Habitability & Climate Mobility Modeling

Alex de Sherbinin, PhD
Interim Director
Center for International Earth Science Information Network (CIESIN)
Columbia Climate School, Columbia University

Workshop on Climate Change and Human Migration:
An Earth Systems Science Perspective

National Academies of Science, 19 March 2024

The “Habitability” Concept

Definition of habitability

- Habitable: capable of being lived in; suitable for habitation
- The environmental conditions in a particular setting that support **healthy human life**, **productive livelihoods**, and **sustainable intergenerational development** *at a reasonable cost*
- Climate change may undermine one or more of the dimensions of habitability: **basic human survival**, **livelihood security**, and **societies' capacity to manage environmental risks**

POLICY FORUM

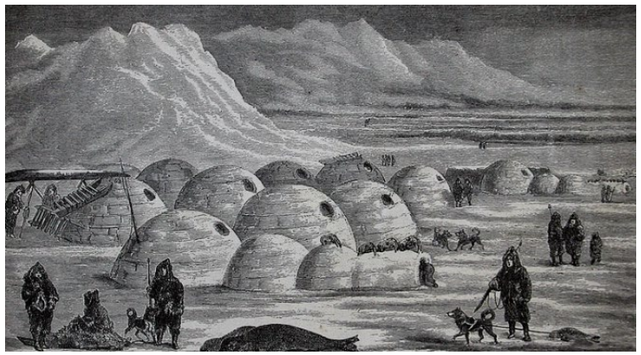
Assessing human habitability and migration

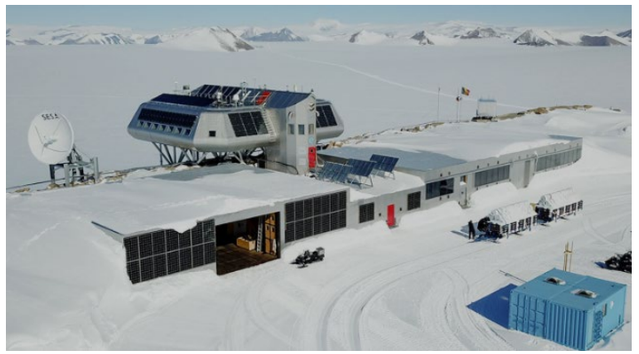
Integrate global top-down and local bottom-up analyses

By Radley M. Horton[1], Alex de Sherbinin[2], David Wrathall[3], Michael Oppenheimer[4]

Habitability loss is increasingly recognized as an important dimension of climate risk assessment and one with complex linkages to migration. Most habitability assessments, like climate risk assessments more generally, are

