Climate Change Hotspots Mapping and Migration as Adaptation

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Population-Environment Research Network (PERN)

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NASA Socioeconomic Data and Applications Center (SEDAC)

SEDAC's mission is to develop and operate applications that support the integration of socioeconomic and remote sensing data and to serve as an "information gateway" between the earth and social sciences.

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Outline

- Mapping hotspots of climate change vulnerability and risk
- Migration as an adaptive response: results of climate-migration modeling work for the World Bank
- West Africa: Does the fact that migration has been a long standing adaptation strategy to climate variability mean that the region is better prepared for future climate impacts?

Mapping hotspots of climate change vulnerability and risk

SESYNC Pursuit: Meta-Analysis of Climate Change Vulnerability Mapping Studies

- Award Year: 2015
- Principal Investigators:
  - Alex de Sherbinin, Columbia University
  - Brian Tomaszewski, Rochester Institute of Technology
- Goal: Identify the strengths and weaknesses of the various vulnerability mapping approaches and benchmark the state-of-the-art with respect to vulnerability mapping practice.
- See: https://www.sesync.org/project/pursuit/climate-change-vulnerability-mapping-studies

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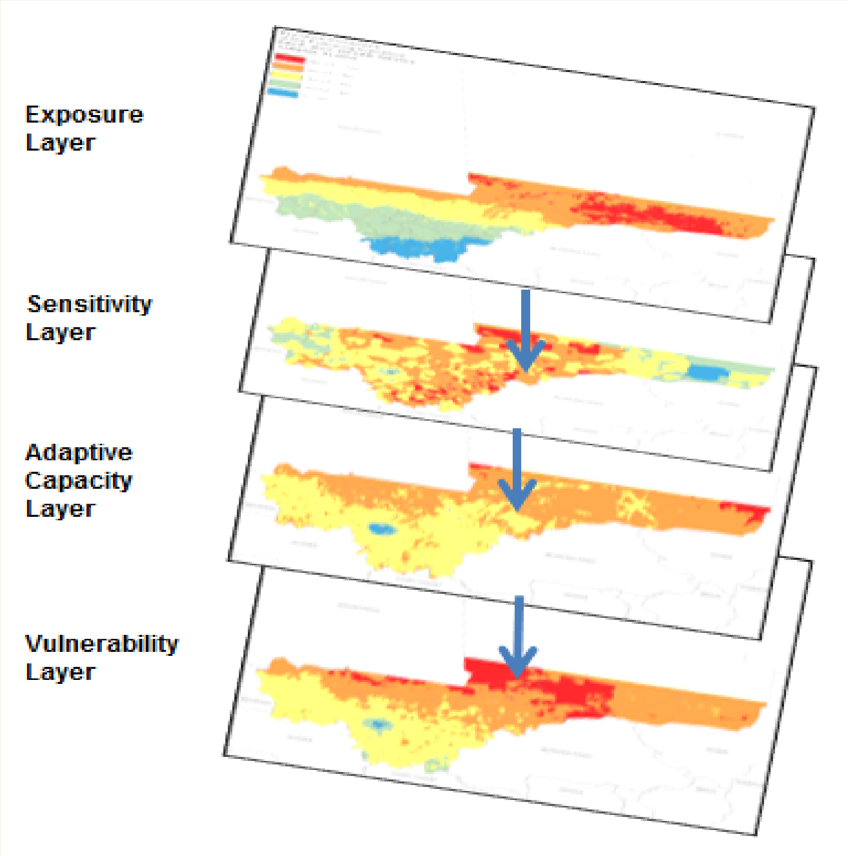
Mapping climate vulnerability "hotspots"

- Integrates *spatial variability* in:
  - Climate / biophysical changes
  - Human / system vulnerabilities



- Exposure, sensitivity, and adaptive capacity are all **spatially** differentiated

Mapping can illuminate key vulnerabilities in the coupled human-environment system and, in turn, inform where adaptation may be required.

