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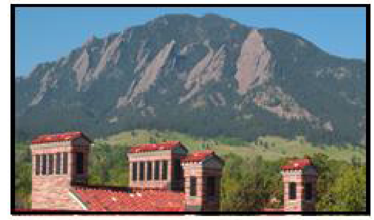

WORKING PAPER

The Influence of Internal Migration on Exposure to Extreme Weather Events in Mexico

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Abstract
Between 2005 and 2010, 6.3 million migrants (approximately 6% of the population) moved domestically within Mexico, predominantly to urban locations. These shifts – both in migratory streams and resulting population distribution– have potential implications for the exposure of populations to natural disasters. We ask: *How have recent migratory patterns in Mexico influenced exposure to extreme weather events?* To examine this question, we use census micro-data in conjunction with recorded data on natural disaster events. The populations exposed to extreme weather events are first calculated based on observed disasters and demographic change between 2005 and 2010. This is compared to a hypothetical scenario with no migration between 2005 and 2010 to identify the contribution of migration to exposure both in the aggregate and for specific municipalities within Mexico. The results demonstrate that, while migration has decreased overall exposure within Mexico, this influence is highly localized in select municipalities – especially of Mexico City and Monterrey.

1.0 Introduction

During the past half century, there has been a sharp increase in the number of individuals affected[1] by natural disasters worldwide (Figure 1). At the same time, the world has been experiencing increasing migration flows within and across national boundaries (UN 2009). These migratory flows have resulted in redistributed populations across regions. As of 2005 there were globally about 763 million people living within their own country but outside their region of birth (UNDP 2013).

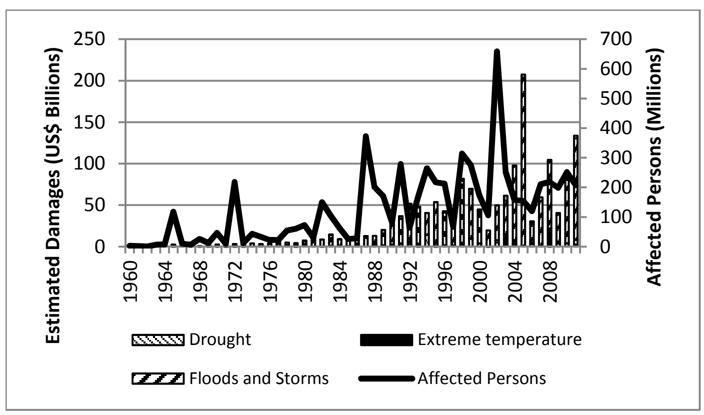

Figure 1. The cost, in US dollars, of different classes of natural disasters and the total number of impacted persons 1960-2011 (EM-DAT, 2013).

Residential location is clearly a key factor in determining the likelihood of being impacted by a disaster – part of a component of vulnerability frequently referred to as exposure (Schröter et al., 2004; Turner et al., 2003). It is likely that the unprecedented shifts in

1 In this instance, affected individuals are defined as "People requiring immediate assistance during a period of emergency; it can also include displaced or evacuated people" (EM-DAT, 2013).

population distribution over the past decades have and will continue to influence the number of individuals exposed to environmental disasters, given the uneven distribution of weather extremes (Balk et al., 2009; de Sherbinin et al., 2007; McGranahan et al., 2007; Parry, 2007).This paper offers an empirical exercise which estimates the influence of migratory patterns on exposure to extreme weather events in Mexico between 2005 and 2010.

To examine this relationship, we use Mexican census micro data to estimate municipality-scale migration streams. We couple this with a disaster database designed to capture not only large-scale environmental events, but also small and medium-impact events across Latin America (OSSO, 2013). We then contrast the total number of individuals exposed to natural disasters between 2005 and 2010 to the total number of individuals that would have been exposed in the case of no migration over the same time period. As such, we empirically identify where and to what degree internal migration contributed to exposure within Mexico.

