Climate Migration Model Intercomparison

Author: Thomas Bearpark

Quantifying and projecting climate migration is a critical challenge for policymakers and researchers. While causal inference, agent-based, gravity, and general equilibrium models have been employed to estimate the climate-migration relationship, their results often diverge, and they are typically used in isolation and at different spatio-temporal scales. This paper aims to bridge this gap by introducing a unified conceptual framework, designed to compare and evaluate the assumptions and outputs of these diverse models at a common scale. We illustrate our comparison using an empirically relevant case study: estimating and projecting the relationship between annual average temperature and internal state-to-state migration in the United States. We show that model results can coincide under certain conditions and illustrate mechanisms through which they can diverge. We conclude by combining insights from each approach, with the aim of improving the quantitative modelling of the climate migration relationship and facilitating future interdisciplinary collaboration.

Development of a sub-national & national habitability index

Author: Brigitte Melly

Global environmental change, social instability, and demographic shifts are fundamentally altering patterns of human habitation (Rockström et al. 2023; Sterly et al. 2025). As climate impacts intensify, governance systems evolve, and populations grow, it is becoming increasingly critical to understand the factors that make a place habitable, and how this habitability may shift over time. Numerous studies highlight increasing pressures on resources and explore potential tipping points where adaptation to severe environmental conditions becomes unattainable. Richardson et al. (2023) observed that six of the nine planetary boundaries have already been transgressed, suggesting that humanity is no longer operating within a safe environmental space. However, the effects of these transgressions are not uniformly distributed, with some regions facing compounding vulnerabilities due to intersecting climate, ecological, and socio-economic challenges. Consequently, the most marginalized populations bear the brunt of these challenges (Horton et al. 2021; Gupta et al 2024). Recent research has highlighted the importance of developing a comprehensive understanding of human habitability that incorporates both the physical systems in which people live and the social contexts shaping those populations. Current indices, however, often focus on specific aspects of habitability, such as development or conservation targets, but fail to provide an integrated perspective. Horton et al. (2021) defines habitability as the "environmental conditions in a particular setting that support healthy human life, productive livelihoods, and sustainable intergenerational development." Building on this definition, Horton et al. (2021) and Wrathall et al. (2023) propose three interacting dimensions of habitability: basic human survival (safety), livelihood security and resilience, and societal capacity to manage and adapt to environmental risks. Thus, a robust assessment of habitability must address these dimensions by evaluating baseline environmental conditions as well as the role of governance and socio-political factors that influence resilience and social capacity. While creating a single uniform index at a global scale to capture all dimensions of habitability is not currently feasible, it is imperative to advance from theoretical discussions toward quantifiable and comparable measures that can be translated from global to regional contexts, while still capturing nuanced multi-scalar understanding of habitability. This study presents the development of a novel habitability index at both national and sub-national scales. The index integrates datasets representing baseline environmental conditions (ecosystems) and socio-political factors (governance and conflict) to assess the potential for regions to support healthy and safe human life. The proposed model incorporates key drivers of habitability using open-source, globally available datasets. Data layers are rescaled to a uniform scale to ensure consistent interpretation, where higher values always indicate more favourable conditions. The model's components include: 1. Ecosystem Condition/Status: Terrestrial ecosystems were evaluated to assess baseline environmental conditions essential for human habitability. Data from the World Terrestrial Ecosystems dataset (Sayre et al. 2020), which categorizes ecosystems based on climate (temperature and moisture), land cover, and landform, serves as the primary source. The dataset consists of 415 ecosystem classes at 250m resolution, providing a granular view of environmental variability. Each ecosystem component (climate, land cover, and landform) was scored on a scale of 0-2, reflecting suitability for human habitation. The individual scores were combined into a composite ecosystem score for each of the ecosystems. These scores were then weighted by the proportion of land area within