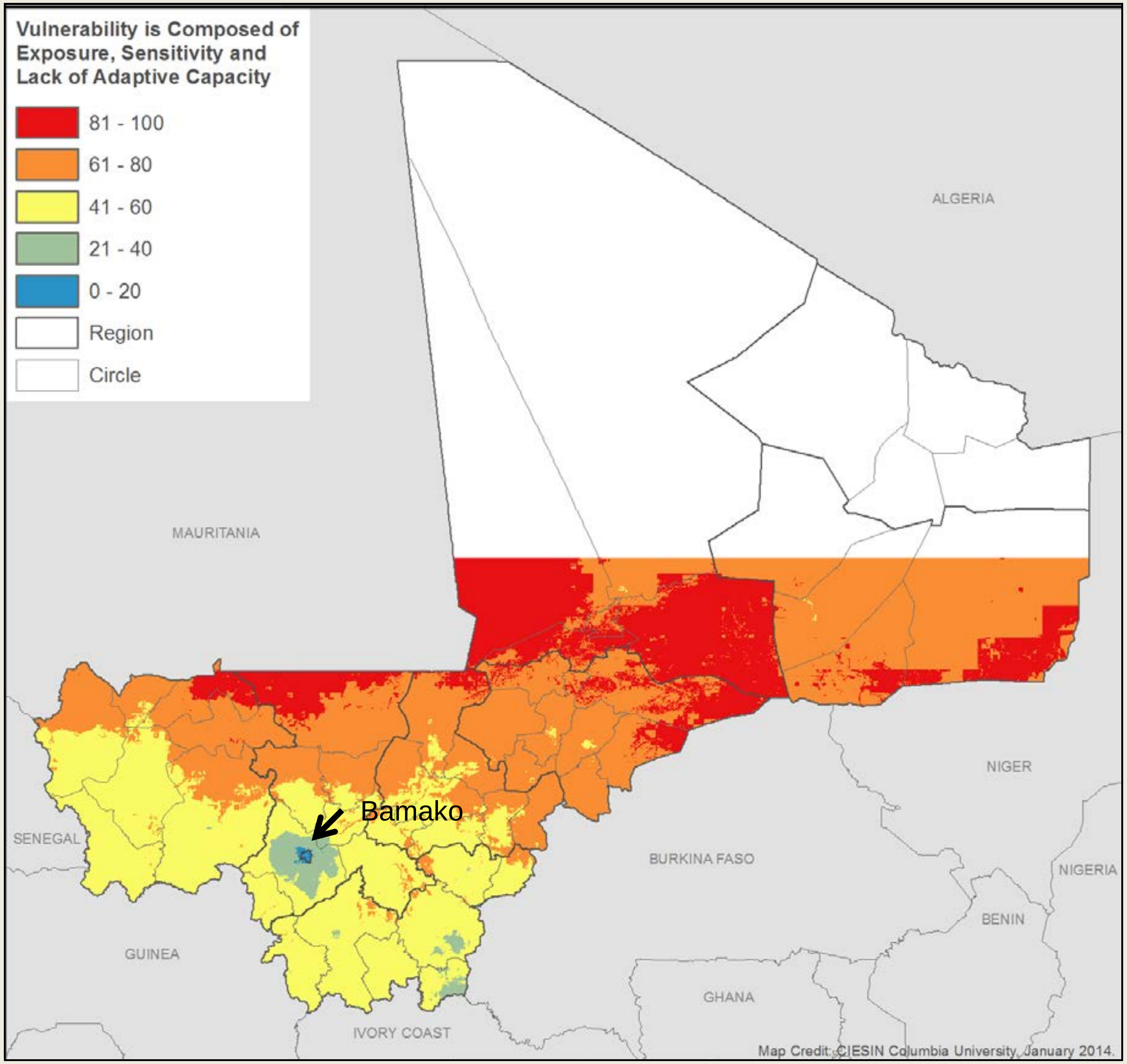
Mapping will *not* necessarily tell you what needs to be done or how to build resilience.

