Mapping and Modeling the Flow of Climate Change Migrants

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Center for International Earth Science Information Network (CIESIN)

The Earth Institute at Columbia University

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Workshop on Data and Methods for Modelling Migration Associated with Climate Change

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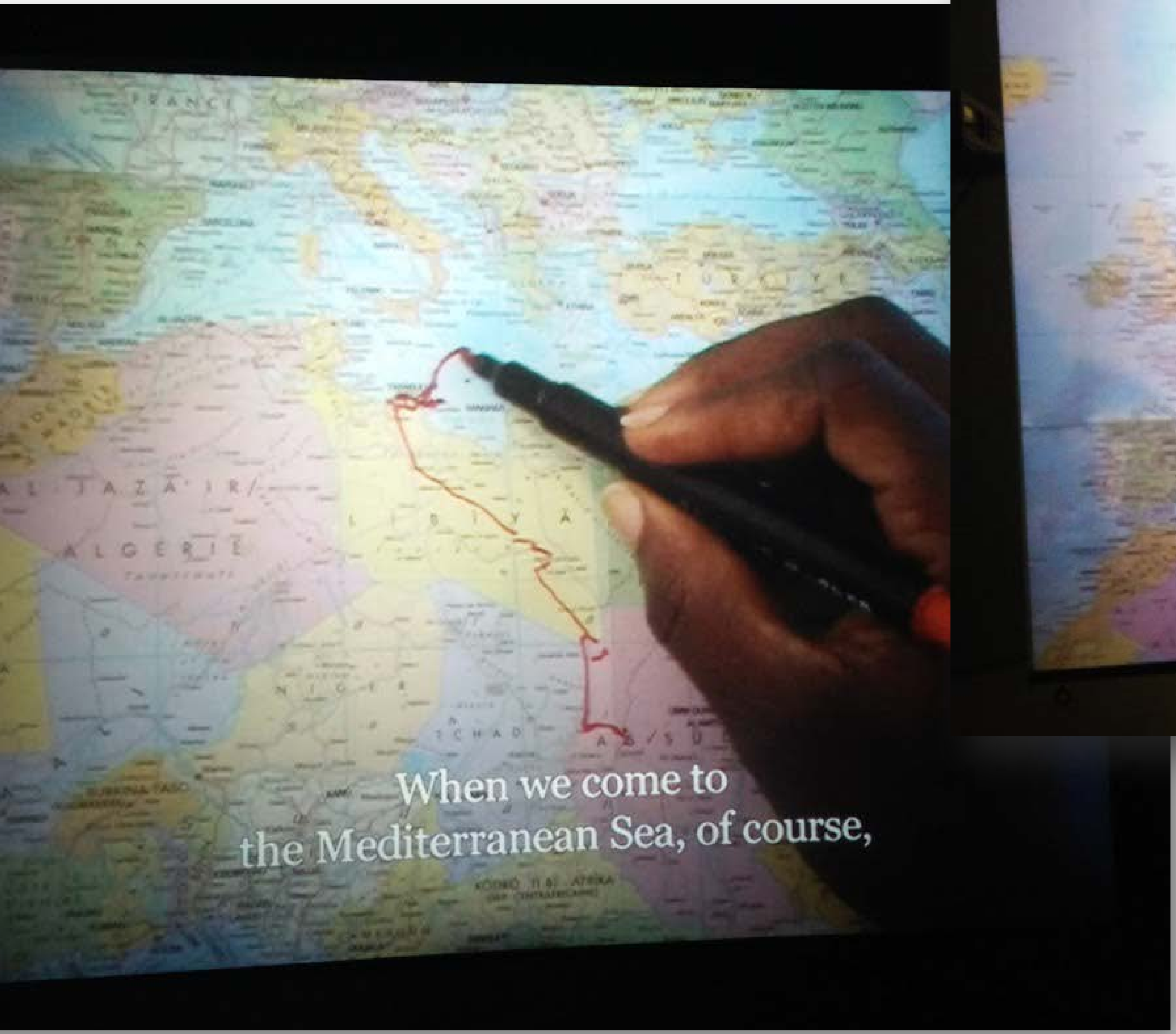
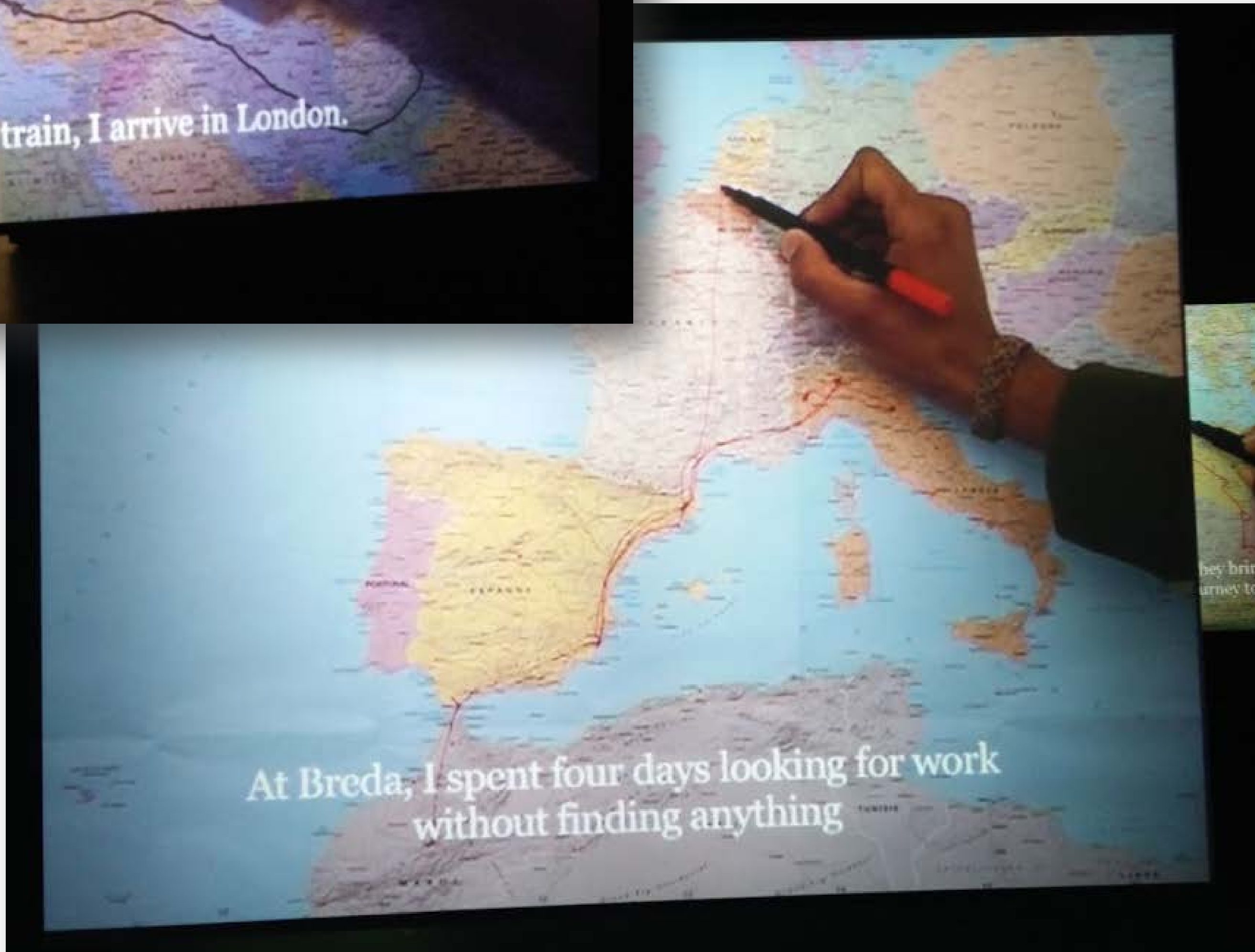
https://ciesin.columbia.edu/confluence/display/CCMM/

Why did we hold the workshop?

Displacement, refugees, mass migration and increasingly "climate refugees" are capturing public attention





Museum of Modern Art (MOMA), **Bouchra Khalili: The Mapping Journey Project**
8 September 2016

Museum of Modern Art (MOMA), **Insecurities: Tracing Displacement and Shelter**
8 November 2016

My personal journey

- In 2007 the UN Population Division commissioned a colleague, Susana Adamo, and me to write a paper “Climate Change Impacts on Population Distribution and Migration” (published 2011)*
  - In that paper we wrote, “The classic way of projecting population, with its assumptions of progressive changes in fertility, mortality and migration, does not incorporate any type of **environmental feedbacks or constraints**, nor any consideration of abrupt changes in the underlying conditions. This is a known issue. For example, **Cohen (1998) has proposed the incorporation of limiting factors** into population projections and estimates, particularly in long-term projections. Depending on the scope, scale and purpose of the projection, these external factors may include **government migration policies, regional water shortages, or locally limited agriculture potential**… Given the information presented in previous sections about the likely impact of climate change events on population distribution and migration, this is an option to be considered in the near future, though the **uncertainties and specific feedbacks are difficult to fully anticipate**.”

* Adamo, S.B., and A. de Sherbinin. 2011. “The Impact of Climate Change on the Spatial Distribution of Populations and Migration.” Chapter in: *Proceedings of the Expert Group Meeting on Migration*, New York: United Nations Population Division.

The following text in our original report* was redacted by the UN Population Division in the published version:

"Although we have deliberately avoided 'worst case' or apocalyptic scenarios, as noted in the introduction, a growing number of reports by reputable organizations and researchers are beginning to describe the potential impacts of a 'business as usual' scenario in which greenhouse gases continue to rise, the global community cannot agree on even minimum measures for mitigation, and little is done to redress global economic inequalities. **In this scenario, temperatures rise inexorably, glaciers and ice caps melt, global hydrology is irreversibly altered, millions of kilometers of productive land (e.g. in the Ganges and Mekong deltas) are under water, climate hazards become more severe, and agricultural systems have difficulty adapting to climate variability.** And all of this occurs in a world of **3-4 billion more people** than at present. Political scientists who have studied the correlates of state failure suggest that such changes would likely lead to an increase in armed conflict – producing more refugee flows and further disruptions. … **The results of unmitigated climate change are highly unpredictable, and might be best modeled as a chaotic, non-linear system, rather than a systematic set of causal chains.** Under such circumstances, traditional population projections might well become a thing of the past. "

* Adamo, S.B., and A. de Sherbinin. 2008. "The Impact of Climate Change on the Spatial Distribution of Populations and Migration." Report submitted to the UN Population Division.

Estimated Magnitudes of Migration & Displacement

Source	Climate Change Impact	Estimates
Myers (2002)	Droughts and other climate change events	50m by 2050
UNFCCC (2007)	Environmental impacts	50m displaced by 2010
Almería Statement on Desertification and Migration (1994)	Desertification	135m
Myers (2002, 2005)	Sea level rise	162m by 2050
Stern (2006)	Climate Change Impact	200m by 2050
Christian Aid (2007)	Climate Change Impact	250m to 1 billion
McGranahan, Balk and Anderson (2007)	Sea level rise (10 meters)	634m living below 10m sea level circa 2000

For the most part we have no idea how these numbers were developed!

Source: Adamo & de Sherbinin 2009; also, see Gemenne F. (2011) “ Why the numbers don’t add up: a review of predictions and forecasts for environmentally-induced migration ”, *Global Environmental Change* 21 (S1): 41-49 for a deeper treatment of this issue.

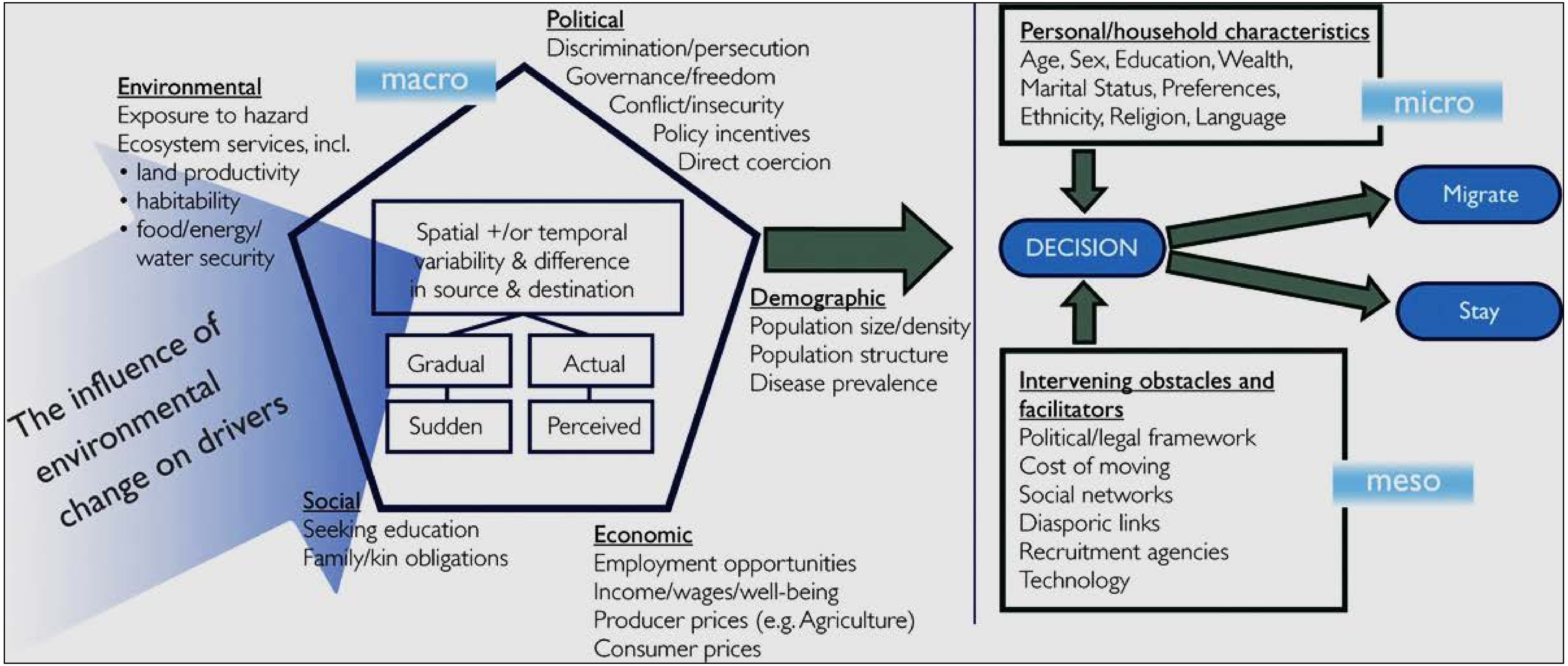
Why develop scenarios of CC-induced migration and population distribution?