doi: 10.1126/science.abi8603

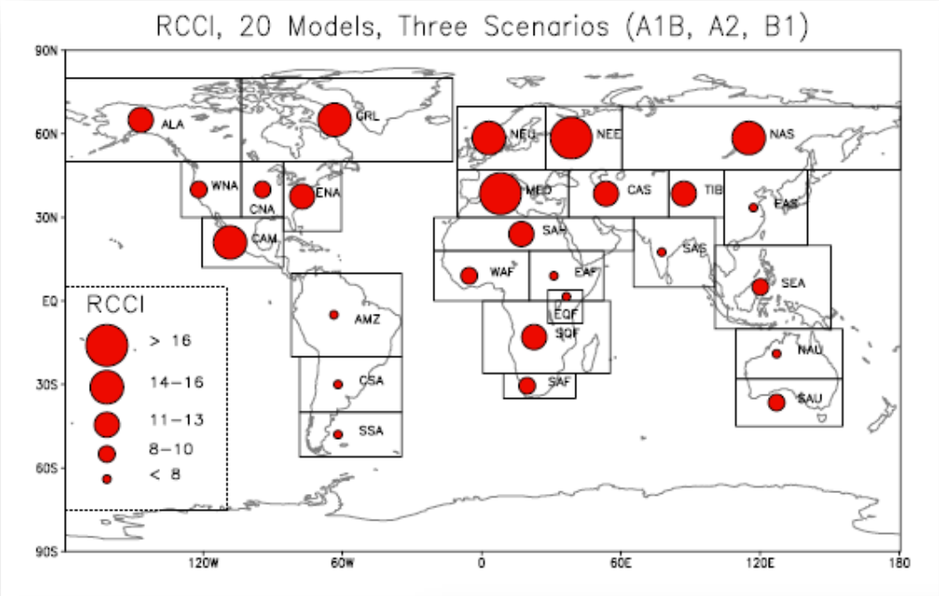




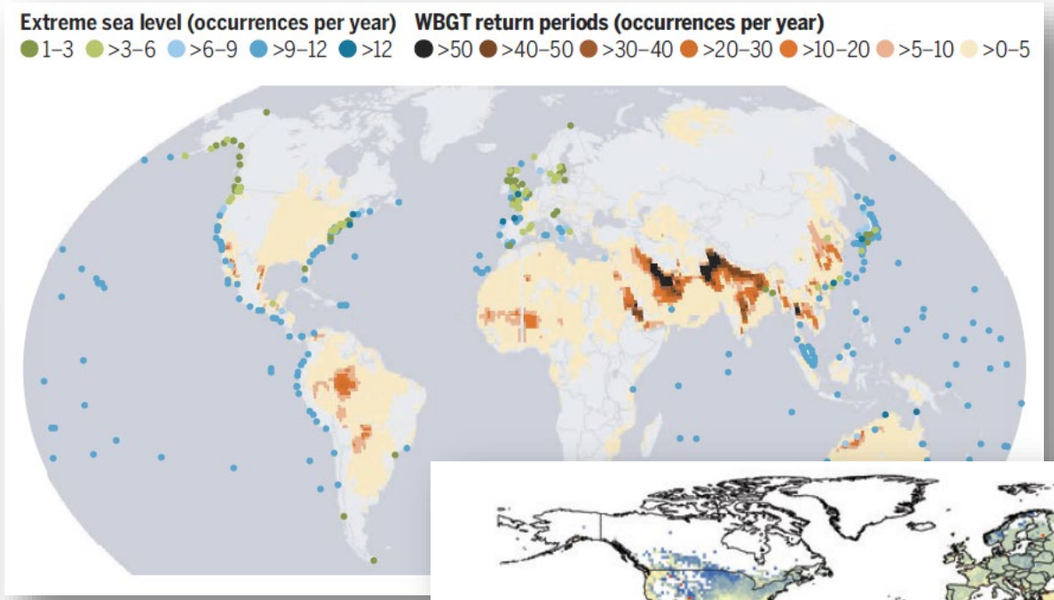
Key messages

- Top-down, climate impact modeling can help ID “hotspots” and warn of potential dire consequences of CC, but is often overly deterministic when considering societal responses (cf. Hulme 2011, “Reducing the future to climate”)
- Amounts of distress migration are likely to rise in response to climate stressors, but also involuntary immobility
  - Policy: “the Global Compact on Migration calls on governments to ‘strengthen joint analysis and sharing of information to better map, understand, predict, and address migration movements’ as a result of climate change impacts—all of which are essential aspects of habitability assessment” (p.1282)
- We propose a marriage of top-down assessment and bottom-up co-production of knowledge for local adaptation solutions (or bottom-up modeling)

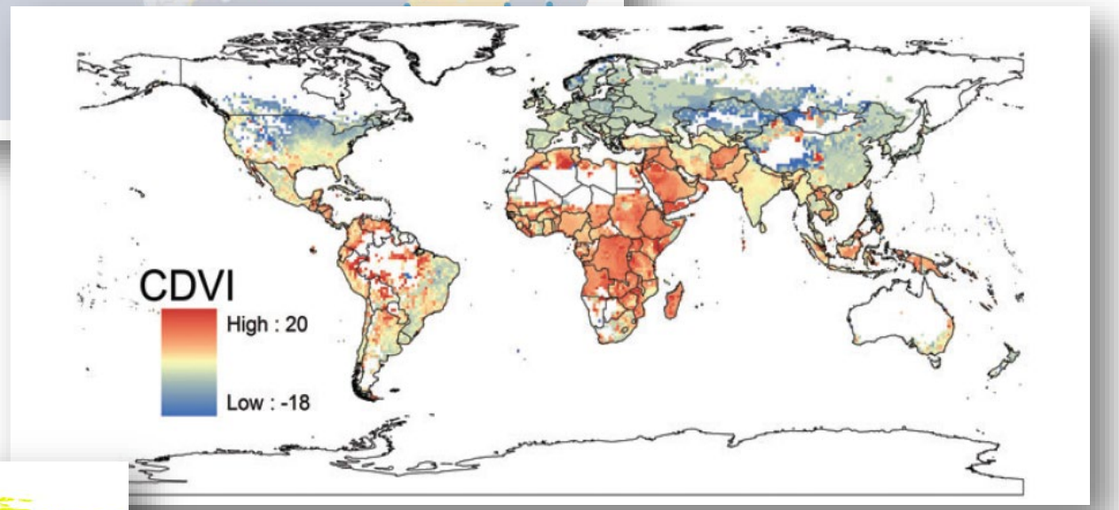
Hotspots of Climate Impacts



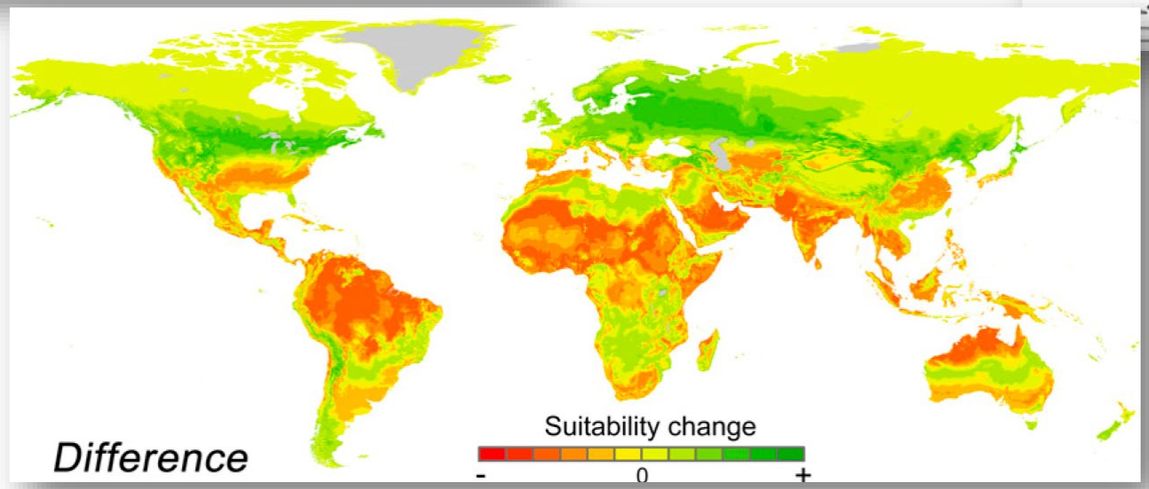
Source: Giorgi, F. 2006. Climate change hot-spots, *Geophysical Research Letters*, 33, L08707



Source: Horton et al. 2020 based on Oppenheimer et al 2019 and Li et al. 2020.