Mali Vulnerability Mapping: Indicators

Component	Indicator Code	Data Layer
Exposure	PRCP	Average annual precipitation (1950-2009)
	IACV	Inter-annual coefficient of variation in precipitation (1950-2009)
	DCVAR	% of precipitation variance explained by decadal component (1950-2009)
	NDVICV	Coefficient of variation of NDVI (1981-2006)
	TTREND	Long-term trend in temperature in July-August-Sept. (1950-2009)
	FLOOD	Flood frequency (1999-2007)
Sensitivity	HHWL	Household wealth (2006)
	STNT	Child stunting (2006)
	IMR	Infant mortality rate (IMR) (2006)
	POVI	Poverty index by commune (2008)
	CONF	Conflict events/political violence (1997-2012)
	CARB	Soil organic carbon/soil quality (1950-2005)
	MALA	Malaria stability index
Adaptive Capacity	EDMO	Education level of mother (2006)
	MARK	Market accessibility (travel time to major cities)
	HEALTH	Health infrastructure index (2012)
	ANTH	Anthropogenic biomes (2000)
	IRRI	Irrigated areas (area equipped for irrigation) (1990-2000)

de Sherbinin et al. 2014. Mali Climate Vulnerability Mapping. USAID-funded ARCC project

Mali Climate Vulnerability Mapping



- Created separate maps for:
  - Exposure
  - Sensitivity
  - Adaptive Capacity
- Aggregated these into an overall **vulnerability index**

de Sherbinin et al. 2014. Mali Climate Vulnerability Mapping. USAID-funded ARCC project

Vulnerability Mapping

- Focus on understanding and quantifying the complex human-environment system
- How does the system *behave* in response to stressors?
- Ideally a vulnerability map helps to:
  - Understand the complex drivers of vulnerability / risk
  - Predict negative outcomes for a given stressor
  - Predict the system's ability to recover

"[T]he true value of vulnerability assessment is the ***social learning that develops from exploring complexity*** *– viewing diverse factors that drive exposure, influence sensitivity and create barriers to adaptation – which* ***contributes to the capacity of individuals and institutions to adapt and manage risk****."*

- Preston et al. (2009)

Climatic Change
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Climate change hotspots mapping: what have we learned?