- Population distributions are unlikely to evolve as they have in the past
- 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**, and how population may be redistributed internally as a result
- Receiving countries want to understand the magnitude of future flows – especially of potential **crisis migration**
- The media have an **insatiable curiosity** surrounding the numbers

Modeling Migration/Displacement

With thanks to presenters at the Workshop on Data and Methods for Modelling Migration Associated with Climate Change

Modeling migration and displacement is messy



Source: Black, R., W. N. Adger, et al. (2011). The effect of environmental change on human migration. *Global Environmental Change-Human and Policy Dimensions* 21: S3-S11. Based on Foresight: Migration and Global Environmental Change (2011) Final Project Report The Government Office for Science, London https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/287717/11-1116-migration-and-global-environmental-change.pdf

Different Approaches to Understanding Climate Change Impacts on Migration (complementary, not exclusive)

- **Historical analog:** What is the empirical evidence for migration being induced by climatic changes or extremes? Can a separate "climate signal" be detected at all?

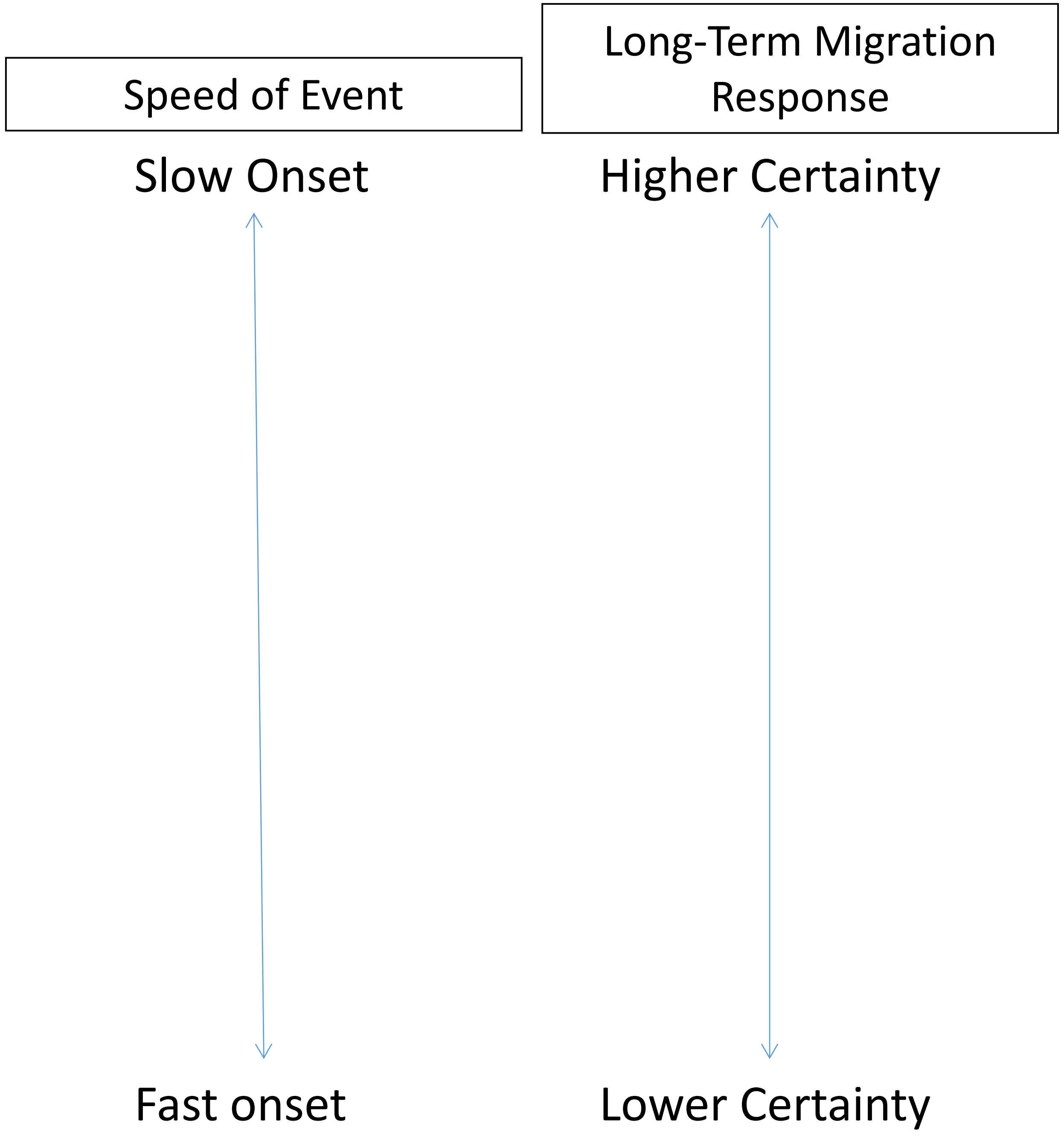
- **Livelihoods focus:** How will climate change impact the natural resources and productive systems upon which many poor people depend?

- **Future impacts:** What are likely impacts? How many people live in areas affected? What proportion of those affected will migrate? How will the proportion vary by impact type?

- **Migration systems:** how will existing migration systems and drivers of migration be impacted by CC? (push, pull, intervening variables)

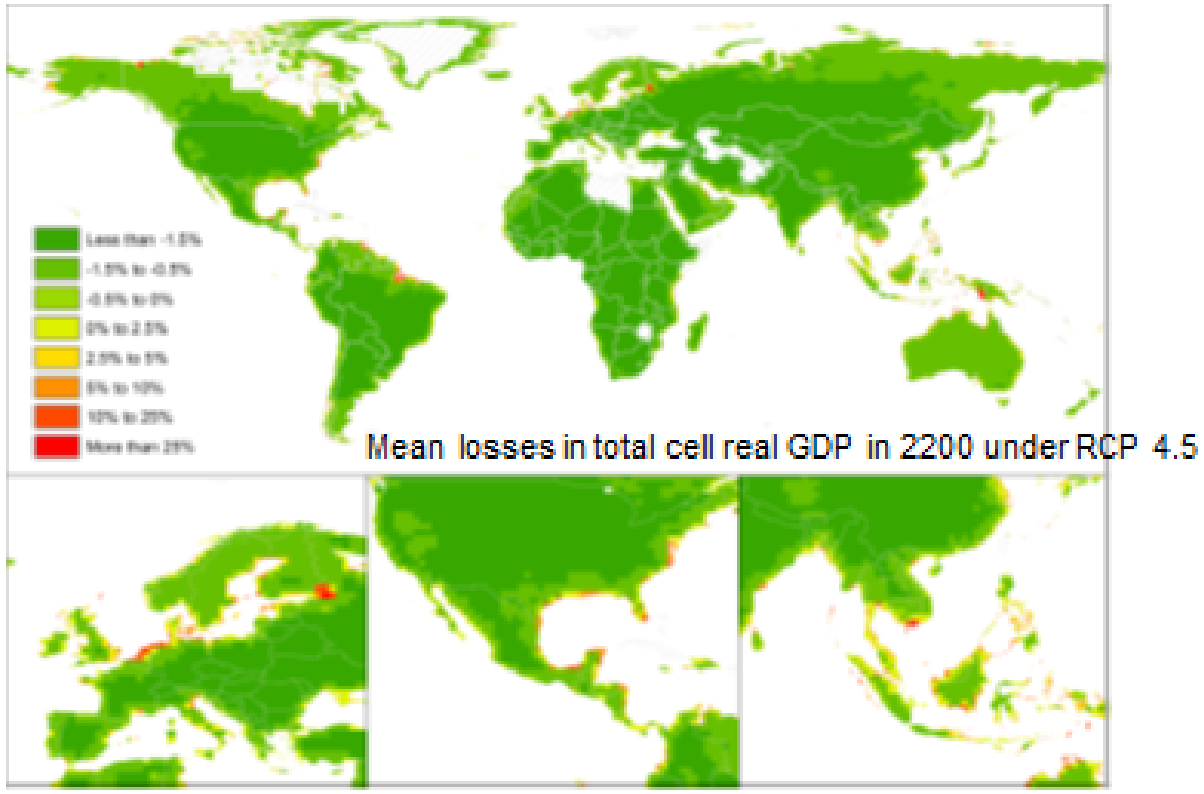
Mobility Response to Climate Extremes and Change

- Sea level rise:
  - Rising average sea level
  - Salt water intrusion in aquifers
- Water availability
  - Increasing
  - Decreasing
- Temperature increases
- Extreme weather events
  - Droughts
  - Heat waves
  - Violent Storms
  - Floods



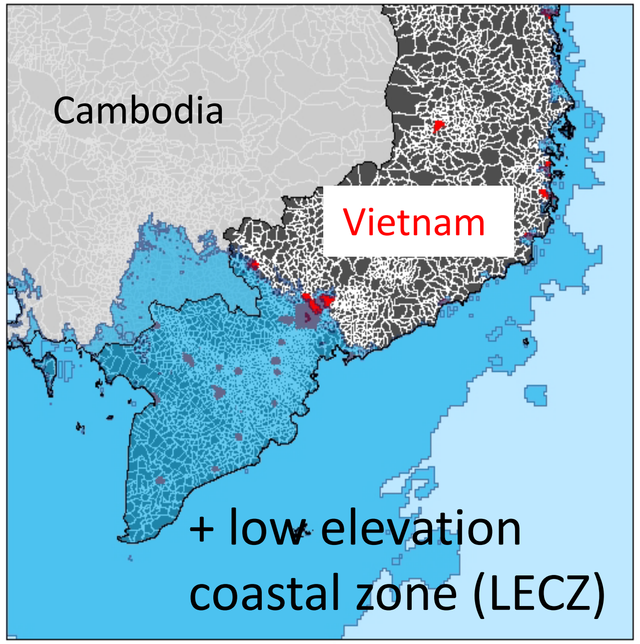
Dynamic Economic Model of coastal inundation ➡ population shifts, ΔGDP

trade and migration endogenous but zero "hard" adaptation

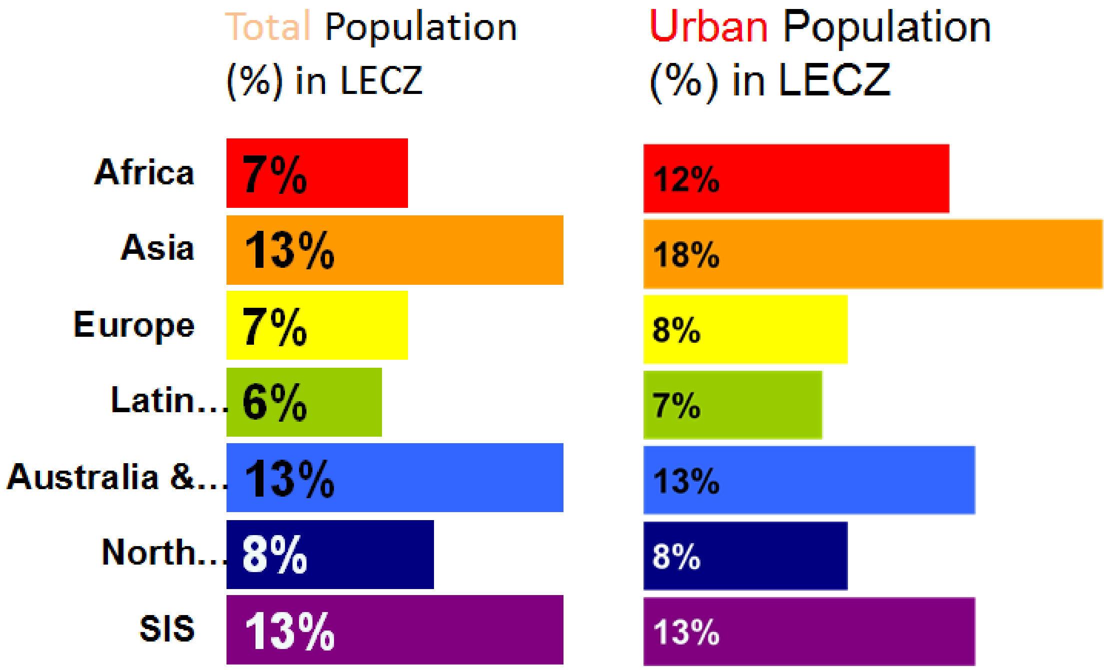


Source: M. Oppenheimer. 2016. "Sea Level Rise", presentation at the Workshop on Climate Migration Modeling, 5-6 December 2016, Paris, France.

634m people in the 10m LECZ



Simple Exposure Model

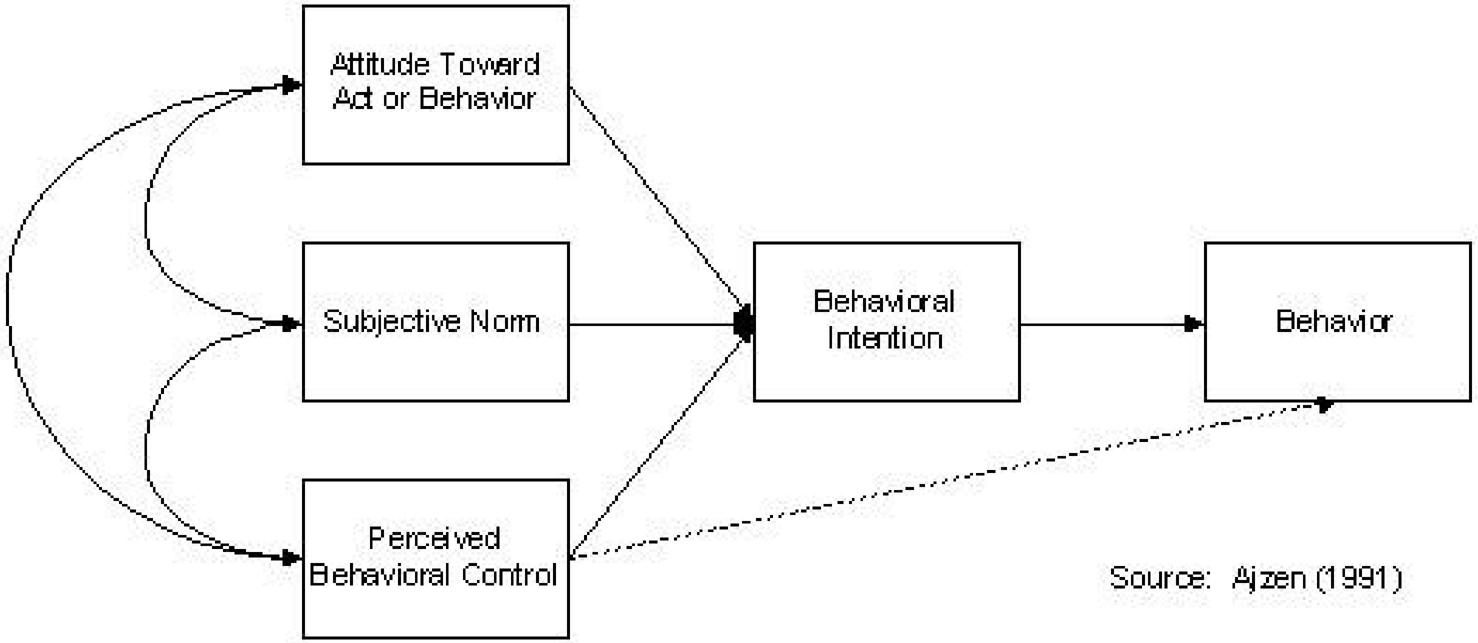


Source: D. Balk. 2013. "Population and Demographic Data for Sustainability Research in an Urban World ", presentation at the World-wide Human Geography Data Working Group Meeting, 18 April 2013, Columbia University .