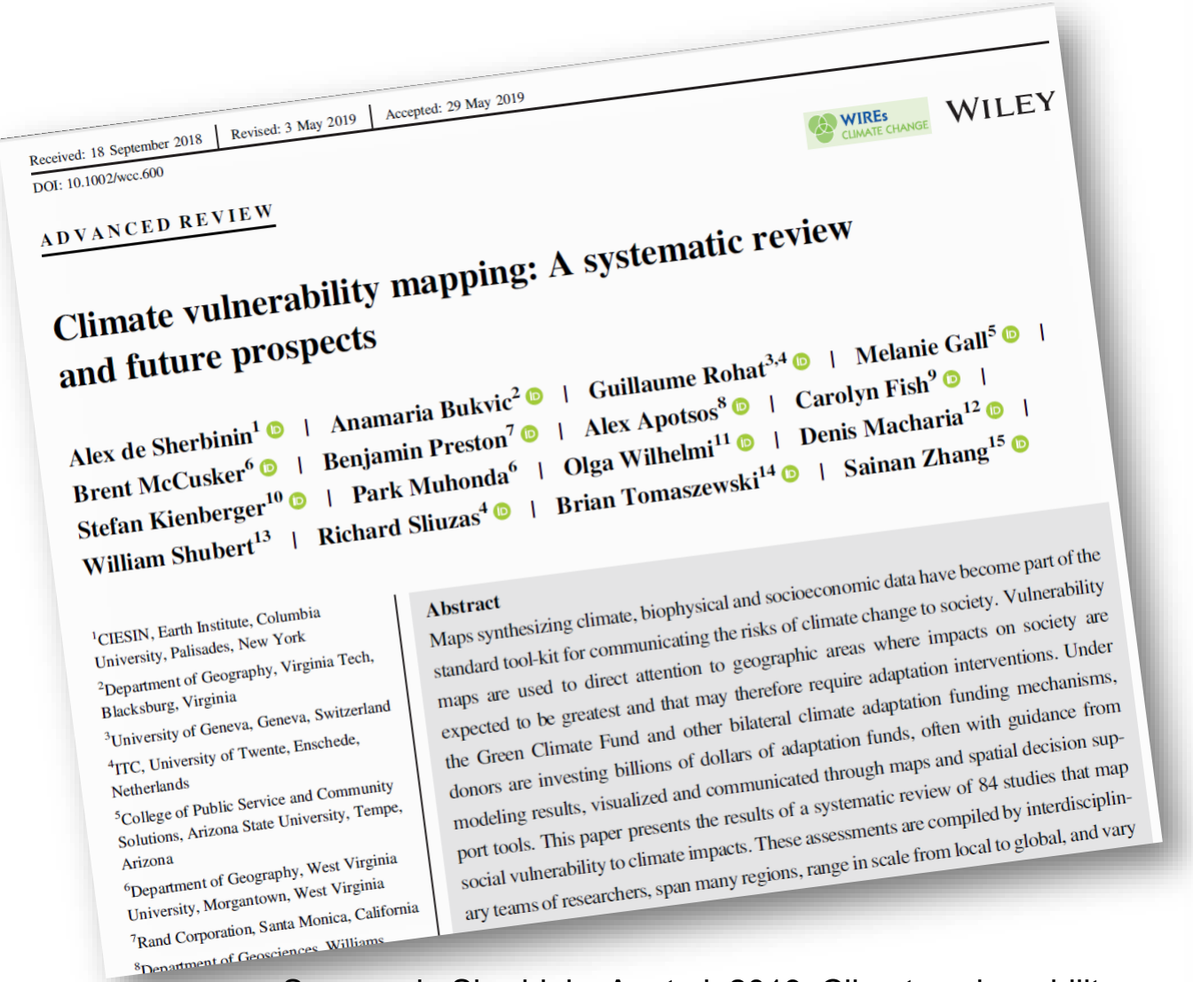


Source: Samson, J. et al. 2011. Geographic disparities and moral hazards in the predicted impacts of climate change on human populations. *Global Ecology and Biogeography* doi:10.1111/j.1466-8238.2010.00632.x



Source: Xu, C. et al. 2020. Future of the human climate niche. *Proceedings of the National Academy of Sciences*, 117(21), 11350-11355.

Climate Vulnerability Mapping



Received: 18 September 2018 | Revised: 3 May 2019 | Accepted: 29 May 2019
DOI: 10.1002/wcc.600

WIREs CLIMATE CHANGE WILEY

ADVANCED REVIEW

Climate vulnerability mapping: A systematic review and future prospects

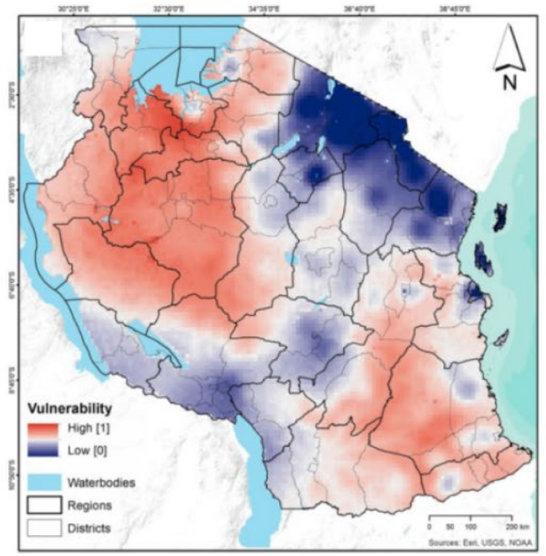
Alex de Sherbinin[1] | Anamaria Bukvic[2] | Guillaume Rohat[3,4] | Melanie Gall[5] | Brent McCusker[6] | Benjamin Preston[7] | Alex Apotsos[8] | Carolyn Fish[9] | Stefan Kienberger[10] | Park Muhonda[6] | Olga Wilhelmi[11] | Denis Macharia[12] | William Shubert[13] | Richard Sliuzas[4] | Brian Tomaszewski[14] | Sainan Zhang[15]

[1]CIESIN, Earth Institute, Columbia University, Palisades, New York
[2]Department of Geography, Virginia Tech, Blacksburg, Virginia
[3]University of Geneva, Geneva, Switzerland
[4]ITC, University of Twente, Enschede, Netherlands
[5]College of Public Service and Community Solutions, Arizona State University, Tempe, Arizona
[6]Department of Geography, West Virginia University, Morgantown, West Virginia
[7]Rand Corporation, Santa Monica, California
[8]Department of Geosciences, Williams

