Extended Abstract: Accounting for Climate Feedback in Population Projections

Jakob Gregor Zellmann,[1,2] Itza Olguín,[1,†] Mikhail Maksimenko,[1]
Raya Muttarak,[1] Rosanna Gualdi,[1], Sirinya Kaikeaw,[1]

(1) Alma Mater Studiorum - Università di Bologna
Bologna, Italy.

(2) Max Planck Institute for Demographic Research,
Rostock, Germany

Introduction

Climate change has significantly impacted various meteorological phenomena, particularly increasing the frequency, intensity, and duration of heat waves. The acceleration of global warming has led to 19 of the 20 hottest years occurring after 2000, with predictions indicating that heat waves will become even more frequent, intense, and long-lasting than historically observed (Annual-Global-Climate-Report, 2024). This alarming trend has increased the urgency to understand how these changes affect human health and behavior.

There has been growing evidence that climate change affects demographic processes. For example, heat-related mortality is projected to rise globally, with only a modest decline in cold-related deaths despite rapid warming (Gasparrini et al., 2017). In the case of fertility trends, recent scientific evidence points to an emerging consensus on the impact of rising temperatures. Studies across various regions worldwide have found that days with high average temperatures or positive temperature anomalies are associated with a decline in birth rates 8 to 10 months later (Barreca, Deschenes, & Guldi, 2018; Cho, 2019; Conte Keivabu, Cozzani, & Wilde, 2024; Marteleto, Maia, & Rodrigues, 2023). As well as on migration, there is growing evidence that sudden-onset and slow-onset climate events tend to impact internal and international migration processes worldwide (Berlemann & Steinhardt, 2017; Hoffmann, Dimitrova, Muttarak, Crespo Cuaresma, & Peisker, 2020). Extrapolating those trends under different SSP-RPC scenarios, as, e.g., in Gasparrini et

[0†]Presenting author, email: itza.olguinzuniga@unibo.it

al. (2017), who estimate the net death burden due to climate change to increase by 49.9% under SSP3-7.0 in European countries, stresses the importance of integrating the impact of changing climate into population projections.

However, to the best of our knowledge, there is no research systematically investigating the effects that climate change will have on future population by jointly modeling its impact on mortality, fertility, and migration at a sub-national level in low-middle income countries. This study aims to address this gap.

Objectives

The primary aim of this research is to incorporate the effects of climate change, specifically temperature-related impacts, into future subnational population projections for Mexico. To achieve this goal, the study is structured around several specific objectives:

1. To evaluate the relationship between temperature and key demographic components—specifically mortality, fertility, and migration—by analyzing how historical temperature trends have affected these components at the sub-national level in Mexico.

2. To develop projections of future trends in mortality, fertility, and migration under a range of climate scenarios, combining Shared Socioeconomic Pathways (SSPs) and Representative Concentration Pathways (RCPs).

3. Quantify the net impact of future climate scenarios on each demographic component by applying the Attributable Fraction (AF) analytical framework. This approach will enable the decomposition of projected demographic changes (e.g., deaths, births) into two parts: one driven by socio-demographic trends independent of climate change, and another directly attributable to shifts in temperature patterns.

4. Implement a cohort-component population projection model that integrates climate-sensitive projections of mortality, fertility, and migration. This model will generate detailed sub-national population projections for Mexico, disaggregated by age and gender, extending through the end of the 21st century.

Data Sources

This study considers a diverse set of demographic and climate data sources to account for the effect of climate change on each demographic component.

Demographic information is primarily sourced from the National Institute of Statistics and Geography (INEGI), specifically from the 2020 Population and Housing Census, which provides detailed age- and sex-specific data at the state level. These data serve as the baseline population for the implementation of the cohort-component projection model.

Vital statistics on births and deaths, also provided by INEGI's civil records system, are used to derive fertility and mortality rates by age and sex across Mexican states. Migration data are compiled from the Mexican official demographic estimates published by the National Population Council (CONAPO). To benchmark and contextualize the socioeconomic future population scenarios, we also reference sub-national projections developed by Regules García, Gómez-Ugarte, Zoraghein, and Jiang (2024), which align with Shared Socioeconomic Pathways (SSPs).