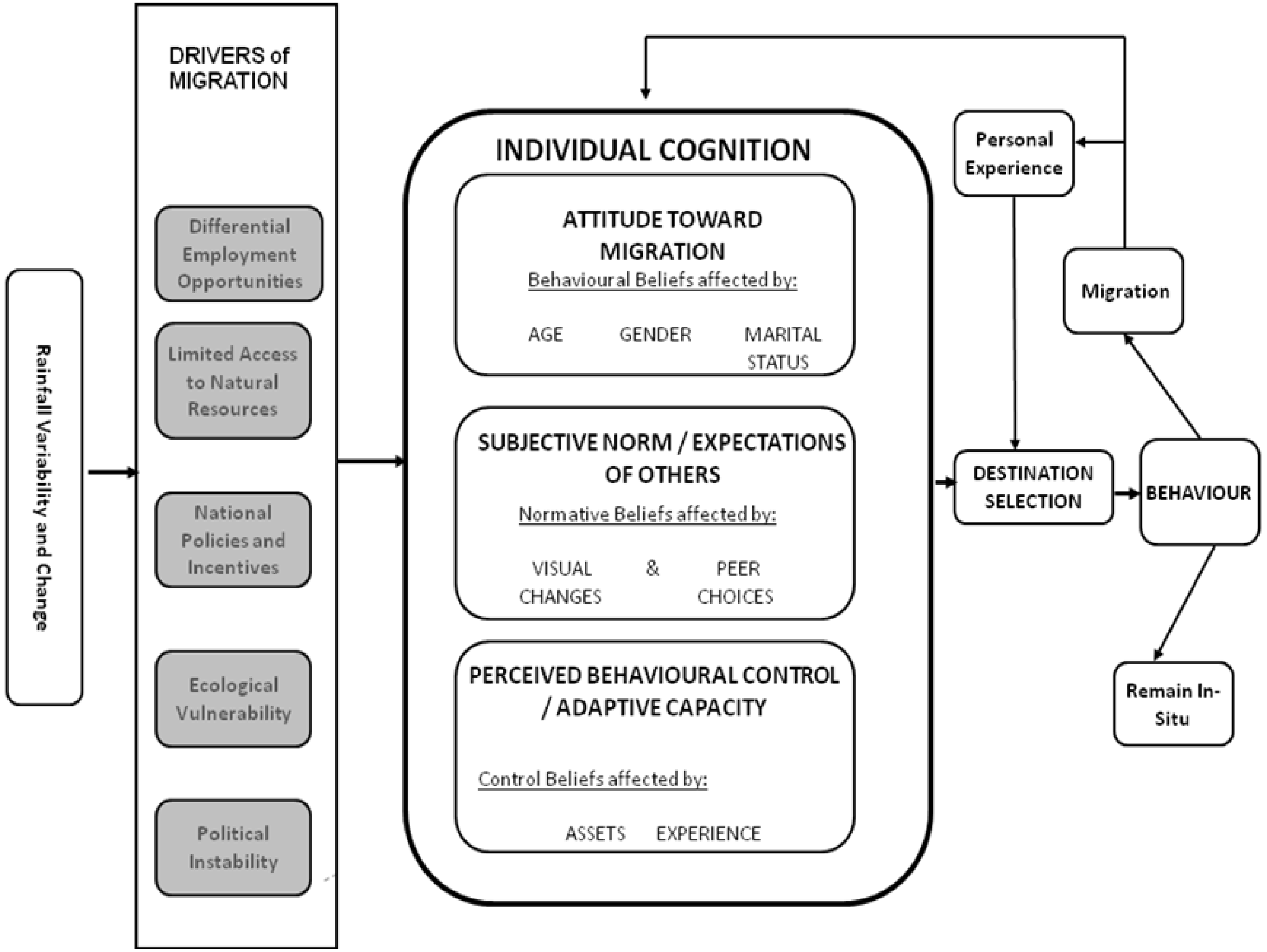
Agent Based Modelling (ABM)

- Involves treating households or individuals as agents.
- Assumes agents interact with each other to produce non-linear outcomes
- The population of agents is heterogeneous; the agents exhibit complex behaviour such as learning and adaptation
- They need to be calibrated with empirical micro-data
- ABMs allow us to test theories about how people react to climate stresses and shocks and policies to manage these
  - e.g., ABMs based on country, livelihood, climate stressor, specific behavioral rules, i.e. what would you do if…

Source: D. Kniveton and C. Smith. 2016. "Agent Based Models (ABMs)", presentation at the Workshop on Climate Migration Modeling, 5-6 December 2016, Paris, France.



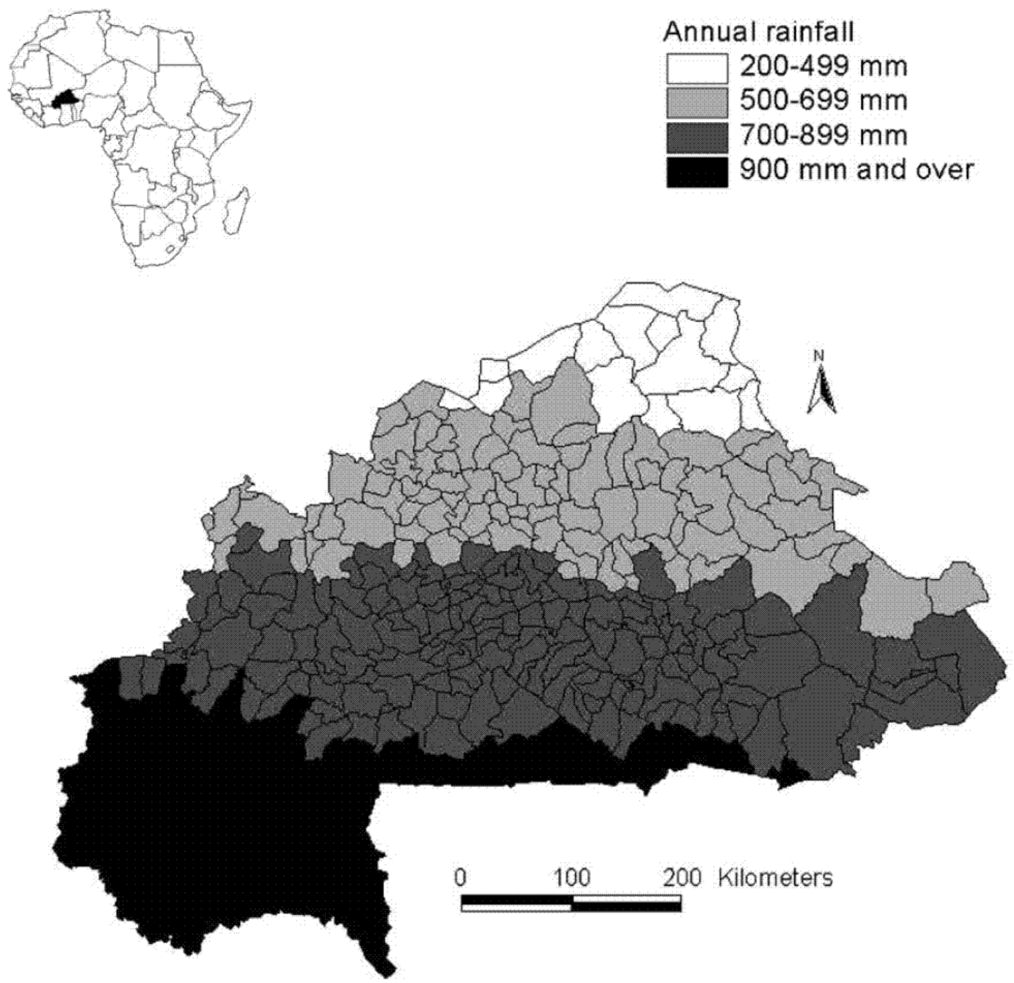
Source: Ajzen (1991)



Kniveton et al 2012. Emerging migration flows in a changing climate in dryland Africa. Nature Climate Change, 10.1038/NCLIMATE1447

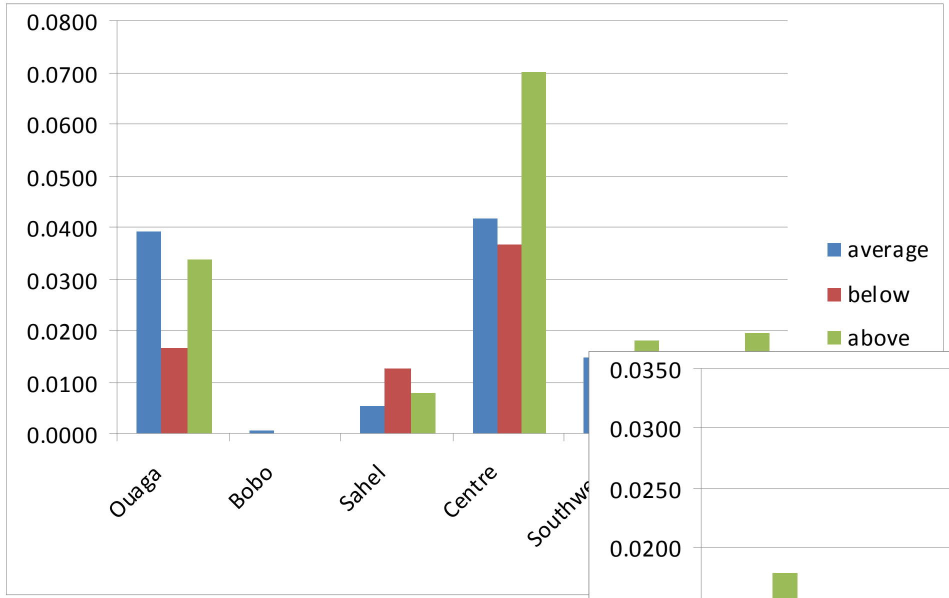
Migration and climate in Burkina Faso

- Population of 15 million.
- North-South rainfall gradient.
- Long characterised by mobility, historically to coastal plantation economies of Côte d’Ivoire and Ghana.
- Migration is mostly seasonal with family members returning home to farm their own land for the wet season (October - April).
- Internal migration is very common, mostly directed towards the wetter southwest of newly found goldmines.

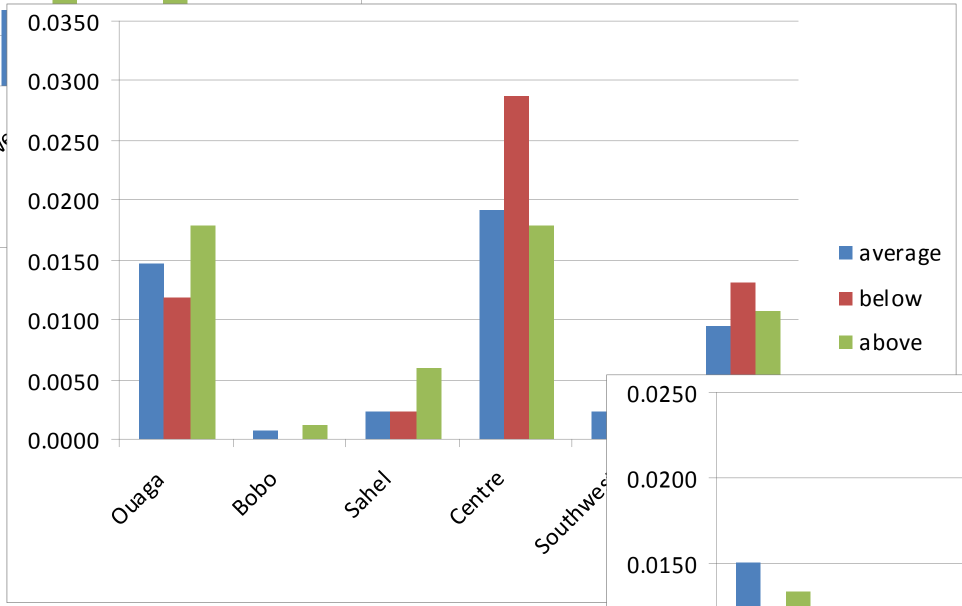


Probabilities of migration from the Sahel region for different rainfall conditions

