods through rural production deficits (e.g., job losses, increased food prices) are not sufficiently strong, 2) urban households have better access to alternative *in situ* (in place) adaptation strategies, or 3) migrant networks that facilitate climate migration (i.e., Bardsley and Hugo 2010) are underdeveloped in urban areas (Fussell and Massey 2004).

On the other hand, climate change measures exhibit statistically significant effects for migration from rural Mexican households. As noted above, rural populations in Mexico depend heavily on subsistence farming and agricultural employment, intensifying vulnerability to climate variability and change (Mueller et al. 2014). Both heat waves and flooding have negative impacts on agricultural productivity. Corn, an important staple in Mexico, is particularly sensitive to heat stress (Sanchez et al. 2014; Schoper et al. 1987; Tollenaar and Bruuslema 1988), and a warming in temperature has been shown to reduce crop yields (Bassu et al. 2014; Lobell and Field 2007). Similarly, flooding and excess soil moisture (saturation and waterlogging) impair plant growth (Ashraf and Habib-ur-Rehman 1999; Zaidi et al. 2003), increase the risk of plant disease and insect infestation (cf., Kozdroj and van Elsas 2000), and may delay planting or harvesting due to inability to operate machinery. As a result, precipitation and harvest yields are non-linearly related and when cumulative precipitation exceeds certain thresholds, a substantial decline in crop yields can occur (Rosenzweig et al. 2002). Overall, we argue that through such adverse agricultural impacts, heat waves and flooding both increase livelihood insecurity and can lead to elevated migration probabilities from rural areas.

To further test this agricultural pathway for climate change effects on rural migration, we estimated a model of international migration with an interaction term, reflecting a combination of the climate change indices and a municipality-level measure of percentage males employed in the agricultural sector (Table 2).

We observe a statistically significant interaction in the combined model ("All") and for the rural sub-sample, but only for the temperature effect (Table 2). Figure 2 provides a visual representation of this important interaction – the warm spell duration index has almost no effect on international migration when only a small proportion of local males are employed in the agricultural sector. However, with higher levels of male agricultural employment, warm spells are associated with greater likelihood of international migration. A similar pathway in which the temperature-migration association is moderated by agricultural income was initially suggested, but not empirically tested, by Mueller et al. for Pakistan (2014).

Even so, no significant interaction emerged for the wet spell duration index. Although longer wet spell durations and possible flooding increase the likelihood of an international move from rural areas in general, this effect is not associated specifically with agricultural employment. This may indicate that flooding is equally harmful for nonagricultural sectors. Indeed, flooding not only damages agricultural production but also may have detrimental impacts on local infrastructure and other economic activities (CEPAL 2008). In short, we find evidence that climate change impacts rural migration through the agricultural sector, but only as related to temperature extremes.

## 5. Conclusion

Evidence continues to emerge suggesting that climate variability and change shapes migration patterns (Gray and Bilsborrow 2013; Mueller et al. 2014). However, most existing research focuses exclusively on rural areas. Given trends of rapid urbanization (Seto et al. 2012), it is of increasing policy relevance to investigate whether climate variability and change similarly influence the probability of international moves from urban areas (cf. Adamo 2010).

This letter reports results from the first empirical study to contrast climate migration from rural and urban areas in Mexico. As a strength of this research project, we employ two ETCCDI climate change indices constructed based on daily temperature and precipitation information at a high spatial resolution. We find that heat waves and wet spells significantly increased international migration from Mexico during 1986–1999. However, our results show that adverse climate variability and change drive international outmigration only from rural areas. In addition, we find evidence that the influence of climate change on migration operates primarily through employment in the agricultural sector. However, this causal pathway emerges only for temperature but not for precipitation effects, suggesting the particular importance of temperature extremes for international migration from rural areas.

These findings have important policy implications. First, the results suggest that attempts to project international climate migration (e.g., Christian Aid 2007; Myers 2002, 2005; Stern 2007) must account for urban-rural differentials in the influence of climate on migration.