Alex de Sherbinin

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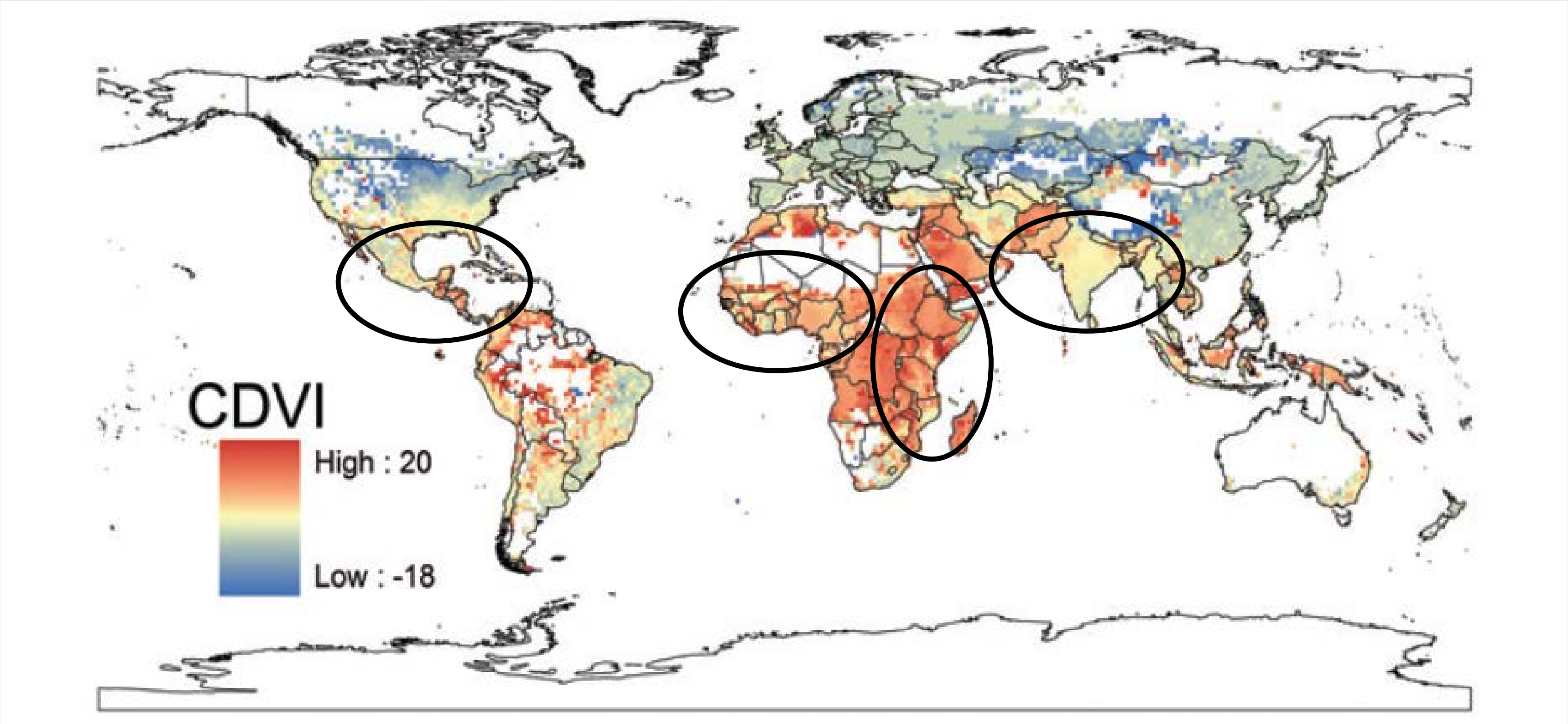
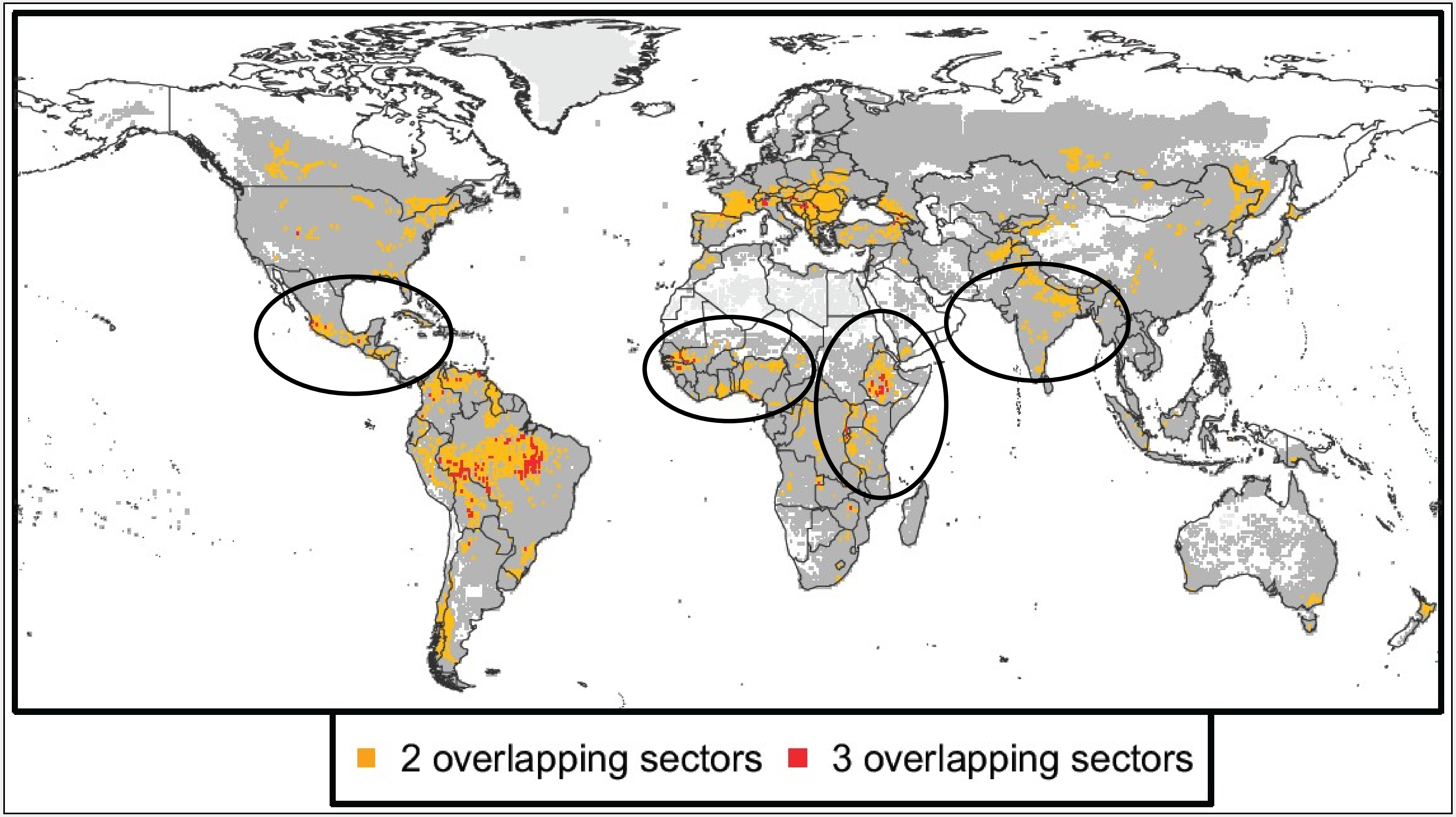
Climate-demography vulnerability index