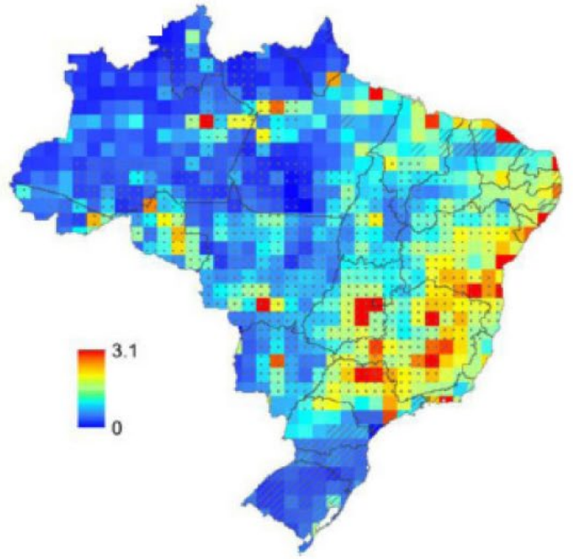
Abstract

Maps synthesizing climate, biophysical and socioeconomic data have become part of the standard tool-kit for communicating the risks of climate change to society. Vulnerability maps are used to direct attention to geographic areas where impacts on society are expected to be greatest and that may therefore require adaptation interventions. Under the Green Climate Fund and other bilateral climate adaptation funding mechanisms, donors are investing billions of dollars of adaptation funds, often with guidance from modeling results, visualized and communicated through maps and spatial decision support tools. This paper presents the results of a systematic review of 84 studies that map social vulnerability to climate impacts. These assessments are compiled by interdisciplinary teams of researchers, span many regions, range in scale from local to global, and vary

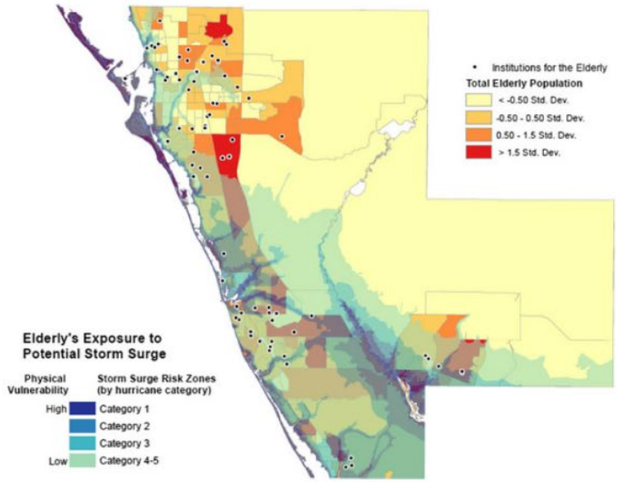
Source: de Sherbinin, A. et al. 2019. Climate vulnerability mapping: a systematic review and future prospects. *WIRES Climate Change.* https://doi.org/10.1002/wcc.600



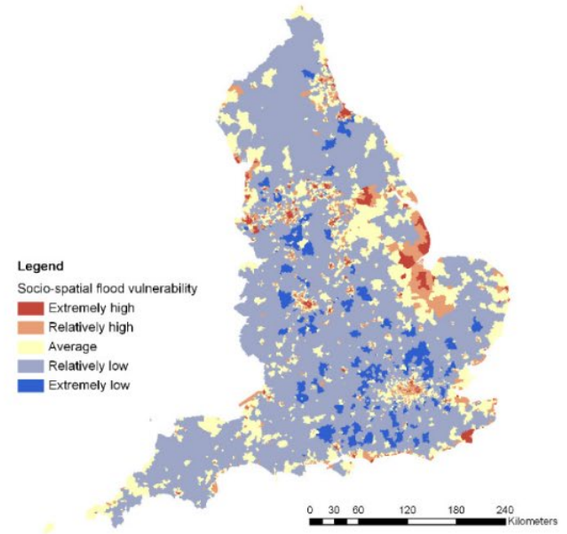
Vulnerability to Malaria in Tanzania, circa 2010 (Hagenlocher and Castro 2015)



Socio-Climatic Vulnerability Index for Brazil circa 2010; hatching indicates regions where climate projection-related uncertainty is high (Filho et al. 2016)



Physical vulnerability of the elderly to potential storm surge in Sarasota County, circa 2010 (Wang and Yarnel 2012)



Socio-spatial flood vulnerability in England (Lindley et al. 2011)

PERN cyberseminar (March 2023)

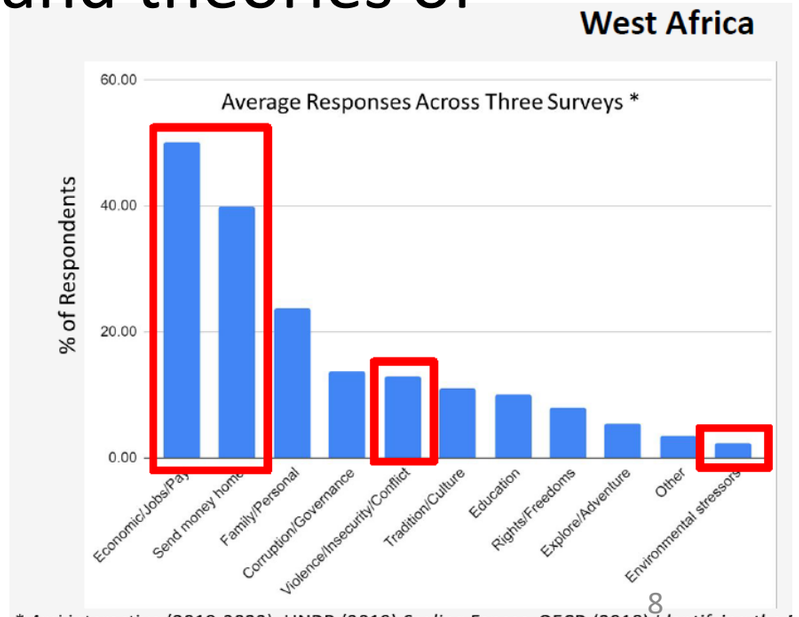
"The habitability concept in the field of population-environment studies"

- Habitability of SESes has a physical dimension, a socially constructed dimension (related to capabilities), and an emotive dimension (place attachment or a sense that a place is "home")
- Habitability is an emergent property – a place cannot easily be defined as habitable or uninhabitable, but its habitability is revealed through other variables, or after successive shocks (Sterly, Gavonel)
- Habitability can be ascertained as an accumulation of individually based determinations of habitability (Wrathall)
- Habitability has three dimensions: collective ability to respond to risk (governance), livelihood resilience (including food security), physical and psychological safety (Wrathall)
- Climate change reduces the level of habitability of a SES up to a point at which a small perturbation (e.g., a marginal increase in temperature variability) could trigger a social tipping point (Gavonel)

See https://www.populationenvironmentresearch.org/cyberseminars/11007

Reflections on day 1 presentations

- Issues with climate as the starting point
  - In diagrams: climate shock is generally on the left hand side
  - May be more tractable as a problem, but mis-identifies the causes (cf. Ribot et al. 2020 “Climate of Anxiety”)
  - How do we better frame our questions? (cf. Cottier et al. 2022 “Framing the frame”)
- Western academics are defining the categories and theories of migration – but we are at risk of “othering” the migrant and missing their voices (cf. Khosravi 2024 “Doing migration studies with an accent”)
  - What do migrants (and “stayers”) themselves say?
  - What are the lived experiences of migrants?