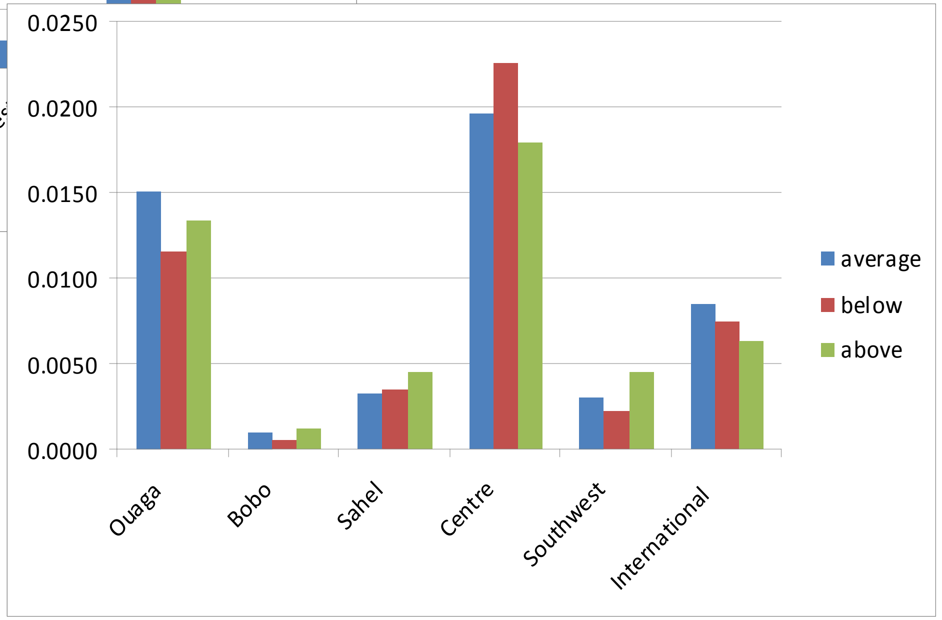
Age: 15-20 years

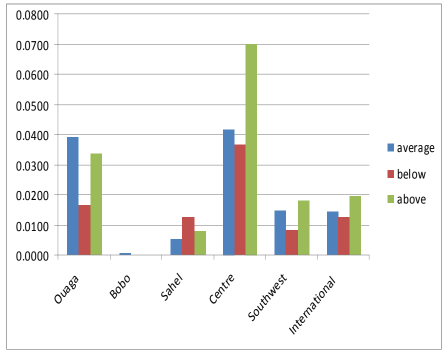


Gender: Male

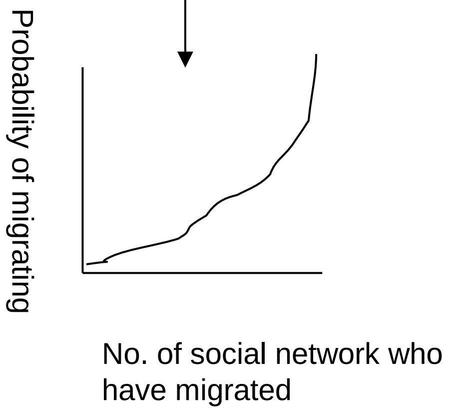


Marital Status: Married

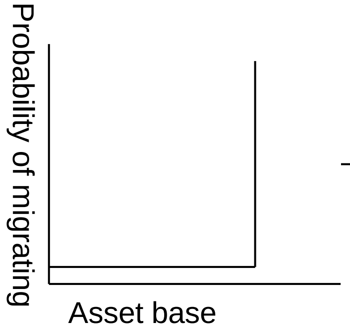




General probability of type of individual to migrate e.g. 15-20 yr old, single male.



Probability of individual to migrate with particular social network



Probability of individual to migrate with particular social network & asset base

Aggregate migration of community

Result:

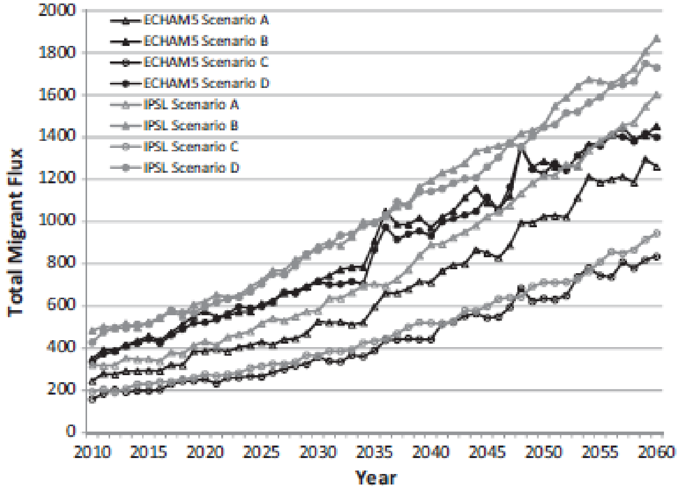


Fig. 4. Modelled total (internal and international) migration flux in Burkina Faso from 2010 to 2060 for scenarios A, B, C, and D (see text) and climate change scenarios from ECHAM5 and IPSL models, for a model population of 4449 agents.

Systems Dynamics models

- These tend to be developed in non-spatial frameworks
- They are useful for policy “what if” scenarios
- Can incorporate a wide range of data on the economy, natural resources, and perturbations

Systems Dynamics models

Slow-onset hazards

- **Global** monitoring
- **Protracted** situations
- **Slow-onset** hazards

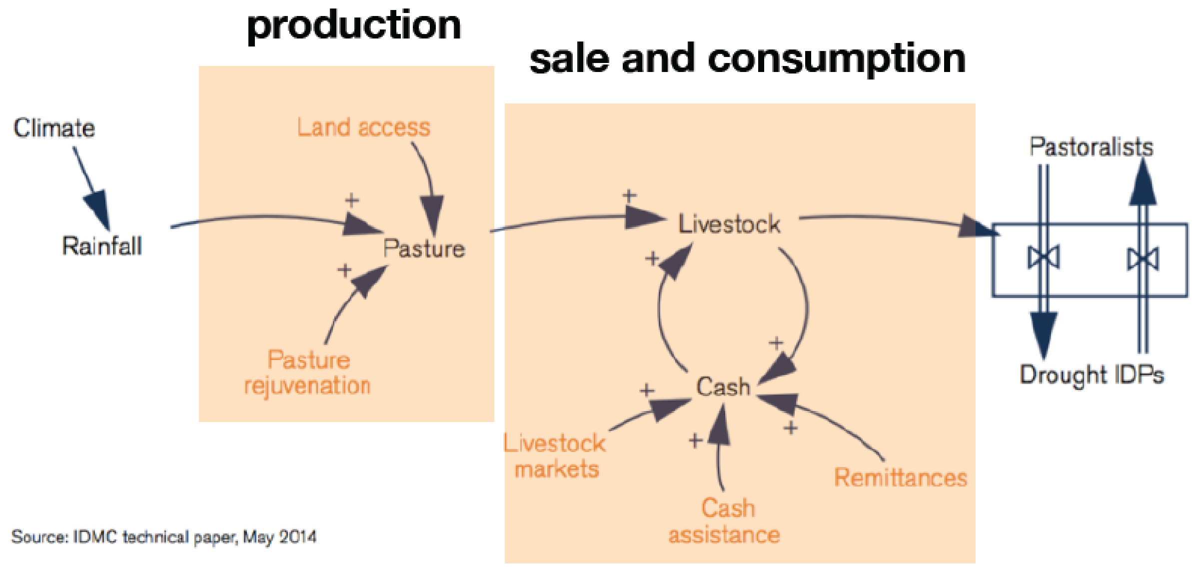
A family walks through the drought-affected area of Barisle vil- lage, outside Jigjiga in Ethiopia. Photo: NRC, April 2016

Modeling the effect of drought on pastoralists in the horn of Africa

Slow-onset hazards

- **Global** monitoring
- **Protracted** situations
- **Slow-onset** hazards

Pastoralism is a livelihood based on:



of livestock and livestock products.

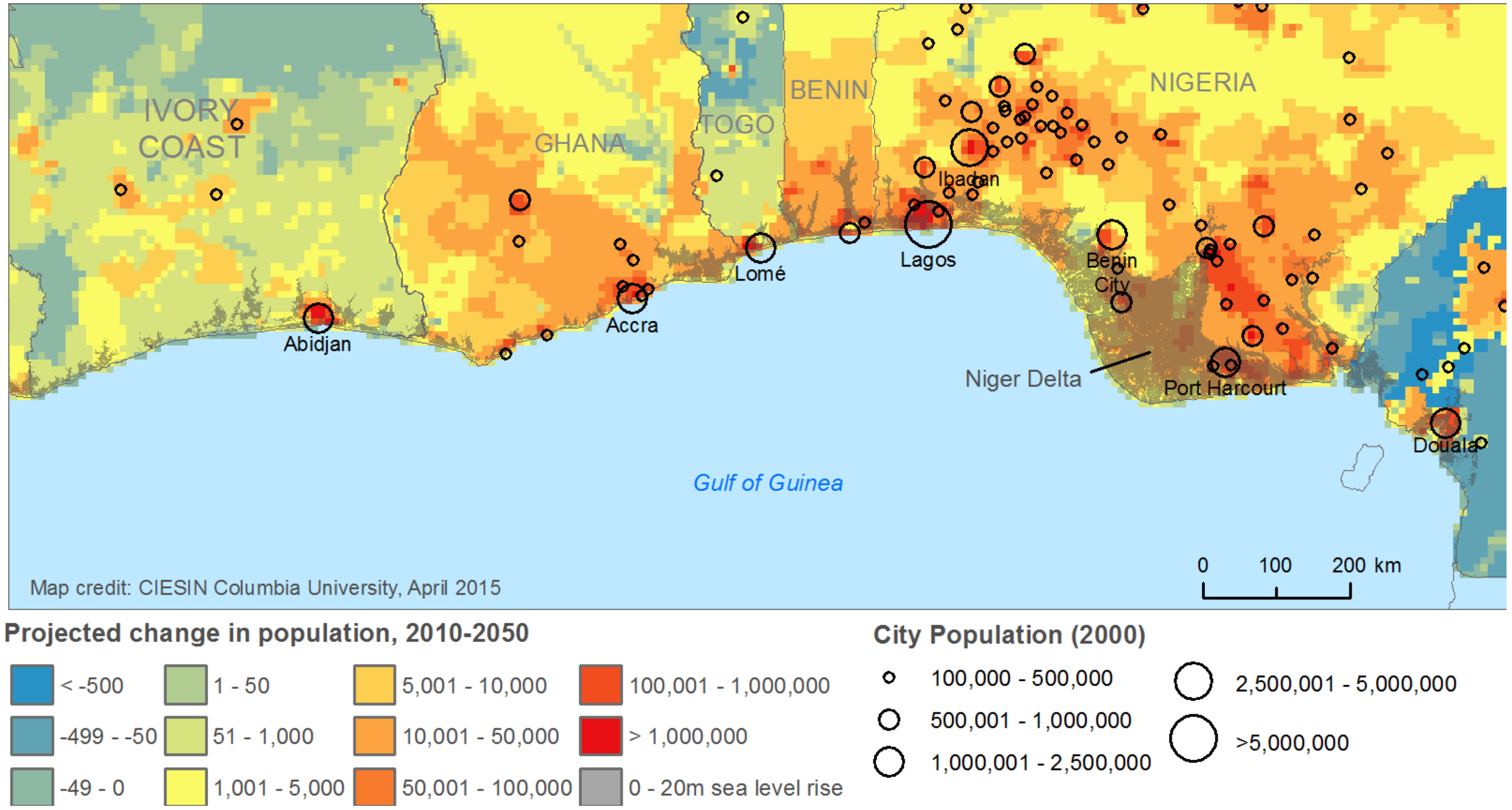
IDMC, Assessing drought displacement risk for Kenyan, Ethiopian and Somali pastoralists - 2014

Source: L. Milano. 2016. “IDMC approaches and work to date”, presentation at the Workshop on Climate Migration Modeling, 5-6 December 2016, Paris, France.

Gravity models of future population distribution

- Gravity models are used to predict the degree of interaction between two places as a function of location and importance
- Importance can be measured in terms of population numbers, gross domestic product, or other appropriate variables
- It is possible to introduce environmental factors into the models in such a way that they affect, positively or negatively, the relative attractiveness of locations, and by extension, the migration that contributes to population distribution

How might climate change hotspots affect future population distribution?



"In the past 5 years there has been a proliferation of efforts to map climate change "hotspots" — regions that are particularly vulnerable to current or future climate impacts, and where human security may be at risk." (de Sherbinin 2014. Climate change hotspots mapping: what have we learned? *Climatic Change*. 123(1):23-37 DOI 10.1007/s10584-013-0900-7

Source: de Sherbinin, A., T. Chai-On, M. Jaiteh, V. Mara, L. Pistolesi, E. Schnarr, S. Trzaska. 2015. Data Integration for Climate Vulnerability Mapping in West Africa. *ISPRS International Journal of Geo-Information*. 4, 2561-2582.

NCAR/CIDR Spatial Population Downscaling Model

Research Goal:

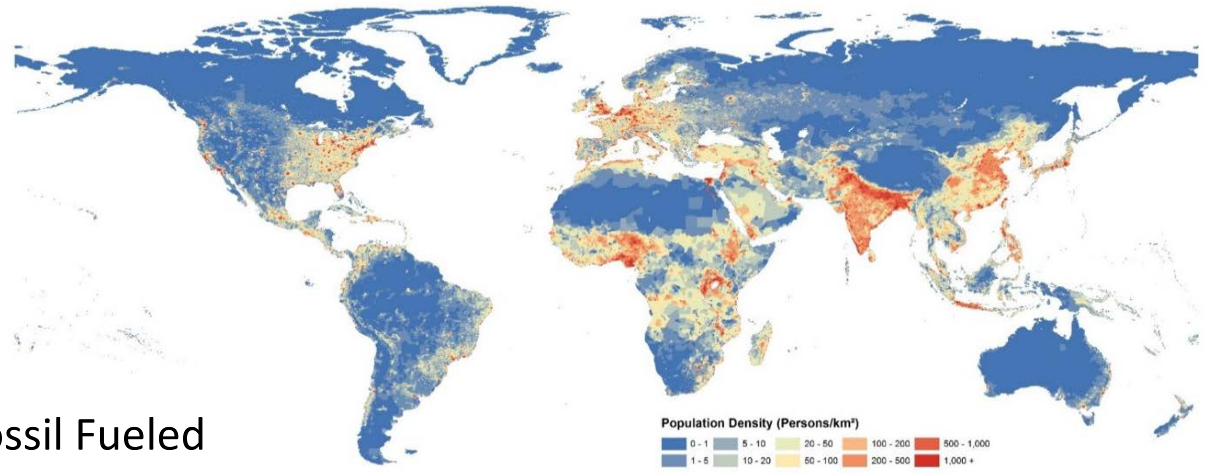
To develop an improved methodology for constructing large-scale, plausible future spatial population scenarios which may be calibrated to reflect alternative regional patterns of development for use in the scenario-based assessment of global change.