Red areas = high vulnerability, where current demographic growth vastly exceeds “climate consistent” population growth
Blue areas = low vulnerability, where population growth is lower than “climate consistent” population growth

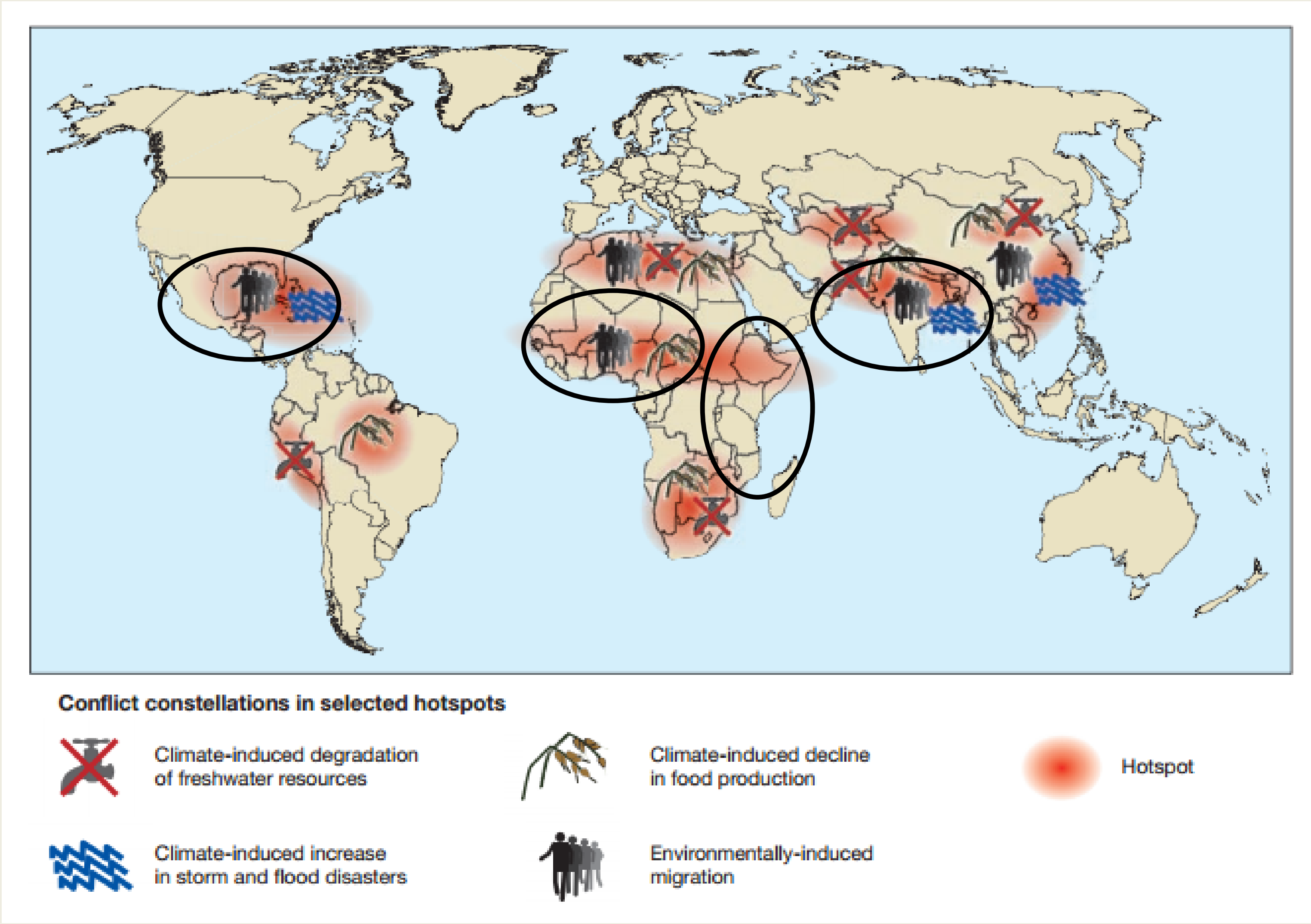
Source: Samson, J., D. Berteaux, B.J. McGill and M.M. Humphries. 2011. Geographic disparities and moral hazards in the predicted impacts of climate change on human populations. Global Ecology and Biogeography
doi:10.1111/j.1466-8238.2010.00632.x