* 4mi interactive (2019-2022), UNDP (2019) *Scaling Fences*, OECD (2018) *Identifying the F Driving W African Migration*

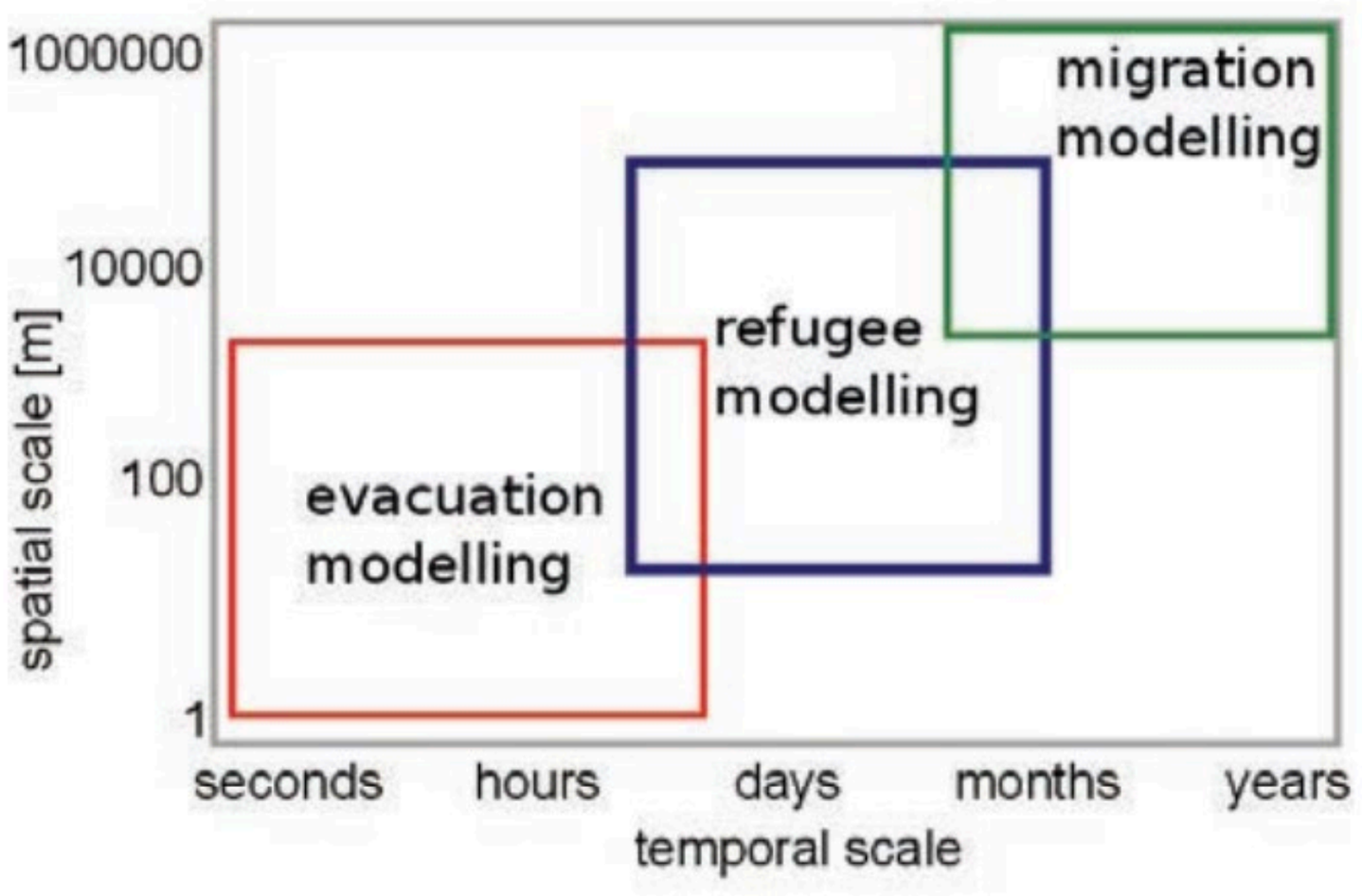
Climate Mobility Modeling

With particular reference to future projections / scenarios

Why develop scenarios for future population distribution and climate migration distribution?

- Population distributions are unlikely to evolve as they have in the past
- Academics have the tools, are curious, and there is **funding for research**
- Demographers have always projected populations to meet needs for **planning purposes**, since population is fundamental
- The humanitarian community wants projections of likely displacement for **humanitarian response**
- Development actors are grappling with potential **limits to adaptation for rural livelihoods**, trapped populations, and how population may be redistributed as a result
- Receiving countries want to understand the magnitude of future flows – especially of potential **crisis migration**
- Policy makers want "**what if"** scenarios based on alternative futures – high/low impacts, pop projections, open/closed borders, and other policy interventions – and we can't do a real world experiment
- Some models are better at causal inference, others prediction, and some can do both