Characteristics

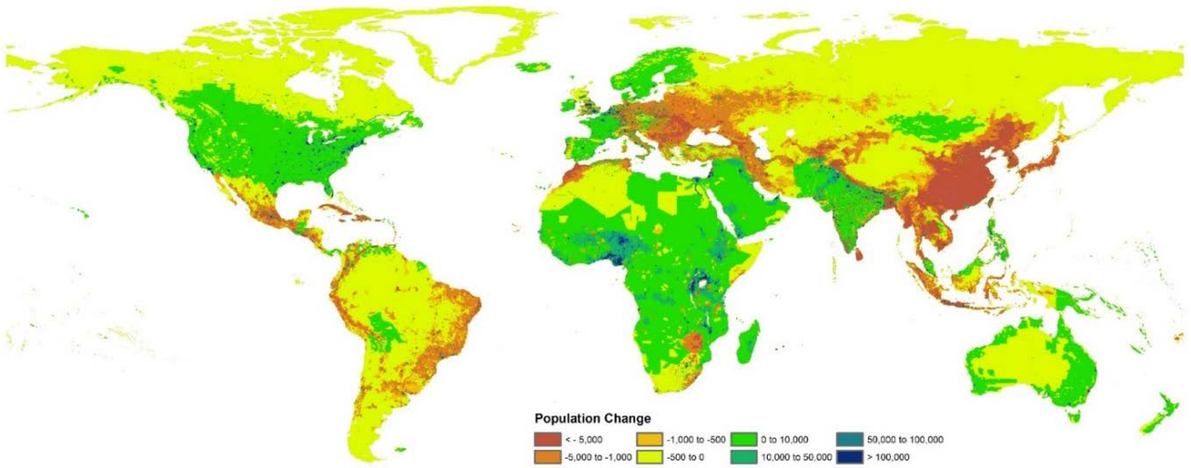
- Gravity-based downscaling model
- Captures observed geographic patterns
  - Calibration
- Flexible framework
  - Data
  - Resolution (temporal & spatial)

SSP-based spatial population scenarios

- 232 countries/territories
- Urban, rural, and total populations
- 10-year time steps, 1/8th degree
- **NO CLIMATE ASSUMPTIONS**

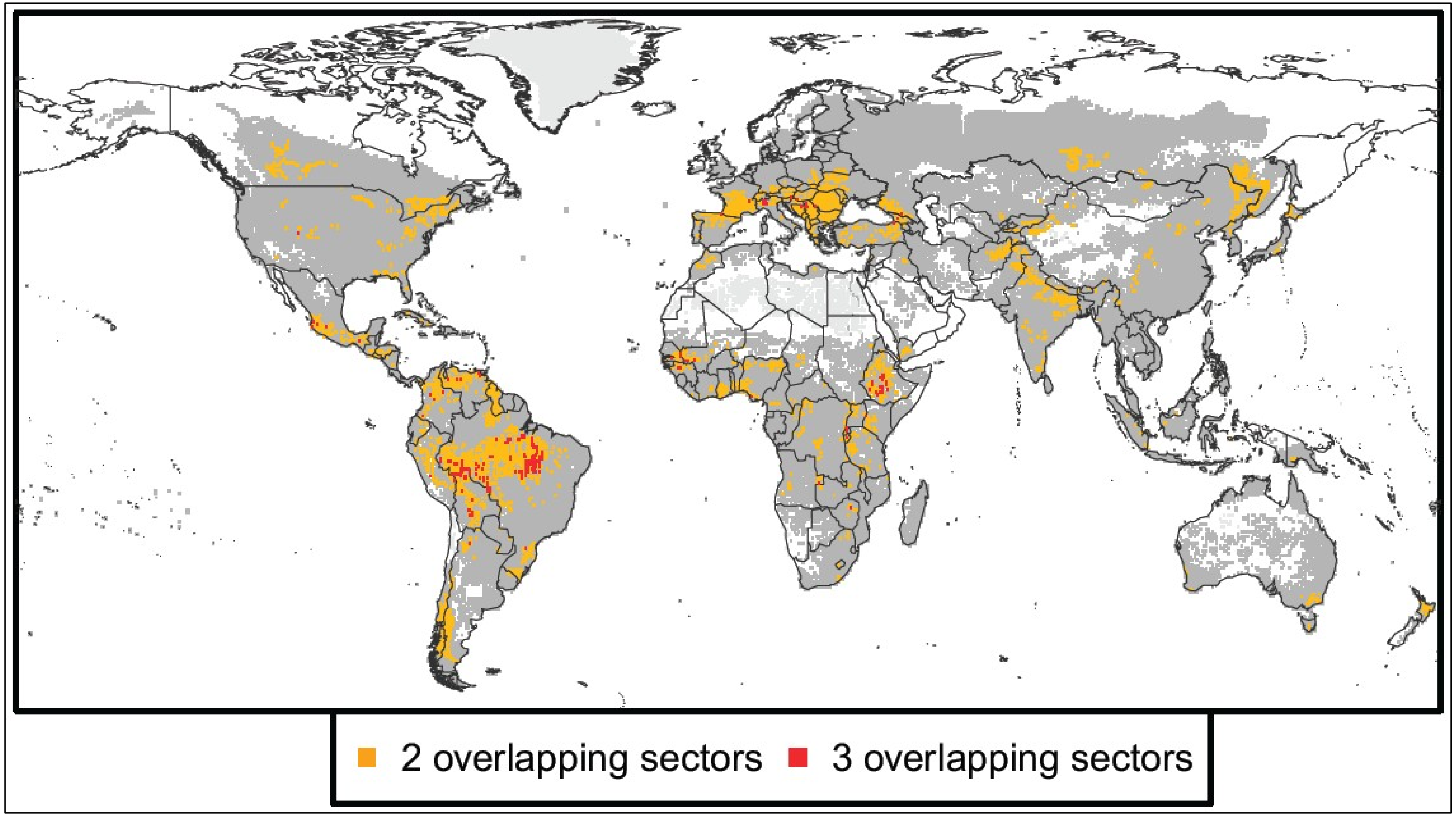


SSP5 – Fossil Fueled Development



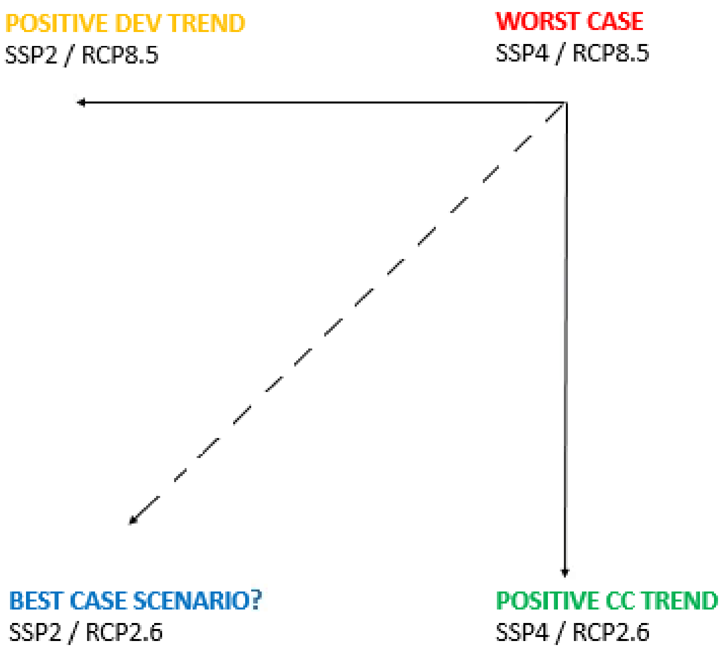
Source: Jones & O'Neill. 2016. Spatially explicit global population scenarios consistent with the Shared Socioeconomic Pathways. *Environmental Research Letters* 11 084003

Future Impacts: Multisectoral Hotspots of Impacts



Source: Piontek F, Müller C, Pugh TAM et al (2013) Multisectoral climate impacts in a warming world. *Proceedings of the National Academy of Sciences*. doi:10.1073/pnas.1222471110.

A scenario-based approach



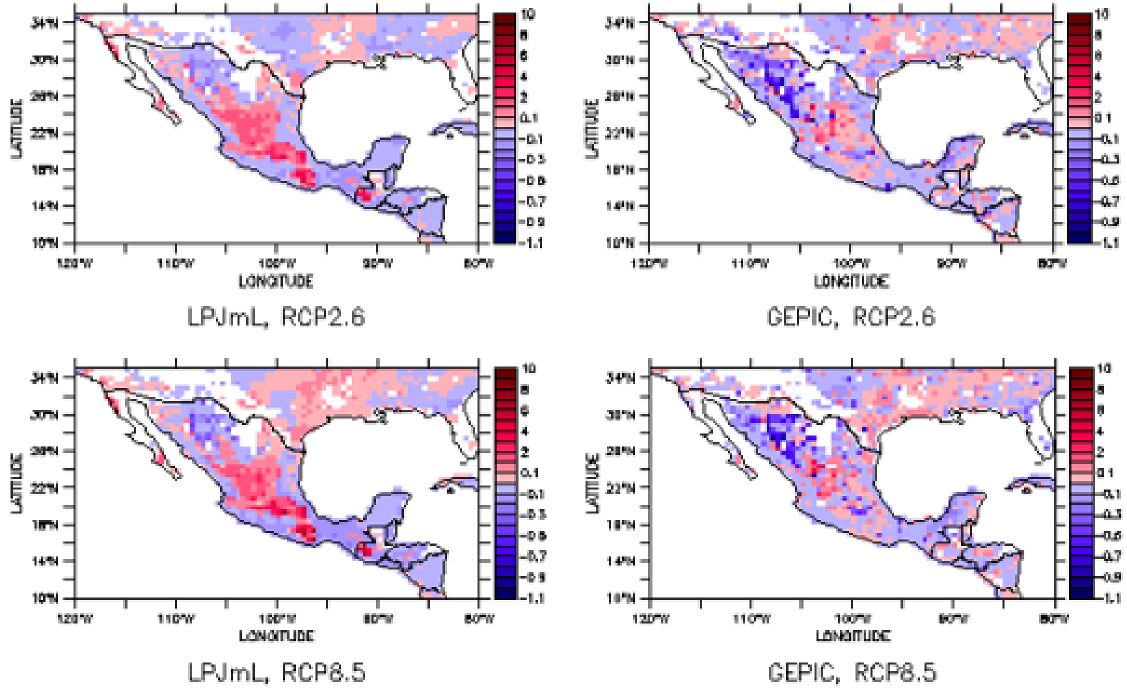
SSP4: A mixed world with relatively rapid technological development in low carbon energy production in high emitting regions, and therefore strong mitigation, however in other regions development proceeds slowly, inequality remains high, and economies are relatively isolated, leaving those regions highly vulnerable to climate change with limited adaptive capacity

Table 2.2. Matrix of GCM and Crop and Water Model Combinations

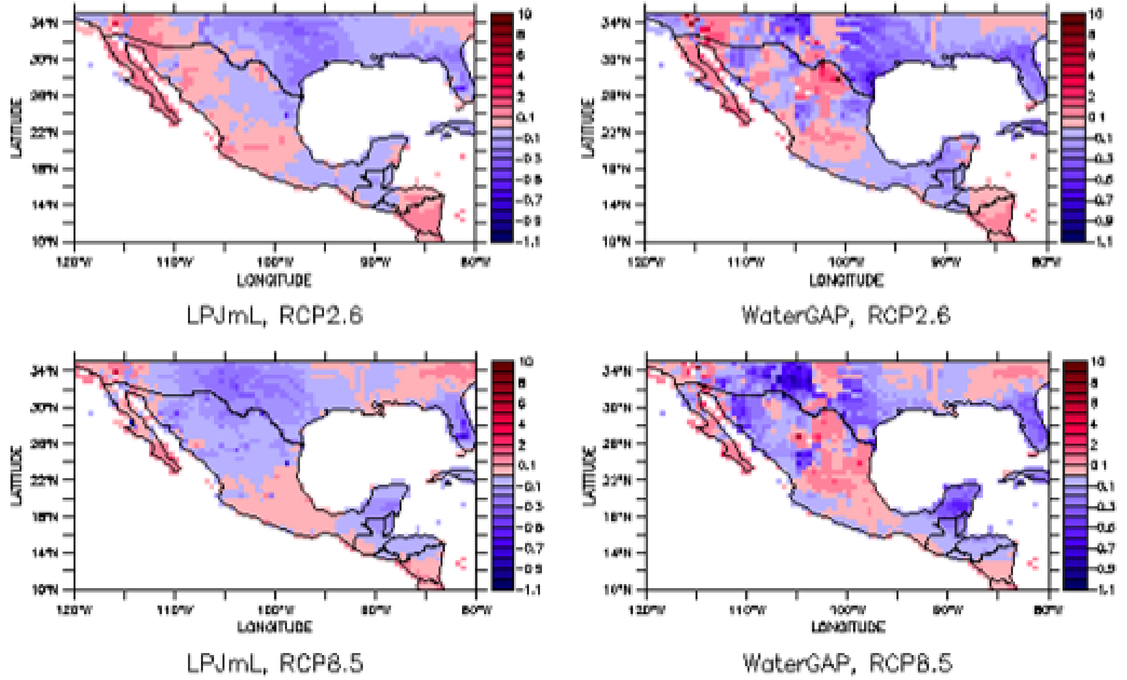
GCM1 = HadGEM2-ES; GCM2 = IPSL-CM5A-LR.