each habitability class to generate aggregated national or sub-national distribution of classes. The analyses also consider land degradation, a critical factor influencing ecosystem status. Existing frameworks, such as those by Cherlet et al. (2018) and Wuepper et al. (2021), use multiple indicators to systematically identify degraded areas. Combining indices in this manner enhances the reliability of outputs by compensating for individual dataset limitations. Thus, we combine six indices that covered different aspects of ecosystem function to derive a degradation score. The degradation score was then added to the ecosystem score to generate an ecosystem status at both national and sub-national scales. Furthermore, we investigated the use of earth system boundary (ESB) transgressions as a mediator for ecosystem status based on Rockström et al. (2023). This dataset indicates the quantity and distribution of the eight earth boundaries that have been transgressed. These transgressions would impact the ability of a system to safeguard its functions thereby impacting its ability to support humans and protect them from harm. We propose that more transgressions would decrease the integrity status of the ecosystem, and so the transgressions were added to the ecosystem score to also generate an ecosystem status and compared with the above scores. 2. Governance and Conflict: Governance and conflict data address the socio-political and economic dimensions of habitability. The Bertelsmann Transformation Index (BTI) and World Governance Indicators (WGI) were evaluated for their suitability in capturing governance-related variables. While BTI provides detailed assessments of political management, its coverage is limited to 134 countries. Conversely, WGI assesses over 200 countries but does not consolidate its six dimensions into a single index. For this study, government effectiveness was selected as a representative indicator due to its robust correlation with BTI scores and its comprehensive evaluation of public service quality, civil service independence, and policy credibility (Kaufmann et al. 2010). Corruption was also included using the Subnational Corruption Index (SCI), which estimates levels of petty and grand corruption across 178 countries (Crombach et al. 2024; Crombach & Smits 2024). Where sub-national data were unavailable, the WGI control of corruption dataset was used to enhance global coverage. Both governance effectiveness and corruption indices were inversely scaled so that lower corruption and higher effectiveness received higher scores. Conflict data were sourced from the Armed Conflict Location & Event Data Project (ACLED), which provides global coverage of conflict events. Fatality data were aggregated at the sub-national level and normalized using WorldPop population data to calculate conflict fatality ratios. These ratios were averaged over five years (2019-2024) to derive a representative score. The three governance components – government effectiveness, corruption, and conflict – were evenly aggregated into a single governance score, ensuring consistency in scaling across all dimensions. The habitability index combines the ecosystem status and governance/conflict scores to represent the interaction between environmental and socio-political factors. For example, strong governance can mitigate the impacts of environmental stress, while weak governance may exacerbate vulnerabilities. This integrated approach provides a holistic perspective on habitability, addressing all three dimensions outlined by Horton et al. (2021). While the index provides a standardized framework for evaluating habitability, it still requires a validation framework. Additionally, the index should be complemented with qualitative data and place-specific characteristics to address local nuances. This combined approach ensures that habitability assessments remain grounded in the realities of the regions being studied. The index has broad applicability, offering insights into: a) Development Planning: Informing strategies for sustainable development by highlighting areas requiring targeted interventions; b) Conservation Priorities: Supporting biodiversity and ecosystem management by aligning habitability goals with environmental conservation and sustainability goals; c) Climate Change Impacts: Identifying regions at risk of becoming uninhabitable due to climate stressors and weak adaptive capacity; d) Population Dynamics: Understanding migration patterns, whether forced or voluntary, and their relationship with environmental and governance factors. This habitability index combined with climate hazard data has the potential to further identify potential hotspots of extreme exposure and risk to the world's most vulnerable populations. This study advances the conceptualisation of habitability by proposing a globally applicable, data-driven index that integrates environmental and socio-political factors. By quantifying habitability across scales, the index bridges theoretical discussions with actionable insights, enabling stakeholders to address pressing global challenges.