2.0 Why Mexico?

Mexico provides an important case study due to both its long history of large-scale migration as well as its unique susceptibility to climate change. Within Mexico, 6.3 million migrants (approximately 6% of the population) moved domestically[2] during 2005-2010– of which around 4 million (~65%) moved to an urban location. These high levels of migration are accompanied by a particular sensitivity to climate change, due to both the larger environmental impacts expected in sub-tropical areas (Boyd and Ibarrarán, 2009) and the socioeconomic vulnerability of many Mexicans in both urban and rural settings (Eakin, 2005; Romero-Lankao et al., 2012). In rural settings in particular, a reliance on natural capital (i.e., precipitation for agricultural productivity) is a key component in the livelihoods of large populations (Nawrotzki et al., 2013). There is growing evidence that Mexico is already experiencing the effects of climate change, including shifts in sea levels, precipitation, increases in temperature extremes, and changes in drought conditions (Kunkel et al., 2008; Magaña et al., 2012; Peterson et al., 2008).

3.0 Data

Data sources are summarized in Table 1. Information on the residential location for 2005 and 2010 (municipality of origin and destination) for a 10% sample of individuals in Mexico is sourced from the Integrated Public Use Microdata Series (IPUMS), retrieved from the Minnesota Population Center (2011) – data originally made available by the National Institute of Statistics, Geography and Informatics in Mexico (INEGI) (also see Ruggles et al. (2003)). These data were augmented by data obtained directly from INEGI, including municipality-scale geographic reference information enabling geo-referencing of both migratory patterns as well as environmental impacts.

2 Domestic migration is defined as a move between municipalities from 2005 to 2010.

	Description	Source
Integrated Public Use Microdata Series (IPUMS)	Internationally harmonized micro-census data. Includes sociodemographic, migration, household, and geographic information in Mexico.	Preprocessed data was retrieved from the Minnesota Population Center (2011). Original data from National Institute of Statistics, Geography and Informatics, Mexico
DesInventar	Collection of environmental disasters at the municipality scale for Mexico (extends more broadly to Latin America)	Data was retrieved from the Sistema de Intentario de Desastres, available online at: http://www.desinventar.org
Geographic Reference Data	Mapped data providing the spatial reference coordinates for each municipality in Mexico, 2010.	National Institute of Statistics and Geography (INEGI), Mexico

Table 1. Datasets used in this analysis.

The census information is used in conjunction with disaster data available within the Disaster Inventory System (OSSO, 2013) which provides details on disaster events across Caribbean and Latin American countries. In Mexico, these data – including the location, time and type of environmental event, and information on monetary impacts where available - are recorded at the municipality scale, allowing for detailed spatial analyses disaster events. During our study timeframe, the "DesInventar" dataset provides information on 12 different classes of natural hazards (frosts, showers, gales, surges, droughts, heat waves, hail, thunder storms, floods, storms, flash floods, mud flows).

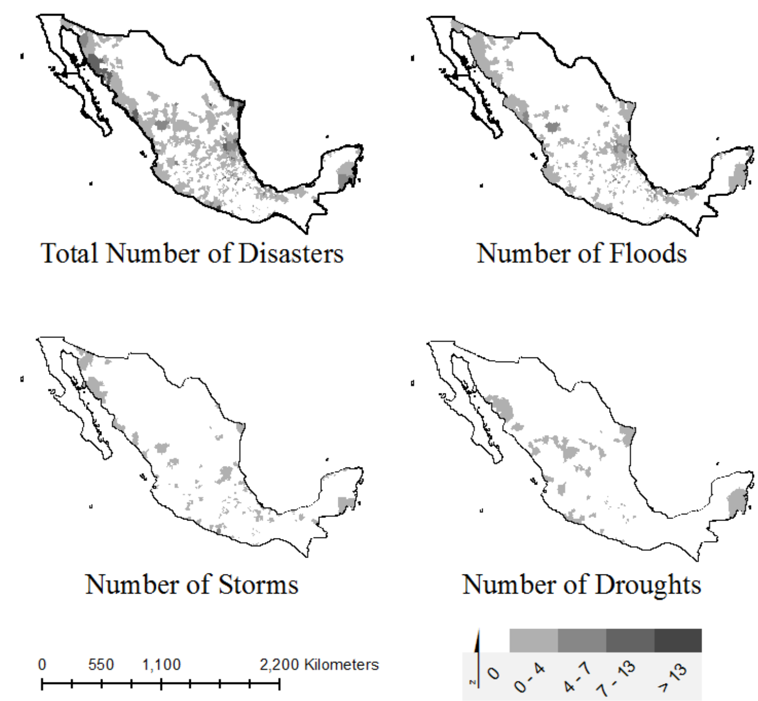

Figure 2. The total number of hydro-meteorological disaster events, 2005-2010 (OSSO, 2013).