Second, our study suggests that adverse climate variability and change will continue to increase international migration from rural areas. Adaptation programs should therefore target rural Mexican communities, potentially as a means of lessening the need for migration as an *ex situ* strategy and to improve livelihoods and wellbeing of local populations.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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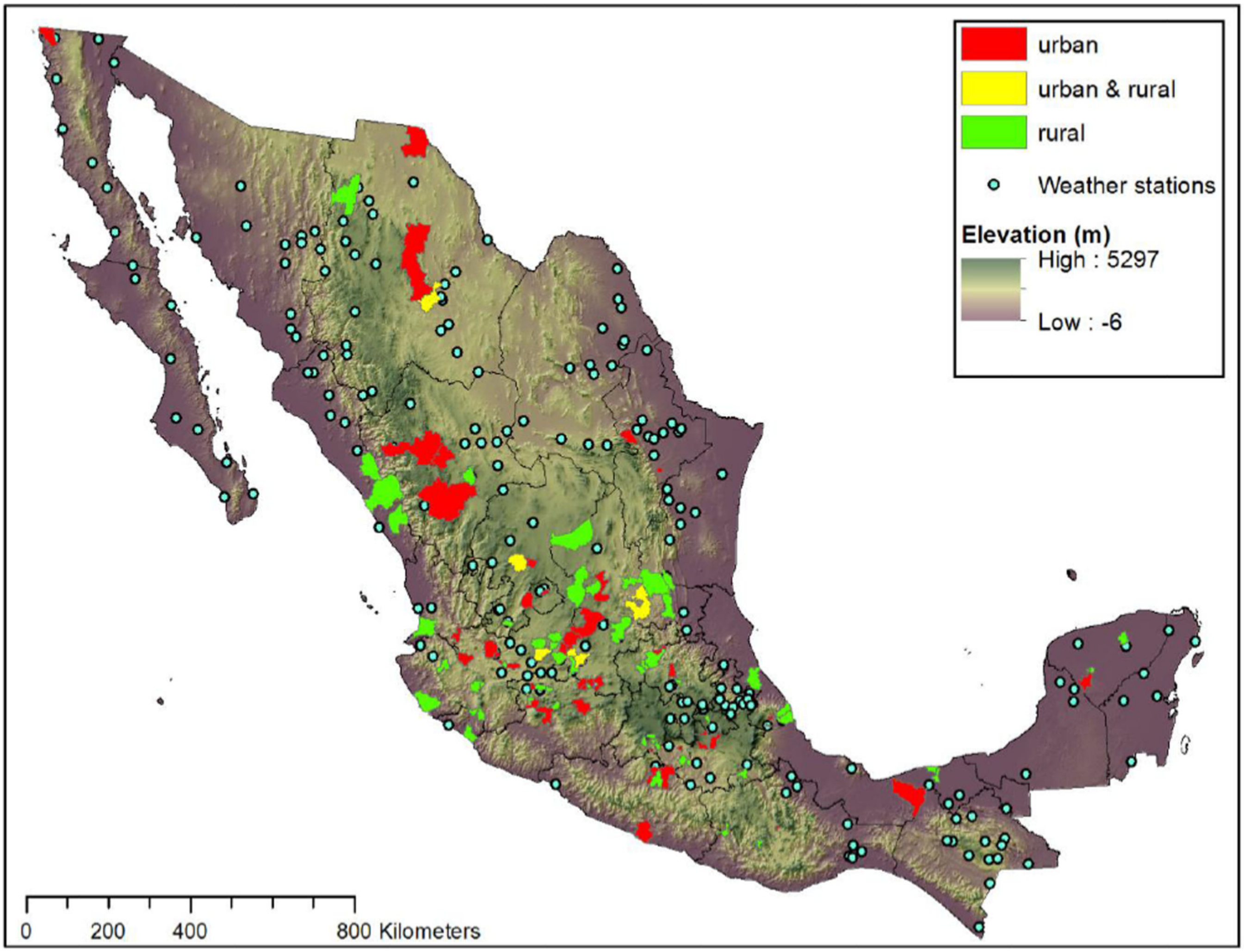


**Figure 1.**

Geographic location of MMP municipalities and spatial distribution of weather stations across Mexico

Notes: Total municipalities: n=111; rural municipalities: n=62; urban municipalities: n=43; municipalities containing both rural and urban municipalities n=6