Harmonized Pan-European Fixed Asset Values: A Critical Variable for Exposure Estimation in Human Settlements

Author: Michele Melchiorri

The Estimation of Fixed Asset Values in human settlements at pan-European scale addresses a significant gap in current exposure and vulnerability data by developing harmonized geospatial data, and integrating this new information in the JRC Risk Data Hub information system. Our research fills this crucial gap in vulnerability information by combining the EU-wide HANZE grid with high-resolution (100m) built-up surface data from the Global Human Settlement Layer BUILT product for 2020. Key aspects of our research include: i. Novelty and data gap: Harmonised geospatial data for fixed asset value (FAV) in European human settlements has been a significant gap in current exposure data. Our study fills this gap, providing essential information for disaster risk management and climate adaptation planning. This comprehensive dataset updated to 2020 enables policymakers and urban planners to make more informed decisions about resource allocation and adaptation strategies, ultimately enhancing community resilience in the face of climate change. The availability of a time series (in 5 years intervals) covering the range 2000 – 2020 allows trend analysis. ii. Innovative methodology based on geospatial data integration: We obtained FAV estimation by constraining and masking the EU-wide HANZE grid to built-up surfaces mapped by the Global Human Settlement Layer BUILT product for 2020 at a high spatial resolution of 100m. This novel approach allows for a more accurate and detailed assessment of fixed asset values, which is crucial for understanding the potential economic impacts of climate-related hazards and informing adaptation measures. The geospatial grid-based approach is flexible to adapt to any user need aggregating the grid to an area of interest (i.e. a province, region, city, etc.). iii. Enhancement of existing crisis management tools: The essential variable we've developed adds significant value to the EC JRC Risk Data Hub, enhancing its ability to characterize the exposure of pan-European human settlements to natural hazards. This improvement allows for more sophisticated risk assessments and adaptation planning, contributing to better-informed policy decisions and more effective climate resilience strategies. iv. Comprehensive analysis: Our dataset quantifies total FAV in EUR, FAV per capita, and FAV per km2, aggregated from the grid level to NUTS3 reporting units (country and EU grand total), and disaggregated by Degree of Urbanisation typology and hazard type. This multi-faceted approach provides a nuanced understanding of asset distribution and vulnerability across different settlement types and regions, enabling targeted adaptation efforts and more equitable resource allocation. v. Practical applications: When integrated into the Risk Data Hub, the FAV dataset can answer critical questions about the FAV of human settlements exposed to specific hazards (e.g., coastal flooding, riverine flooding, earthquake hazards etc.), the average FAV of different settlement types (cities, towns and suburbs, rural areas), and the residual FAV outside human settlements. These insights are invaluable for prioritizing adaptation efforts, designing climate-resilient infrastructure, and developing targeted policies to protect vulnerable assets and communities. By providing a comprehensive view of fixed asset values across pan-European human settlements, this research contributes significantly to the field of disaster risk management in all fields that require knowing the value of assets at risk. It also actively contributes to the Sendai Framework Priority 2 (understanding disaster risk), and it enables more accurate risk assessments, informs targeted adaptation strategies, and contributes to the development of resilient communities in the times of a changing climate. About the JRC Risk Data Hub: https://drmkc.jrc.ec.europa.eu/risk-data-hub#/atlas. The Risk Data Hub (RDH) of the Disaster Risk Management Knowledge Centre (DRMKC) is a pioneering platform designed to centralize and standardize risk, damage and loss data at a pan-European level. Developed with the goal of supporting risk assessment and risk analysis processes, the RDH facilitates the collection, sharing, and analysis of data that is crucial for understanding and mitigating risks. This comprehensive repository offers a variety of datasets, tools, and resources that can be utilized by policymakers, researchers, and practitioners in the field of disaster risk reduction.

Natural Hazard Risk Modeling for Global Human Displacement

Author: Simona Meiler

Globally, disasters, conflict, and violence displace millions of people every year. Disasters encompass both geophysical and weather-related events, with climate change driving increases in the frequency and intensity of the latter and, consequently, the displacements they cause. Quantifying displacement risk from these events at a global scale is essential for understanding the magnitude of potential impacts and informing strategies to build more resilient societies. To address this need, the Internal Displacement Monitoring Centre (iDMC) has recently launched a new iteration of its global disaster displacement risk model. Here, we present the results of this effort to develop a globally consistent displacement risk model that integrates multiple hazards - tropical cyclones, coastal floods, river floods, and droughts - to assess both present-day and future risks under optimistic and pessimistic climate scenarios for mid- and late-century. Our findings reveal that current displacement risk amounts to 27 million Annual Average Displacements (AAD). By 2100, global displacement risk could increase by 89% (180%) under optimistic (pessimistic) climate scenarios, displacing over 52 (77) million people annually. We evaluate the application of classic probabilistic risk modeling methods to human displacement through a methodological stocktaking, highlighting challenges and opportunities to enhance understanding. The modular design of our risk model supports continuous updates and the integration of additional hazards. For example, we demonstrate its flexibility by incorporating earthquake-induced displacement risks, showcasing its potential for further development. These advancements provide critical insights to support global climate negotiations, including loss and damage initiatives, adaptation strategies, and disaster risk reduction efforts.