The total number of disaster events as well as spatial distributions of the three most common types of disasters between 2005 and 2010 can be seen in Figure 2. Flooding was the most common disaster type in Mexico, representing 45.7% of disaster observations (N= 561). As might be anticipated, the majority of floods occurred along the coasts, though flooding is still quite common throughout the interior. Storms are distributed fairly evenly across the country, excepting the low-precipitation north. Droughts occurred primarily in west, north and central Mexico.

4.0 Methods

We use a five-step process to estimate the influence migration had on the number of individuals exposed to environmental disasters in Mexico between 2005 and 2010, each step of which is explained in more detail below. First, we tabulate the total number of disaster events between 2005 and 2010 within each municipality. Second, each municipality's population in 2010 is multiplied by the number of disaster events, providing an estimate of the maximum number of times residents could have been exposed to a disaster. Third, a hypothetical scenario of 2010 is created which represents the distribution of population within Mexico had no migration occurred between 2005 and 2010. Fourth, we repeat the multiplication procedure conducted in step 2, and finally we contrast the results.

Tabulating and Calculating Exposure

The no-migration scenario estimates a 2010 national total population of approximately 112,300,000, contrasting with 111,500,000 individuals in the observed data. The slightly larger population (0.8%) in the no-migration case is the result of moving international migrants back to their origin municipality within Mexico, i.e. we prevent international out-migration from occurring (see figure 3). The difference between the no migration scenario population and the observed population – net migration from 2005 to 2010 - is shown in Figure 4. As these figures illustrate, between 2005 and 2010 outmigration occurred from locations all across the country, while the destinations of migrants were much more concentrated. Further, many of the municipalities which had negative net migration between 2005 and 2010 also had high levels of international migration. Positive net migration occured in the city of Monterrey and some cities along the Gulf coast, particularly areas near Cancun and Quintana Roo, as well as some municipalities near the northern border.

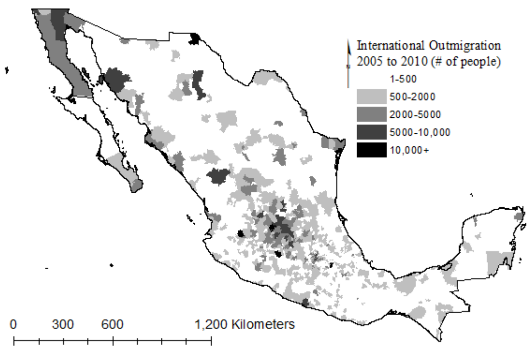

Figure 3. Number of international migrants between 2005 and 2010. These migrants are added to the total population in the no-migration scenario.

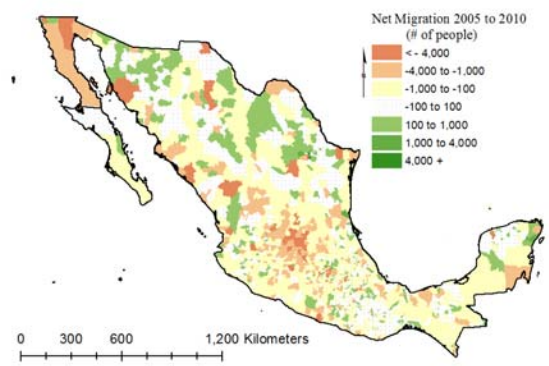

Figure 4. Net migration from 2005 to 2010.

Scenario Comparison

We compare the overall exposure of populations in Mexico under our two scenarios using both absolute and relative measures as illustrated in equations 1 and 2 below:

$$A_n = O_n - S_n \qquad \text{equation1.}$$

$$R_n = \frac{(O_n - S_n)}{O_n} \qquad \text{equation2.}$$

where *n* is a unique index for each municipality, S_n is the estimated exposure (number of possible occurrence events) in the hypothetical no-migration scenario within municipality *n*, O_n is the observed exposure, A_n is the absolute contribution of migration to exposure (measured in possible occurrence events), and $R_n$is the contribution of migration relative to the total observed exposure.