Scales for modeling



Source: Groen (2016) *Simulating Refugee Movements: where would you go?*

Modeling should be grounded in migration theory

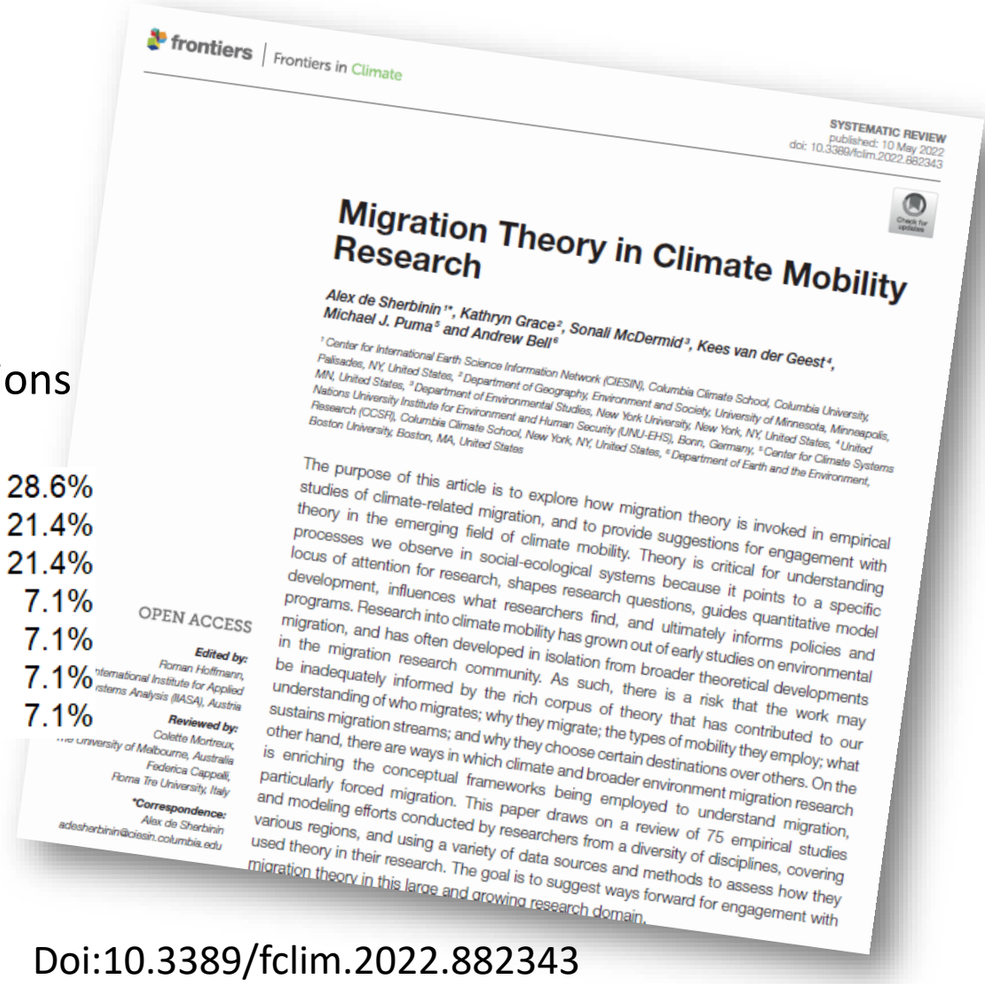
Migration theory invoked by econometric studies (n=22)

Neoclassical	27.3%
NELM	18.2%
Livelihoods Framework	13.6%
Other Theories *	9.1%
Push-Pull	9.1%
Env Mig Frameworks	9.1%
No Theory	9.1%
Theories Sust Mig	4.5%

Migration theory invoked by projections and future scenarios studies (n=14)

Neoclassical	28.6%
Push-Pull	21.4%
Other Theories *	21.4%
No Theory	7.1%
NELM	7.1%
Mobility Transition / Migration Hump	7.1%
Env Mig Frameworks	7.1%

* Other Theories (e.g. Life Course, Socio-Ecological Systems, Cultural Ecology)


frontiers | Frontiers in Climate

SYSTEMATIC REVIEW
published: 10 May 2022
doi: 10.3389/fclim.2022.882343

Migration Theory in Climate Mobility Research

Alex de Sherbinin[1]*, Kathryn Grace[2], Sonali McDermid[3], Kees van der Geest[4], Michael J. Puma[5] and Andrew Bell[6]

[1] Center for International Earth Science Information Network (CIESIN), Columbia Climate School, Columbia University, Palisades, NY, United States, [2] Department of Geography, Environment and Society, University of Minnesota, Minneapolis, MN, United States, [3] Department of Environmental Studies, New York University, New York, NY, United States, [4] United Nations University Institute for Environment and Human Security (UNU-EHS), Bonn, Germany, [5] Center for Climate Systems Research (CCSR), Columbia Climate School, New York, NY, United States, [6] Department of Earth and the Environment, Boston University, Boston, MA, United States

The purpose of this article is to explore how migration theory is invoked in empirical studies of climate-related migration, and to provide suggestions for engagement with theory in the emerging field of climate mobility. Theory is critical for understanding processes we observe in social-ecological systems because it points to a specific locus of attention for research, shapes research questions, guides quantitative model development, influences what researchers find, and ultimately informs policies and programs. Research into climate mobility has grown out of early studies on environmental migration, and has often developed in isolation from broader theoretical developments in the migration research community. As such, there is a risk that the work may be inadequately informed by the rich corpus of theory that has contributed to our understanding of who migrates; why they migrate; the types of mobility they employ; what sustains migration streams; and why they choose certain destinations over others. On the other hand, there are ways in which climate and broader environment migration research is enriching the conceptual frameworks being employed to understand migration, particularly forced migration. This paper draws on a review of 75 empirical studies and modeling efforts conducted by researchers from a diversity of disciplines, covering various regions, and using a variety of data sources and methods to assess how they used theory in their research. The goal is to suggest ways forward for engagement with migration theory in this large and growing research domain.

OPEN ACCESS

Edited by:
Roman Hoffmann,
International Institute for Applied Systems Analysis (IIASA), Austria

Reviewed by:
Colette Mortreux,
University of Melbourne, Australia
Federica Cappelli,
Roma Tre University, Italy

*Correctness:
Alex de Sherbinin
adesherbinin@ciesin.columbia.edu

Doi:10.3389/fclim.2022.882343

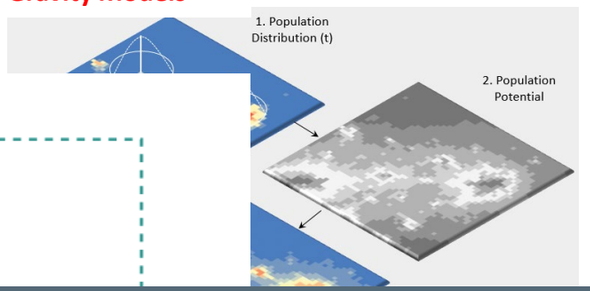
		Migration capabilities	
		Low	**High**
Migration aspirations	High	Involuntary immobility (feeling "trapped")	Voluntary mobility (most forms of migration)
	Low	Acquiescent immobility	Voluntary immobility and involuntary mobility (refugees, resettlement)

Based on De Haas (2021, Table 1, p. 22).