Climate data are obtained from two main sources. For historical climate analysis, we use data from ERA5-Land, a high-resolution reanalysis dataset, which offers daily and monthly temperature series suitable for sub-national demographic analysis. For future climate projections, we rely on the outputs from the Coupled Model Intercomparison Project Phase 6 (CMIP6), corresponding to various combinations of Shared Socioeconomic Pathways (SSPs) and Representative Concentration Pathways (RCPs). These projections allow for the analysis of temperature trajectories at sub-national levels across Mexico throughout the 21st century.

Contribution

By employing this methodology,, we propose a framework that enables to (i) incorporate empirical evidence of the climate change effect on population dynamics (ii) dynamically accounts for the second round effect of demographic processes in the cohort component model (for instance, increase mortality due to climate extremes would affect the number of women with reproductive age which in turn influence fertility) (iii) explicitly make assumption on adaptation for each demographic component.

This research is expected to provide crucial insights for policymakers in Mexico by quantifying the potential demographic consequences of climate change at a sub-national level. The findings will support the development of targeted adaptation and mitigation strategies to build resilient communities in the face of ongoing and future climate change.

References

Annual-Global-Climate-Report. (2024). *Annual 2019 global climate report — national centers for environmental information (ncei).* `https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/201913`. (Accessed: 2024-06-09)

Barreca, A., Deschenes, O., & Guldi, M. (2018, jul). Maybe next month? temperature shocks and dynamic adjustments in birth rates. *Demography*, *55*(4), 1269–1293. Retrieved from `http://dx.doi.org/10.1007/s13524-018-0690-7` doi: 10.1007/s13524-018-0690-7

Berlemann, M., & Steinhardt, M. F. (2017, nov). Climate change, natural disasters, and migration—a survey of the empirical evidence. *CESifo Economic Studies*, *63*(4),

353–385. Retrieved from http://dx.doi.org/10.1093/cesifo/ifx019 doi: 10.1093/cesifo/ifx019

Cho, H. (2019, dec). Ambient temperature, birth rate, and birth outcomes: evidence from south korea. *Population and Environment*, *41*(3), 330–346. Retrieved from http://dx.doi.org/10.1007/s11111-019-00333-6 doi: 10.1007/s11111-019-00333-6

Conte Keivabu, R., Cozzani, M., & Wilde, J. (2024, aug). Temperature and fertility: Evidence from spain. *Population Studies*, 1–15. Retrieved from http://dx.doi.org/10.1080/00324728.2024.2382152 doi: 10.1080/00324728.2024.2382152

Gasparrini, A., Guo, Y., Sera, F., Vicedo-Cabrera, A. M., Huber, V., Tong, S., ... Armstrong, B. (2017, dec). Projections of temperature-related excess mortality under climate change scenarios. *The Lancet Planetary Health*, *1*(9), e360–e367. Retrieved from http://dx.doi.org/10.1016/S2542-5196(17)30156-0 doi: 10.1016/s2542-5196(17)30156-0

Hoffmann, R., Dimitrova, A., Muttarak, R., Crespo Cuaresma, J., & Peisker, J. (2020, sep). A meta-analysis of country-level studies on environmental change and migration. *Nature Climate Change*, *10*(10), 904–912. Retrieved from http://dx.doi.org/10.1038/s41558-020-0898-6 doi: 10.1038/s41558-020-0898-6

Marteleto, L. J., Maia, A. G., & Rodrigues, C. G. (2023, aug). Climate and fertility amid a public health crisis. *Population Studies*, *77*(3), 437–458. Retrieved from http://dx.doi.org/10.1080/00324728.2023.2228288 doi: 10.1080/00324728.2023.2228288

Regules García, R., Gómez-Ugarte, A. C., Zoraghein, H., & Jiang, L. (2024, jun). Subnational population projections for mexico under the shared socioeconomic pathways (ssps) in the context of climate change. *Population Research and Policy Review*, *43*(3). Retrieved from http://dx.doi.org/10.1007/s11113-024-09888-1 doi: 10.1007/s11113-024-09888-1