Results

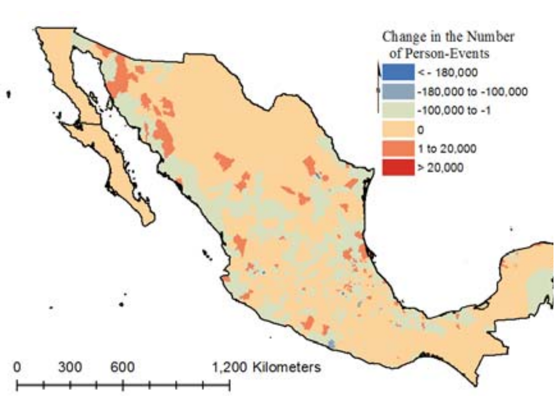

Figure 5. The absolute contribution of migration to exposure, measured in potential occurrence events. See equation 1.

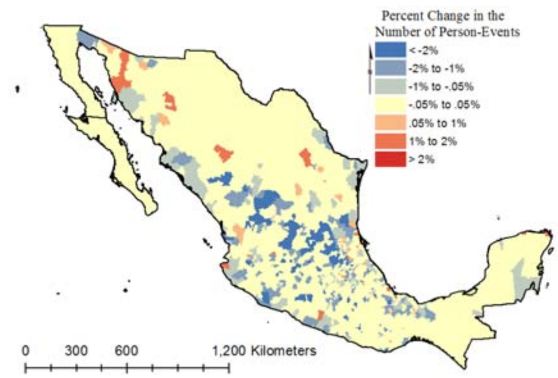

Figure 6.The relative contribution of migration to exposure, 2005-2010. See equation 2.

Municipality (Constituent city when relevant)	Absolute Increase/Decrease in Exposure
Apodaca (Monterrey)	+13,375
Altamira (Tampico)	+12,700
Cuautitlan (Mexico City)	+3,434
Garcia (Monterrey)	+2,150
Tepotzotlan (Mexico City)	+2,032
Guadalajara	-226,179
Monterrey	-224,250
Ecatepec de Morelos (Mexico City)	-198,573
Acapulco de Juarez	-173,080
Puebla (Puebla)	-123,918

Table 2. Five largest increases and decreases in exposure: absolute change in number of potential person events.

Municipality (Constituent city when relevant)	Relative Increase/Decrease in Exposure
Oquitoa	+14%
San Pedro del Gallo	+11%
Soyopa (Sonora)	+7%
Mazatlan	+7%
MelchorOcampo	+6%
Landa de Matamoros	-7.7%
Tasquillo (Mexico City)	-7.3%
Puruandiro	-5%
Alvaro Obregon (Mexico City)	-5%
Dolores Hidalgo Cuna	-5%

Table 3. Five largest increases and decreases in exposure: relative change (compared to observed data) in number of potential person events.

Across the entire country, between 2005 and 2010 migration resulted in approximately 1% fewer individual-level disaster exposures. While this value is small relative to the entire population of Mexico, it represents ~2.6 million fewer individual disaster exposures over the five year study window. Particularly important is the spatial variation in the migratory impacts on disaster vulnerability.

Figure 5 shows the absolute difference between exposure in the "no migration" scenario and the observed 2010 data. This map shows that: (1) migration streams from central-eastern Mexico to other destinations resulted in a decrease in exposure; (2) increased migration to very small, coastal municipalities frequently led to increases in exposure (i.e., see small municipalities on the Yucatan coast); and (3) in a few rare cases, coastal municipalities (such as Acapulco de Juarez) experienced a decrease in exposure attributable to migration. Table 2 shows the largest absolute changes in exposure, which were found in Apodaca (+13,374 person-events) and Altamira (+12,700), located in the suburbs of Monterrey and Tampico respectively. The largest decreases were in Guadalajara (-226,179) and within the core of the city of Monterrey (-224,250).

Figure 6 shows the relative contribution of migration to the observed exposure (the result of equation 2). This map shows a similar pattern to Figure 5, identifying many small coastal “destination” municipalities as having an increased exposure, and large decreases throughout the central region. Table 3 shows the largest relative changes in exposure, found in Oquitoa, Sonora (14%) San Pedro del Gallo, Durango (11%). The largest relative decreases were found in Landa de Matamoros (-7.7%) and Tasquillo (-7.3%), both in the central region of Mexico.

Discussion

Policy Implications

Migratory dynamics in Mexico observably resulted in fewer people living in the path of extreme weather events 2005 -2010. For Mexican policymakers, this research suggests that diversification of economic opportunities to less environmentally exposed areas could help to mitigate the impacts of future weather events, especially considering the likely intensification of extreme weather due to climate change.