Crop simulation ➔ Water simulation ↓	**GCM1, LPJmL (crop)**	**GCM1, GEPIC**	**GCM2, LPJmL (crop)**	**GCM2, GEPIC**
GCM1, LPJmL (water)	**#1**			
GCM1, WaterGAP2		**#2**		
GCM2, LPJmL (water)			**#3**	
GCM2, WaterGAP2				**#4**

CROP MODELS

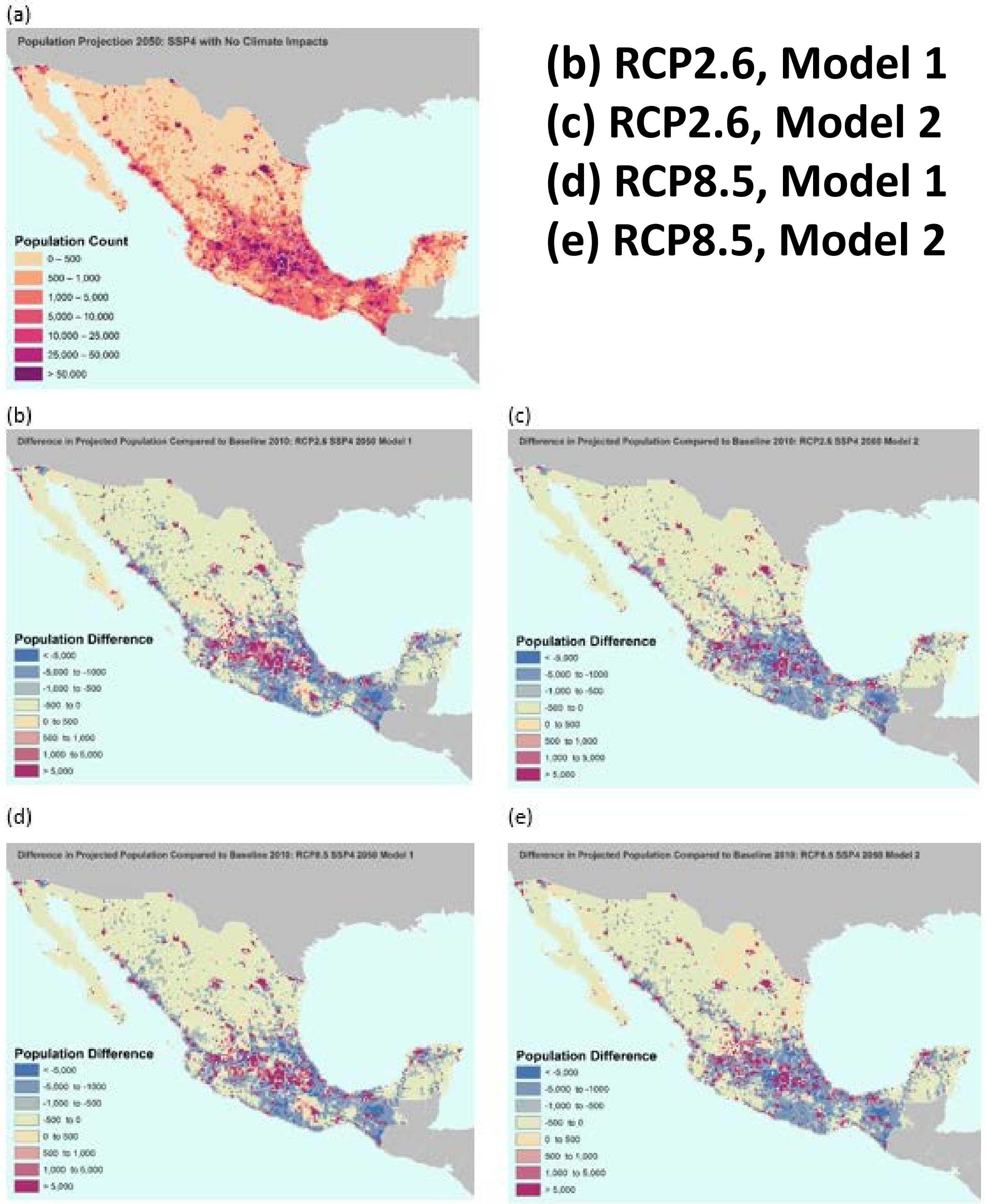


WATER MODELS



COMPARISON OF NO CLIMATE VS. CLIMATE IMPACTS

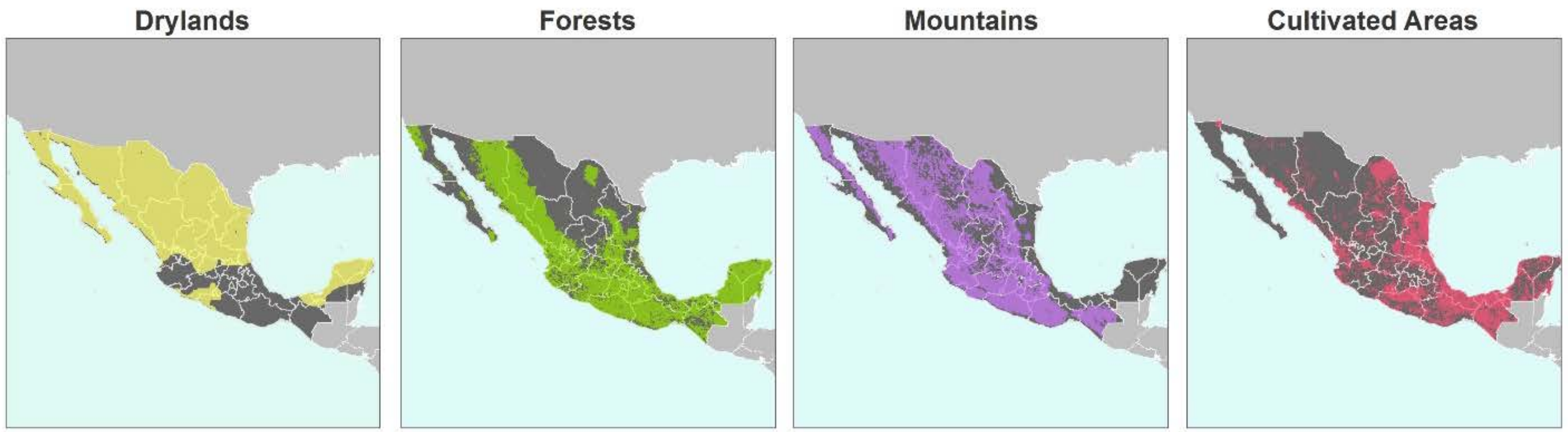
Gravity Models

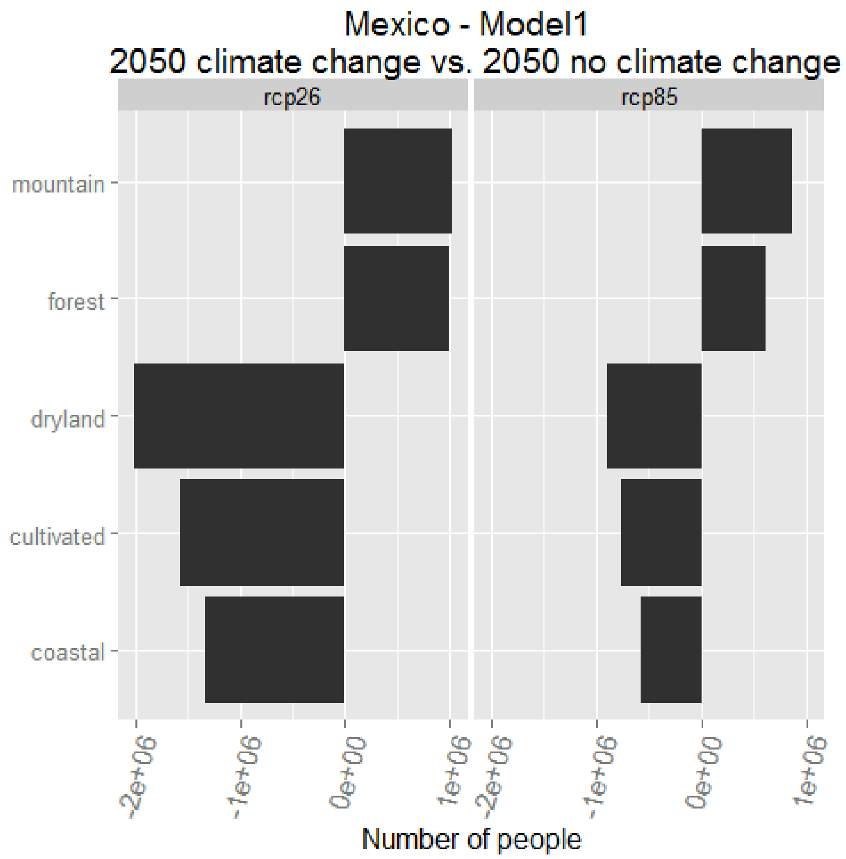


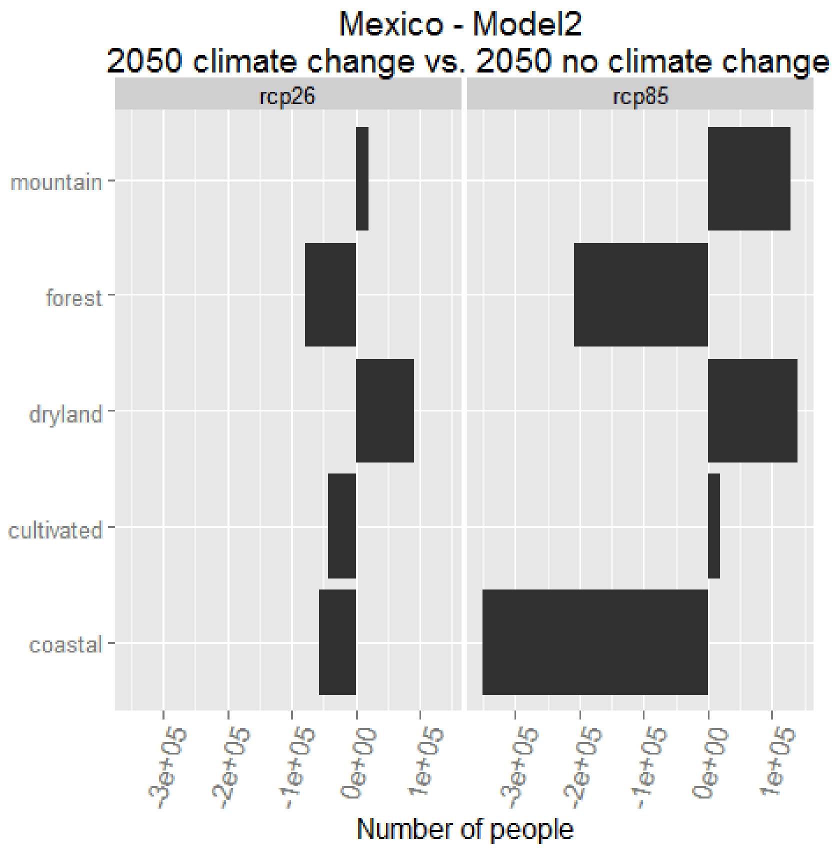
(b) RCP2.6, Model 1
(c) RCP2.6, Model 2
(d) RCP8.5, Model 1
(e) RCP8.5, Model 2

Results by Ecosystem

Gravity Models







Limitations of each approach

- **Exposure models**: assume that adaptation is not possible, and everyone who is exposed will move
- **ABMs**: Require a lot of historical data, and results generally have limited spatial definition (i.e., a few migration destinations)
- **Systems dynamic models**: Generally lack spatial detail, and can result in a bewildering array of scenarios
- **Gravity models**: Focus on aggregate demographic behavior rather than individual behavior or motivations for migration; they rely instead on assumptions of relative attractiveness of locations

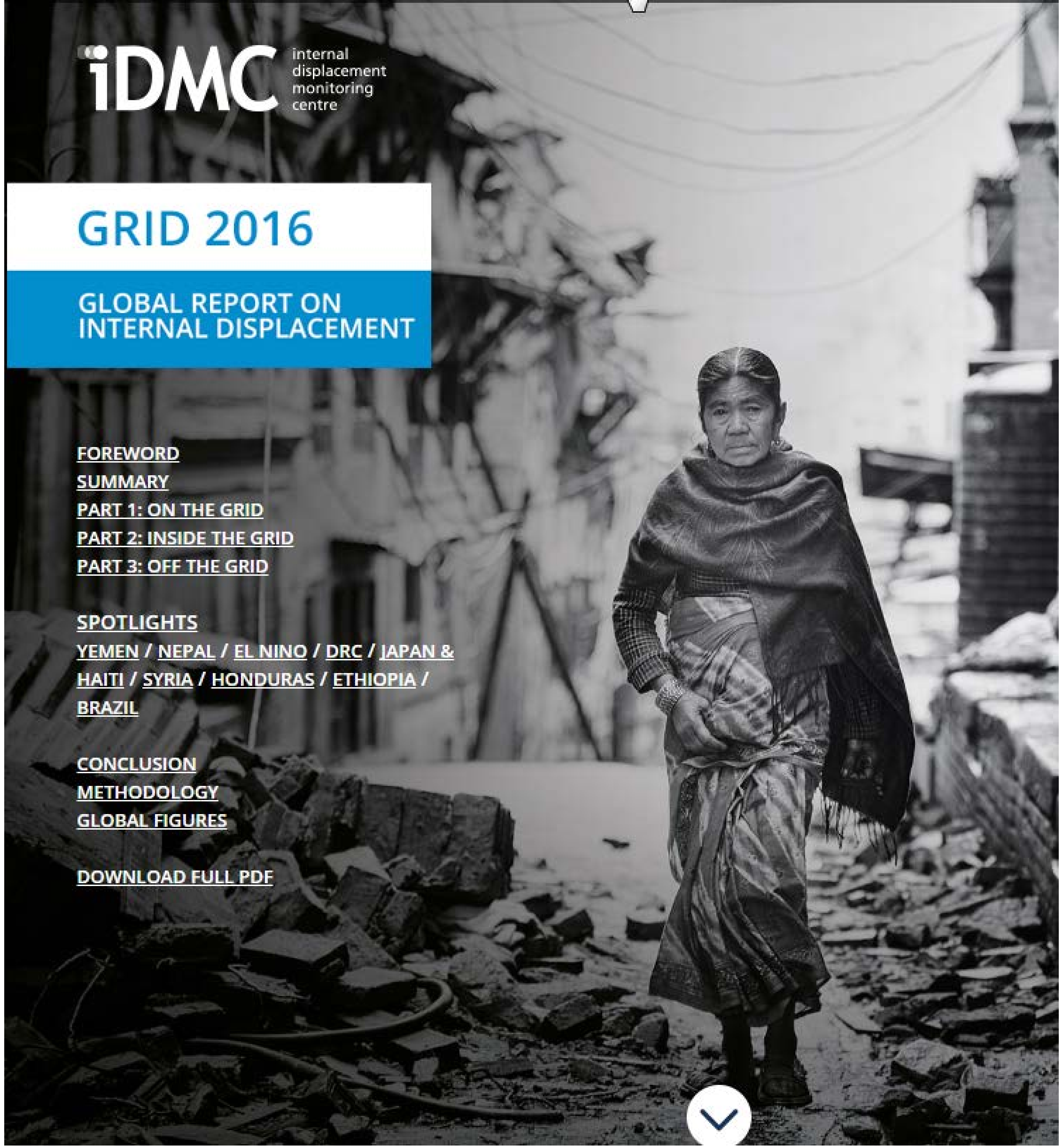
Source: de sherbinin, A. and L. Bai. 2017 (forthcoming). "Geospatial Modeling and Mapping", *Handbook on Environmental Displacement and Migration*. F. Gemenne and R. McLeman (eds.).

Questions

- What do policy makers need to know that they currently do not know? What information can we provide them?
- Operational use: If you put projections in front of people who are responsible for programs, will they know how to use them? Will they be dismissed as irrelevant or overly complicated, with all their embedded uncertainty?
- How might limits to adaptation shift as a result of adaptation interventions or unforeseen technologies?
- Under future climate impacts, what proportion of the affected populations will leave? Who will stay? Are they “trapped” or “voluntary”? Who will go?
- Can we predict large scale crisis migration through understanding the ingredients such as economic crises, state failure, climate shocks, etc.?
- How will scenario-based global/regional/country projections be used? What is the potential for mis-use of these numbers? Who defines “mis-use”?