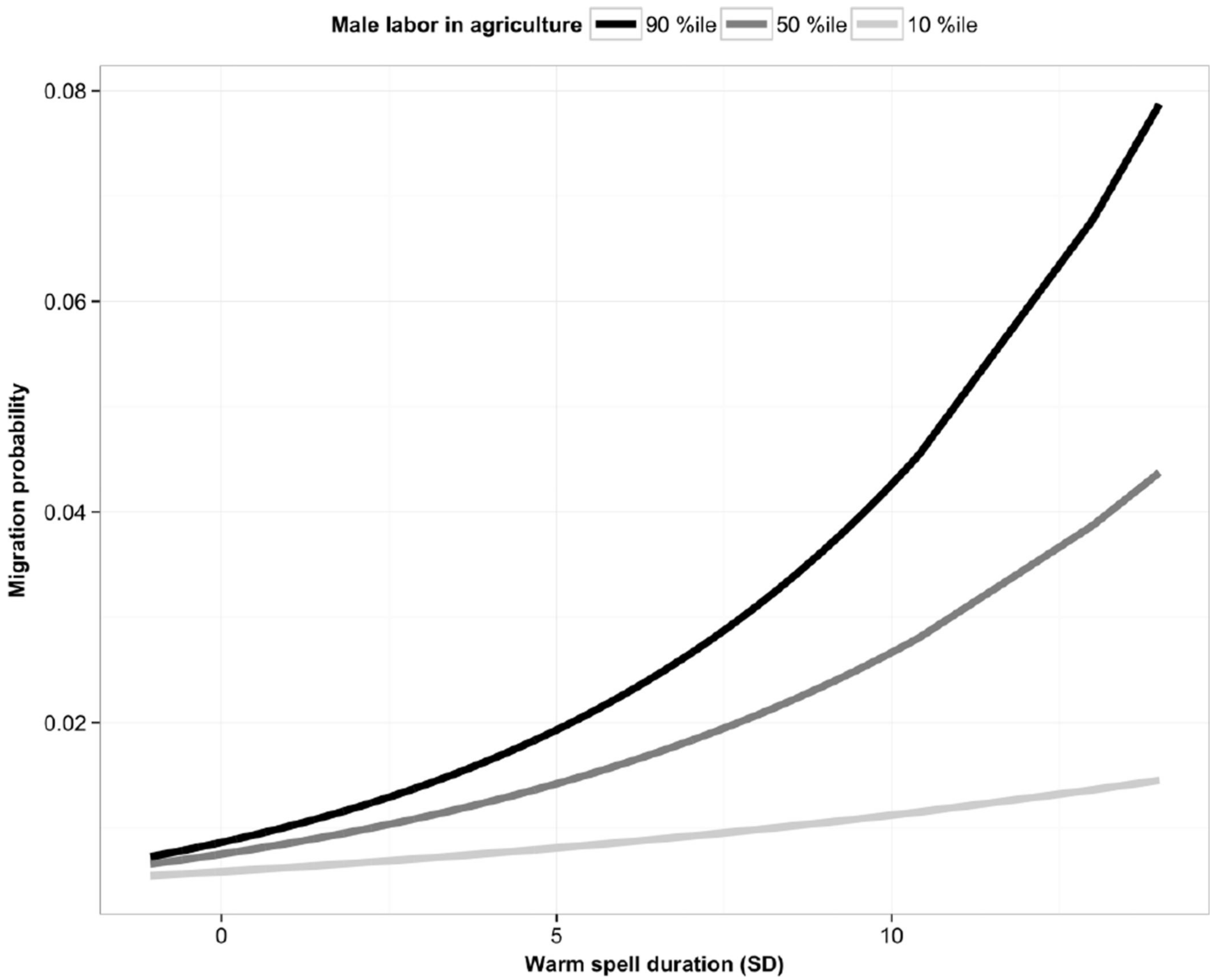


**Figure 2.**

Interaction between warm spell duration index and the percentage of males employment in the agriculture sector on the probability of international migration across Mexico (combined rural and urban sample), 1986–1999

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**Table 1**

Impact of climate change on the odds of international migration from rural and urban Mexico, 1986–1999

| | **All** | | **Rural** | | **Urban** | |
|---|---|---|---|---|---|---|
| | **b** | **sig.** | **b** | **sig.** | **b** | **sig.** |
| Warm spell duration | 1.15 | *** | 1.22 | *** | 1.05 | |
| Wet spell duration | 1.05 | * | 1.06 | * | 1.02 | |

Note: Coefficients reflect odds ratios; climate effects were estimated using the fully adjusted multi-level event history models (Table S2); Municipality N: All=111, Rural=68, Urban=49; a jackknife procedure, omitting one municipality at a time from the sample (Nawrotzki 2012; Ruiter and de Graaf 2006), demonstrated that the estimates were highly robust;

[*] $p<0.05$;

[**] $p<0.01$;

[***] $p<0.001$

**Table 2**

Interaction between climate change indices and the male labor force employed in the agricultural sector predicting the odds of international migration from rural and urban Mexico, 1986–1999

| | All | | Rural | | Urban | |
|---|---|---|---|---|---|---|
| | b | sig. | b | sig. | b | sig. |
| Temperature interaction model | | | | | | |
| Warm spell duration | 1.13 | *** | 1.15 | *** | 1.05 | |
| Male labor in agriculture | 1.09 | ** | 0.98 | | 1.19 | *** |
| Warm spell duration×Male labor in agriculture | 1.01 | * | 1.03 | ** | 1.01 | |
| Precipitation interaction model | | | | | | |
| Wet spell duration | 1.06 | * | 1.08 | | 0.99 | |
| Male labor in agriculture | 1.09 | ** | 1.00 | | 1.17 | *** |
| Wet spell duration×Male labor in agriculture | 0.99 | | 0.99 | | 0.97 | |

Note: Coefficients reflect odd ratios; coefficients for male labor force employed in the agricultural sector relate to a 10% change; each row represents a fully adjusted interaction model (all controls of Table S2 included) of which only the coefficients for the terms involved in the interaction are shown; variables were grand mean centered;

[*] p<0.05;

[**] p<0.01;

[***] p<0.001