Though the time frame analyzed here is short, three patterns emerge. **First**, many of the most notable changes in environmental exposure at the nation-scale are occurring in cities (see table 2), suggesting urbanization dynamics are particularly important for understanding these processes. This suggests that understanding urban migratory dynamics will be an important factor in our understanding of likely future environmental impacts.

Second, some larger cities are experiencing decreases in exposure in some locations and increases in exposure in others, representing the impact of suburbanization. This relationship can be seen in terms of absolute exposure for both Monterrey and Mexico City, with some municipalities within each of these metropolitan areas gaining population and others shrinking (see tables 2). While suburbanization has been examined in terms of its environmental impacts (Giner et al., Accepted; Runfola and Hankins, 2010; Runfola et al., In Press), the influence of suburbanization on disaster exposure has not been a topic of study. As a novel contribution to the literature, our findings illustrate a link between suburbanization and relative exposure for large urban centers such as Mexico city, and suggests further research should examine this relationship.

Third, notable decreases of population exposure in Acapulco de Juarez are likely attributable to other factors, notably increasing drug violence (Chi et al., 2013)), suggesting an important interplay between political instability, migration, and the environment that warrants further investigation. This highlights one of the limitations of the present study, that no explanatory factors are present. Future research drawing more explicit links between causal migratory factors and environmental exposure could overcome this challenge.

6.2 Study Limitations& Future Directions

This study has a number of critical limitations, suggesting several useful extensions. First, the time frame (2005 – 2010) is too short to generalize or extrapolate the findings more broadly. This is primarily driven by data limitations, though we are currently working to secure longer-term historical records of both migration and environmental disasters. Second, the methodological approach does not control for birth or death rates which would also influence exposure across time. However, for a short time period of 5 years the introduced bias is likely to be small. Third, the size of our analytical units varies, resulting in the spatial accuracy of our estimates of environmental disasters to vary (i.e., a disaster attributed to a small municipality is likely influenced the entire municipality, while in an extremely large municipality that is almost certainly not the case). Gridded population and/or disaster data could provide a uniform, more spatially accurate estimate of the relationship between migration and environmental exposure, but such detailed data is not available at present. Fourth, because our approach is limited to Mexico it discounts any changes in exposure for international migrants (i.e., individuals that relocated to Mexico from a different international origin are "removed" from the country totals in the construction of the no-migration scenario)[3]. Finally, this study is explicitly limited to measuring exposure, but could be extended to encompass the multidimensional notion of vulnerability which includes the sensitivity and/or adaptive capacity.

By focusing on a limited definition of exposure, this study does not examine many possible pathways for change Mexico might consider. For example, encouraging the densification of populations provides an opportunity to reduce the overall exposure of Mexican populations – i.e., implementing mitigating infrastructure or introducing emergency response systems to increase resilience or promote the adaptive capacity of (especially urban) communities (Romero-Lankao, 2010; Sperling and Szekely, 2005). However, any such policy would need to carefully consider the context-specific factors and process that shape vulnerability, as infrastructure deficits, lack of institutional capacity and high levels of socio-spatial segregation could introduce unforeseen risks (Romero-Lankao et al., 2012; Tiefenbacher, 2006).

5.0 Conclusion

This paper (1) provided a methodological framework to examine the impact of migration on environmental exposure, (2) applied this methodology to Mexican migration for 2005-2010, and (3) found that migration has resulted in a net decrease in environmental exposure within Mexico, though with a large degree of spatial variation. Much of the migration (~65%) in Mexico from 2005 to 2010 was to urban destinations. Across the entire country, migration resulted in a net 1% decrease in exposure to environmental events, i.e. the number of times individuals would have experienced extreme weather between 2005 and 2010. Specific municipalities ranged from a 14% increase in exposure to an 8% decrease. To mitigate the impacts of future, intensified, natural disasters it is important that urban land planning policies take into consideration the environmental exposure of targeted regions.

3 Currently, we can only make coarse estimates – for example, if it is assumed international migrants experienced the same average rate of disasters as citizens within Mexico, each individual has a 51% chance of being affected by a single disaster. This would lead to an overall reduction of 2.2 million occurrence events attributable to migration, as opposed to the reduction of 2.6 million when there is no account for international migration.

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