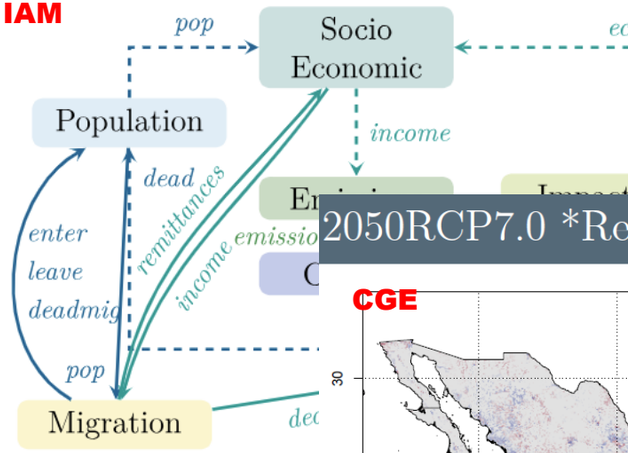
Modeling approaches that have been applied to climate migration

1. The “Exposure Model”
2. Agent Based Models (ABMs)
3. System Dynamics
4. Statistical Extrapolation Models
5. Machine Learning
6. Gravity Models
7. Integrated Assessment Models (IAMs)
8. Computable General Equilibrium (CGE) models

Gravity Models

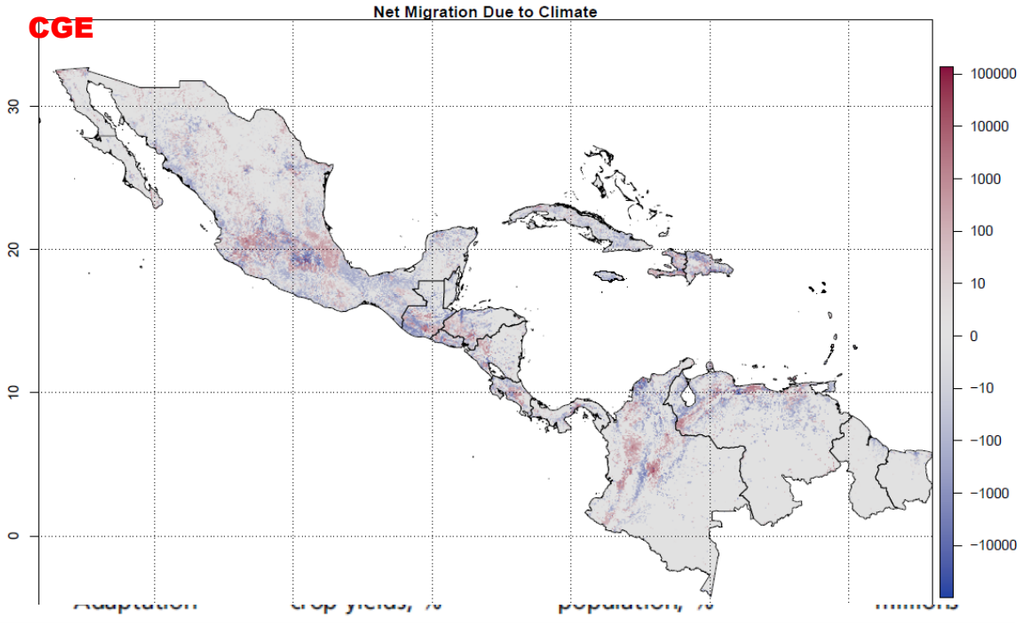


IAM



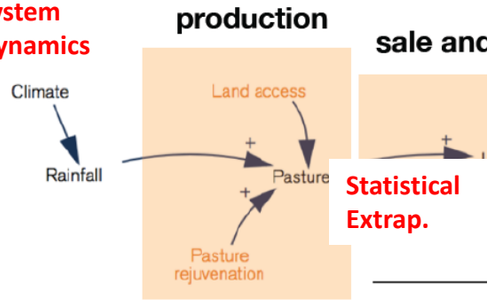
2050RCP7.0 *Results* - Climate Induced Migration

CGE



Pastoralism is a livelihood based on:

System Dynamics



Statistical Extrap.

Source: IDMC technical paper, May 2014

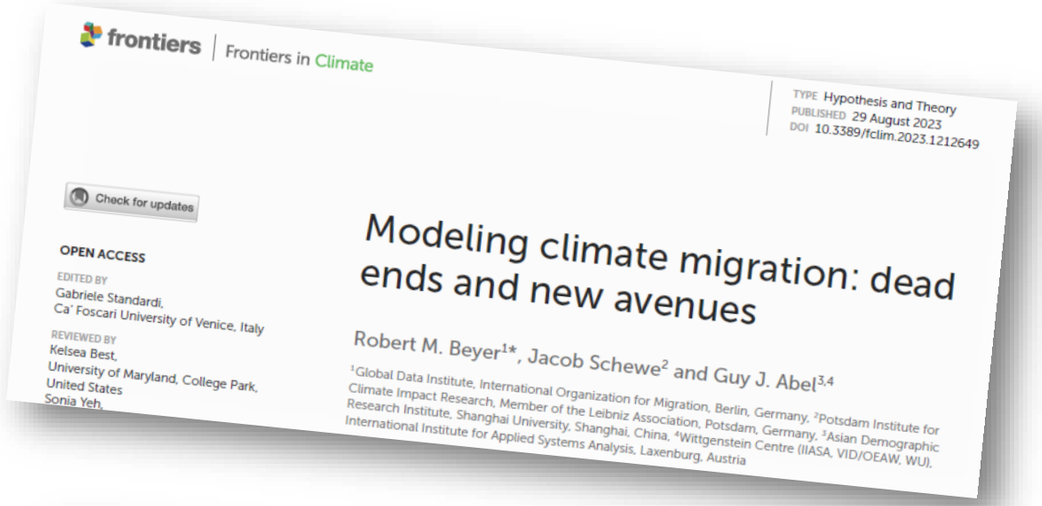
CO_2 effect				
Rosenzweig and Iglesias (38): GISS‡				
No	No	−46	9.2	6.4
Yes	No	−35	7.0	4.9
Yes	Level 1	−27	5.4	3.8
Yes	Level 2	−13	2.6	1.8