Future Impacts: Multisectoral Hotspots of Impacts



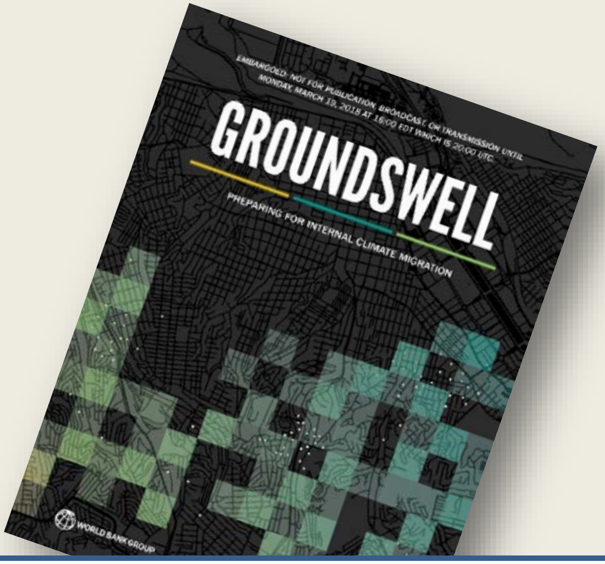
Source: Piontek F, Müller C, Pugh TAM et al (2013) Multisectoral climate impacts in a warming world. *Proceedings of the National Academy of Sciences*. doi:10.1073/pnas.1222471110.

Security risks associated with CC



Source: Schubert, Schellnhuber, et al. 2007. *Climate Change as Security Risk*. London: Earthscan.

Migration as an adaptive response: Results from the Groundswell Project



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Rigaud, K.K., A. de Sherbinin, B. Jones, J. Bergmann, V. Clement, K. Ober, J. Schewe, S. Adamo, B. McCusker, S. Heuser, and A. Midgley. 2018. *Groundswell: Preparing for Internal Climate Migration*. Washington DC: World Bank. https://openknowledge.worldbank.org/handle/10986/29461