Backup Slides: Data on Past Migration/Displacement

With thanks to presenters at the Workshop on Data and Methods for Modelling Migration Associated with Climate Change

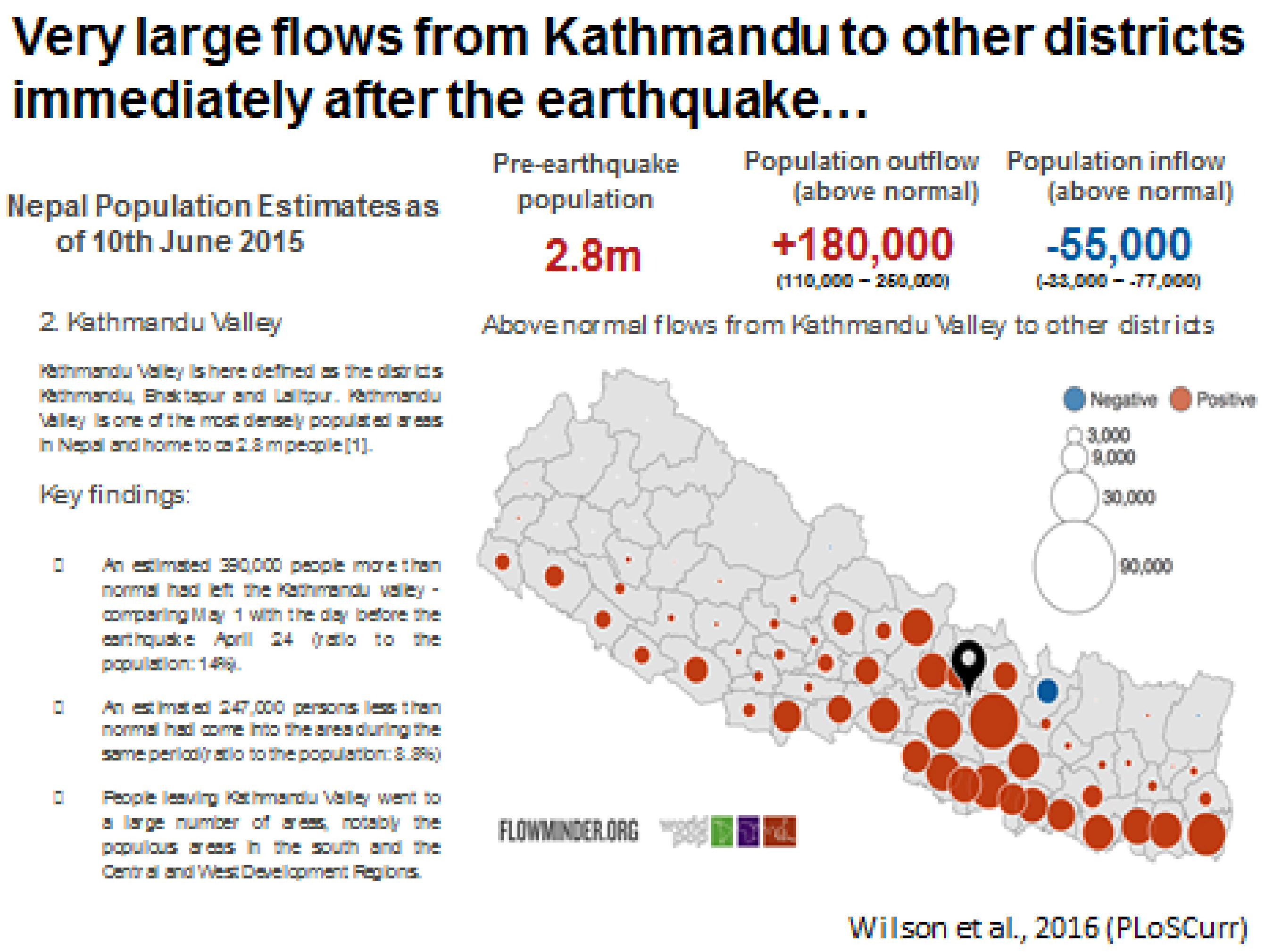


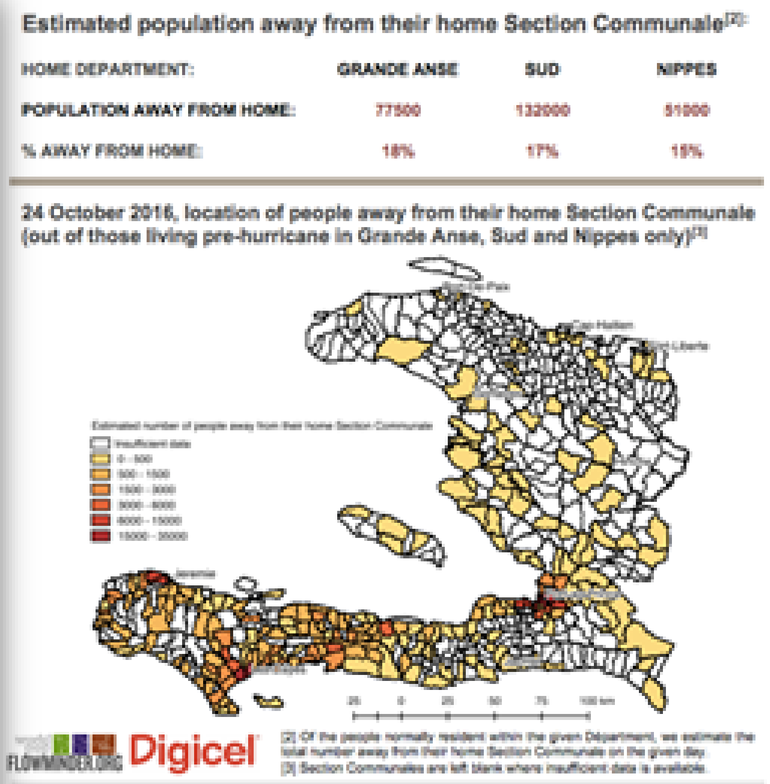
TABLES

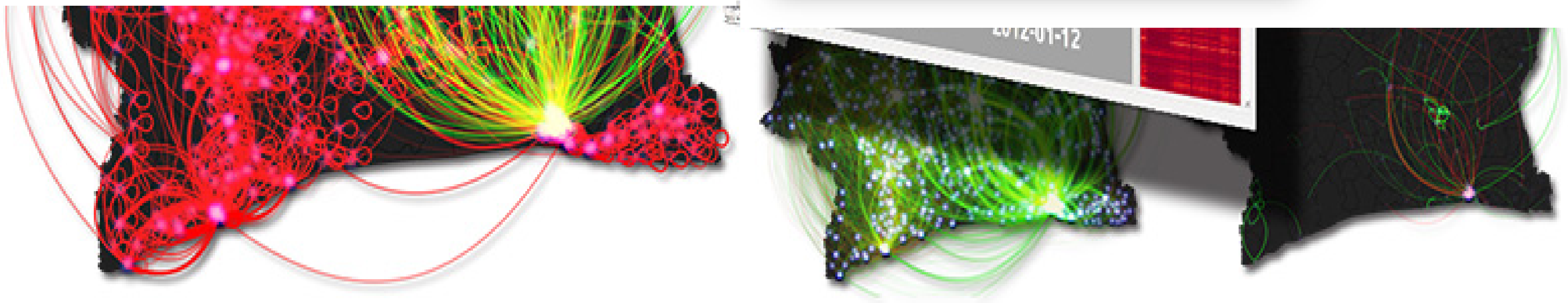
Table 1: New displacement by country for disasters and conflict and total number of IDPs for conflict and violence

Country or region	Total number of IDPs as of 31 December 2015 (conflict)	New displacements in 2015 (conflict)	New displacements in 2015 (disasters)
Abyei Area	82,000		
Afghanistan	1,174,000	335,000	71,000
Albania			4,200
Algeria			19,000
Angola			5,600
Argentina			36,000
Armenia	8,400		
Australia			5,700
Azerbaijan	564,000		
Bahamas			2,800
Bangladesh	426,000		531,000
Belize			300
Bhutan			2,900
Bolivia			11,000
Bosnia and Herzegovina	98,000		300
Botswana			300
Brazil			59,000
Bulgaria			800
Burkina Faso			3,700
Burundi	99,000	23,000	3,100
Cabo Verde			200
Cambodia			8,900
Cameroon	124,000	71,000	11,000

Population Displacements

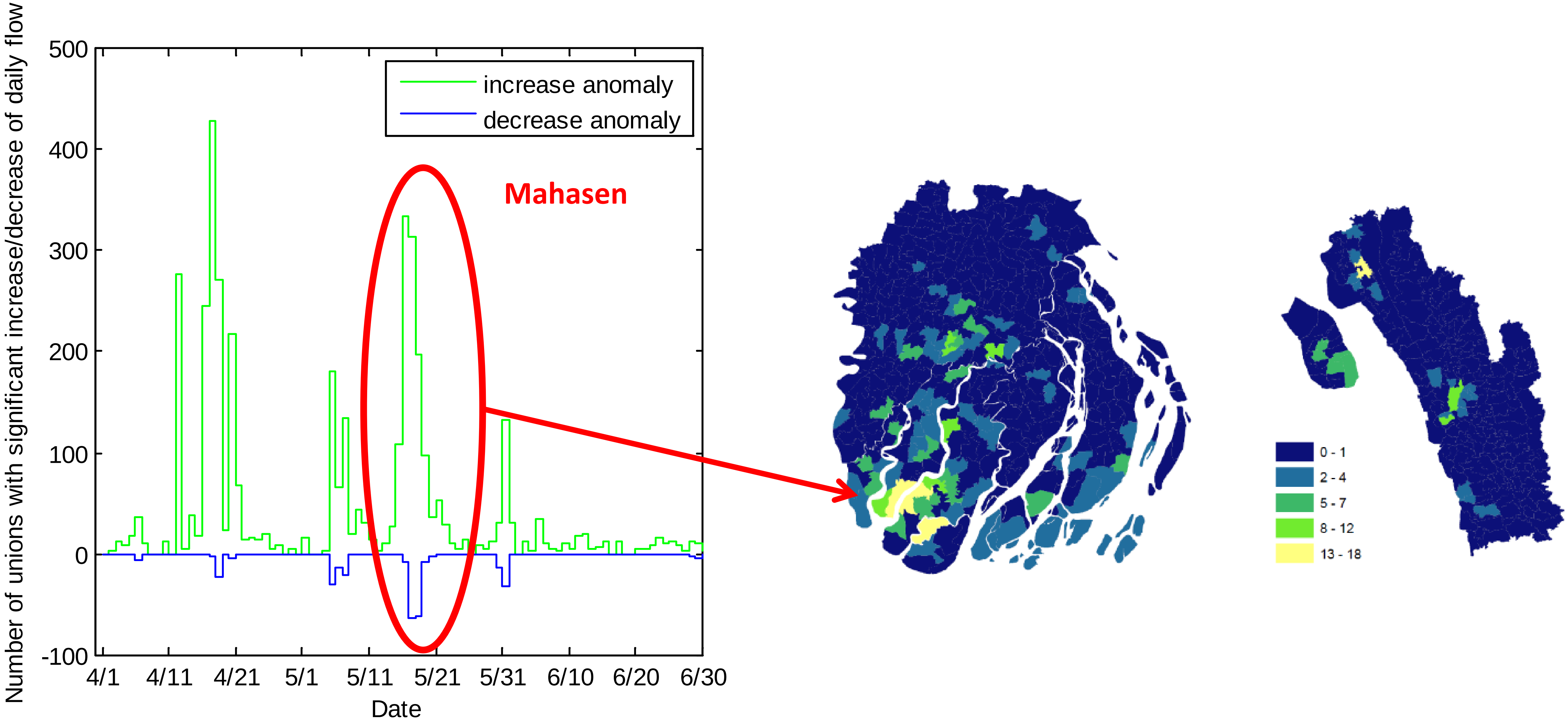






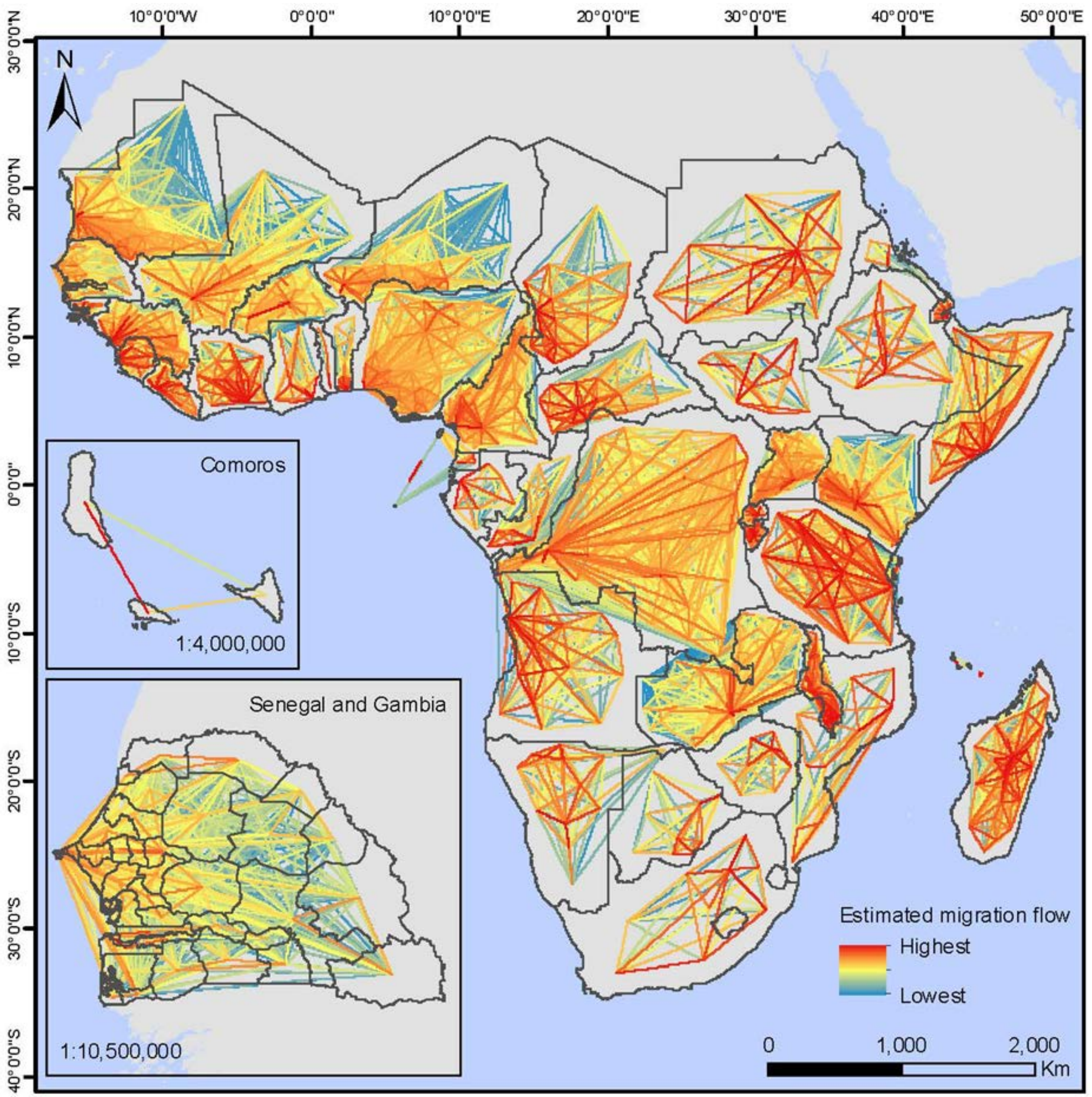
Source: A. Sorichetta. 2016. “Cell phone data and census microdata to model human movement and migration”, presentation at the Workshop on Climate Migration Modeling, 5-6 December 2016, Paris, France.