Modeling issues

"Whilst the use of different migration data and different climatic and non-climatic variables considered in models account for some of the discrepancies [in observed relationships between climate factors and migration], **several other fundamental issues are present in the large majority of models introduced to date that limit what such models can contribute to our understanding of historical trends and our ability project future trajectories of climate mobility** …" (Beyer et al 2023, p.2)

"Global human mobility in response to climatic changes and associated environmental hazards is as much a geopolitically significant topic as **an exceptionally complex challenge for quantitative modeling and forecasting**." (Beyer et al 2023, p.6)

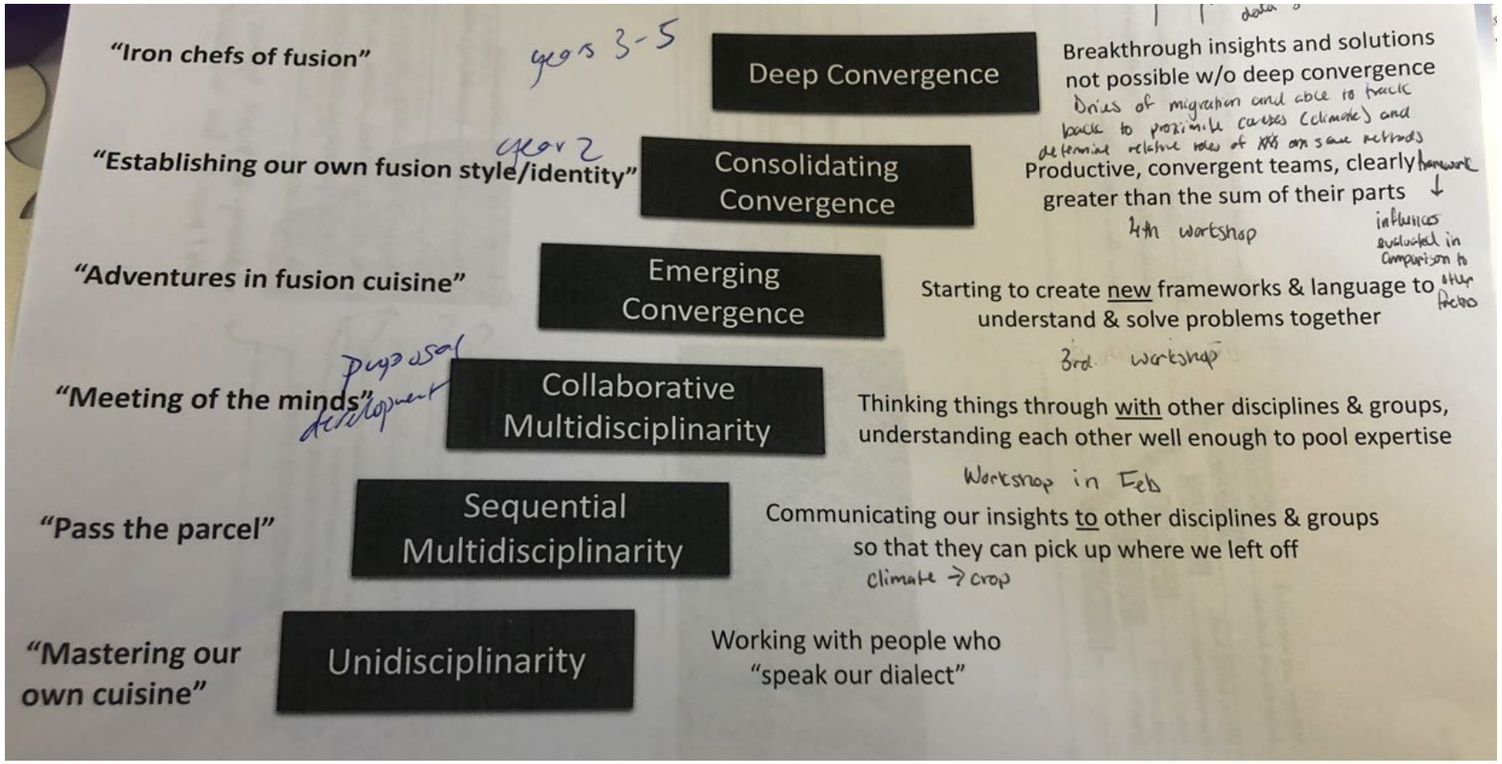
"Further model refinement will also require inputs from a broad community of experts. **Greater trans-disciplinary collaboration between natural and social scientists could help modelers capture climate-related and environmental conditions** that are unaccounted for in current models." (Schewel et al. 2024, p.13)



See: https://www.frontiersin.org/research-topics/49300/climate-mobility-modeling-methodological-advances-and-future-prospects

Thoughts on inter-/trans- disciplinary research

- From 2019-2023 served as co-I on an NSF Global Convergence Research project "Disentangling Environmental Change and Social Factors as Drivers of Migration"
- We had two climate scientists (R. Seager, S. McDermid), a geographer (me), an economist (W. Schlenker), a systems modeler (A. Bell), an environmental engineer/hydrologist (M. Puma), a political scientist (F. Cottier), and some hangers on
- Yes on:
  - shared vocabulary
  - training
  - limited resources
  - assessment / evaluation
- And, it's hard!
- Heartening that social scientists are now equal partners



Thanks!

We plan a climate mobility modeling intercomparison workshop, 25-27 September, in New York City, co-organized by CIESIN, Columbia Climate School, Princeton, Cornell, and the Global Centre for Climate Mobility. Reach out to me for more information – amd155@columbia.edu