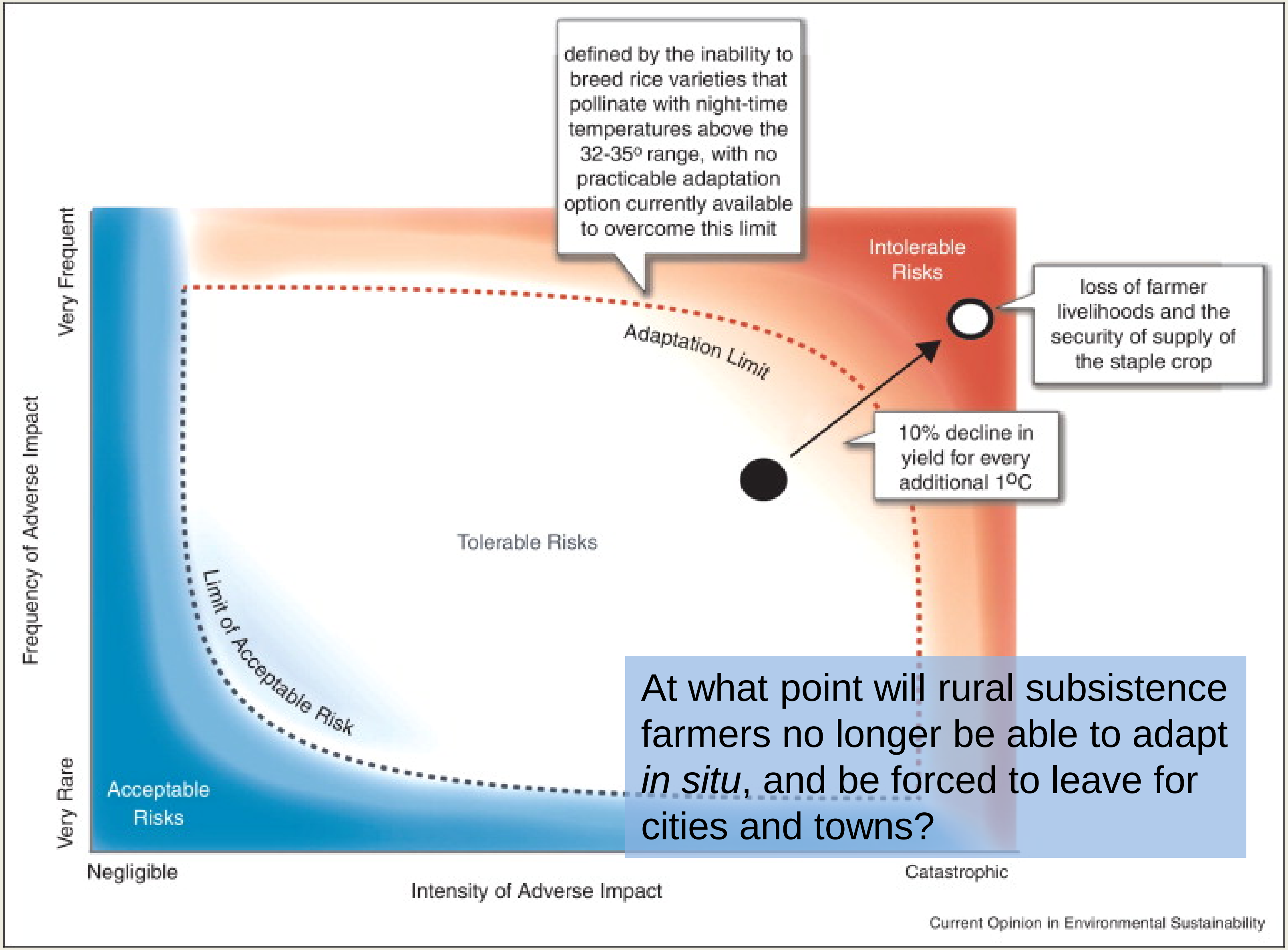


Figure 2 An adaptation limit to rice cultivation leading to loss of livelihoods and security of supply.

Source: Dow et al., 2013. Limits to adaptation to climate change: a risk approach. Current Opinion in Environmental Sustainability Volume 5, Issues 3–4 2013 384 - 391

Why model CC-induced migration and population distribution?

- Population distributions are unlikely to evolve as they have in the past
- Pop projections are needed for **planning purposes**
- The humanitarian community wants projections of likely displacement for **humanitarian response**
- Receiving countries want to understand the magnitude of future flows – especially of potential **crisis migration**
- Development actors are grappling with potential **limits to adaptation for rural livelihoods**, and how to **avoid distress migration**

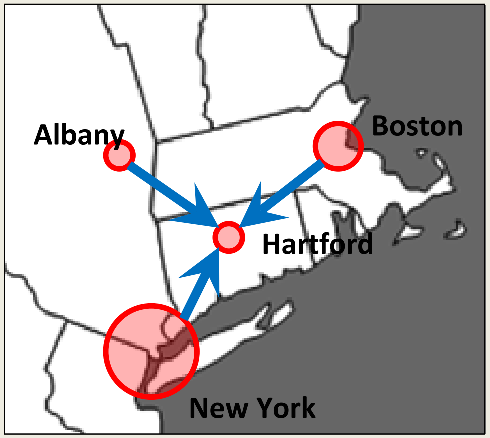
"All models are wrong, but some are useful"
- George Box