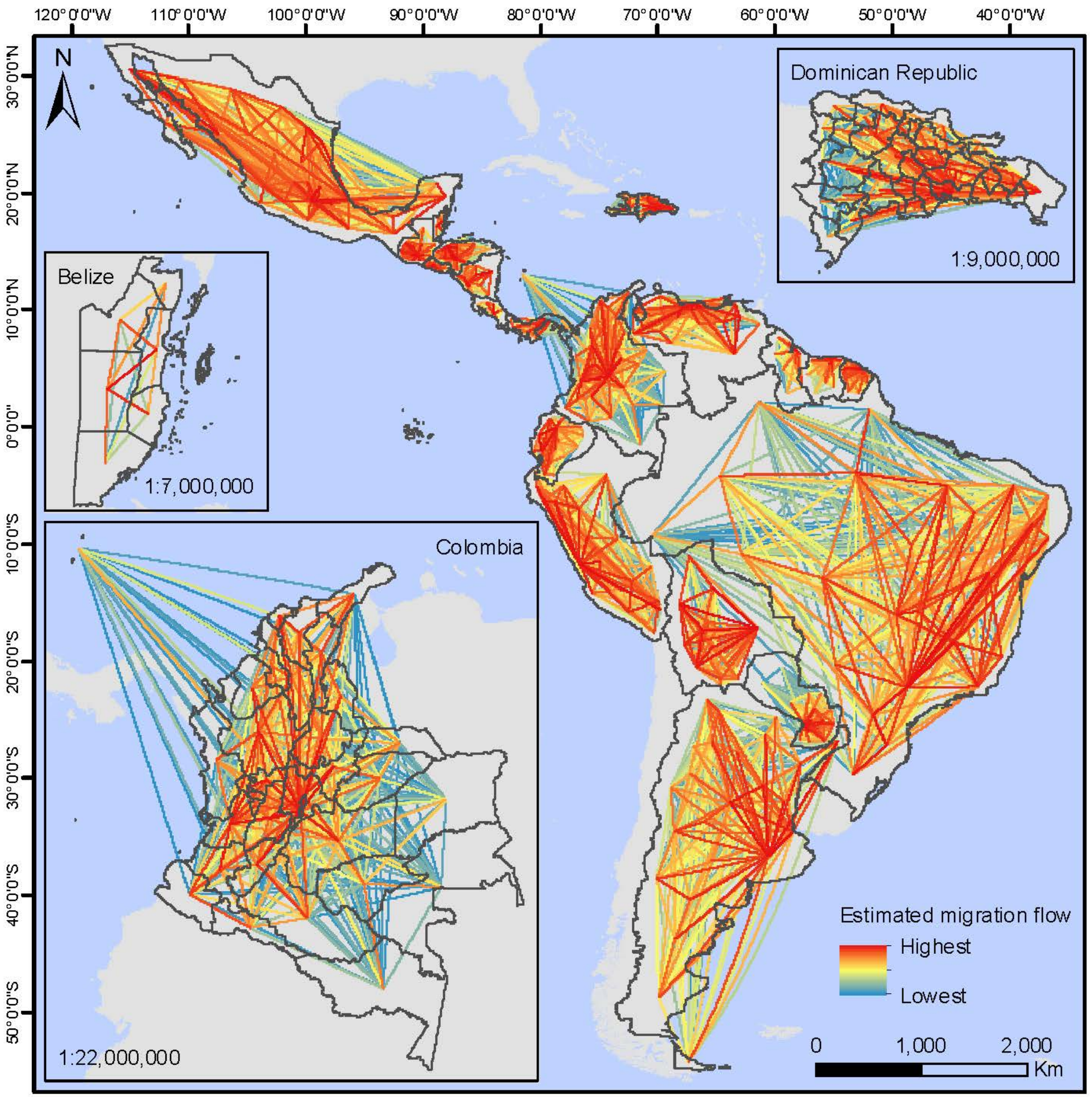
What is “normal” mobility? Anomaly detection



Lu, X., **D. Wrathall,** P. Roe Sundsøy, M. Nadiruzzaman, E. Wetter, A. Iqbal, T. Qureshi, A. Tatem, G. Canright, K. Engø-Monsen, L. Bengtsson (2016) Detecting climate adaptation from anomalies in mobile network data: analysis of Cyclone Mahasen in Bangladesh. *Climatic Change*

Internal Migration





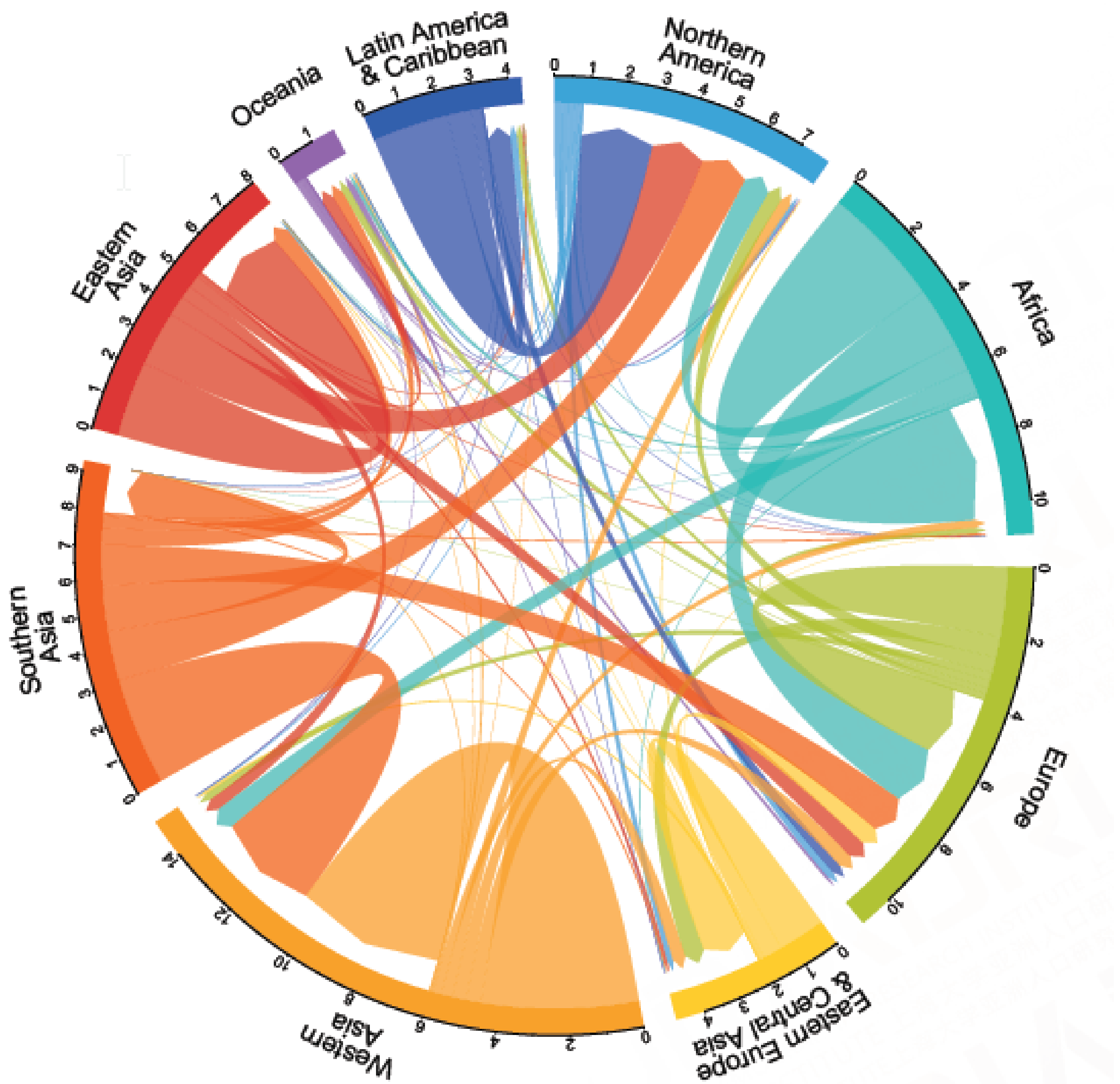
Source: A. Sorichetta. 2016. "Cell phone data and census microdata to model human movement and migration", presentation at the Workshop on Climate Migration Modeling, 5-6 December 2016, Paris, France.

Additional sources for internal migration

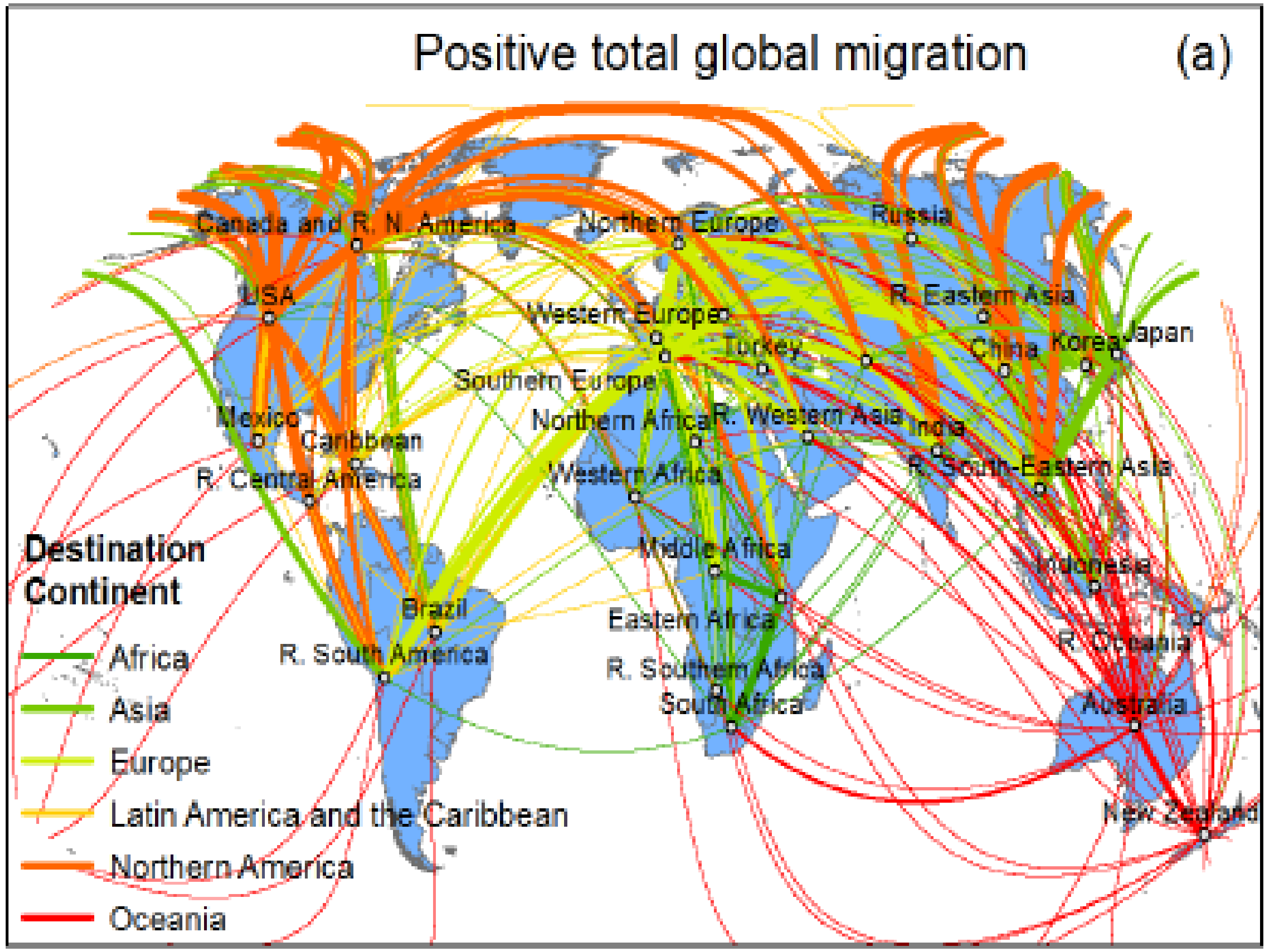
- **CELADE's Internal migration in Latin America and the Caribbean (MIALC)**
  - Based on census microdata databases (censuses of the 1980, 1990, 2000 and 2010 rounds), version 2 underway
- **World Bank's African Migration and Remittances Surveys (AMRS)**
  - Conducted for the Africa Migration Project jointly undertaken by the African Development Bank and the World Bank. Covers: Burkina Faso, Kenya, Nigeria, Senegal, South Africa, Uganda
- **Mexican Migration Project (MMP)**
  - Created in 1982 to further understanding of the complex process of Mexican migration to the United States (binational research effort)
  - The MMP's main focus has been to gather social as well as economic information on Mexican-US migration

Source: S. Adamo 2016. "Survey and other data sources on subnational stocks and flows", presentation at the Workshop on Climate Migration Modeling, 5-6 December 2016, Paris, France.

International Migration



Source: G. Abel. 2016. “Quantifying Global International Migration Flows”, presentation at the Workshop on Climate Migration Modeling, 5-6 December 2016, Paris, France.



Source: L. Jiang. 2016. “International Migration in NCAR Community Demographic Model (CDM)”, presentation at the Workshop on Climate Migration Modeling, 5-6 December 2016, Paris, France.