"Planning is everything, the plan is nothing."
- Dwight Eisenhower

Gravity models in spatial population research

- Gravity models in demography/geography are generally used to **simulate aggregate human behavior or broad trends**.
- Commonly used in models of spatial interaction, spatial allocation, migration, accessibility, and attractiveness.
- The “gravitational pull” of any location is typically measured using some local characteristic such as **population, jobs, GDP**, etc.
- As in the Newtonian laws of gravity, **the attraction or interaction between places is a function of mass (population or local characteristic) and distance**.
- **Environmental characteristics can be included as push or pull factors**, thus positively or negatively impacting the relative attractiveness of locations to potential migrants, and by extension, the ongoing evolution of subnational population distributions.

Gravitational Potential



$$v_i = \sum_{j=1}^{n} \frac{P_j}{D_{ij}^2}$$

NCAR-CIDR Spatial Population Downscaling Model

Research Goal:

To develop an 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.

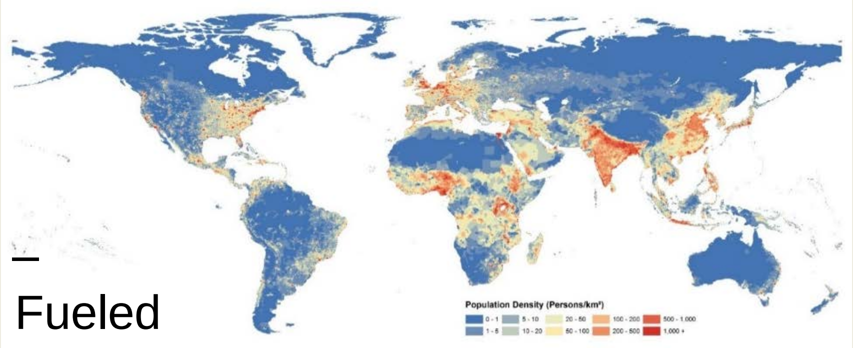
Characteristics

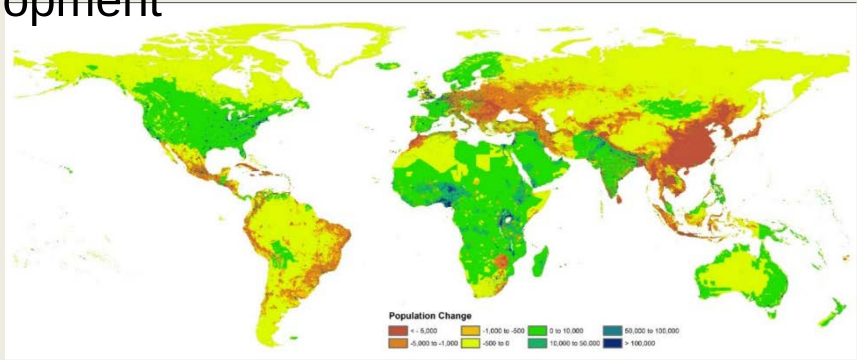
- Gravity-based downscaling model
- Captures observed geographic patterns
  - Calibration to historic data
- Flexible framework
  - Data (easy to include ancillary layers)
  - Resolution (temporal & spatial)

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

Model Modifications

- The original model takes advantage of the observed correlation between the agglomeration effect quantified in the gravity model and urban/rural patterns of spatial population change
- Here we incorporate **changing environmental conditions** by considering sectoral impact indicators from the ISI-MIP project, specifically crop production and water availability
- We hypothesize that the **prediction error** in the original model results from missing variables, and that changes in crop production and water availability explain a portion of observed error
- We modified the existing NCAR-CIDR model to include local climate impacts as measured through the crop and water indicators (deviations from long term averages), as well as sea-level rise

MODELING INPUTS

Development pathways
Shared Socioeconomic Pathways (SSPs)—SSP2 (moderate development) and SSP4 (unequal development).

GHG emission pathways drive climate impacts using ISIMIP water and crop model results, and sea-level rise augmented by storm surge. Two Representative Concentration Pathways (RCPs) used: RCP 2.6 (low emissions) and RCP 8.5 (high emissions).

PLAUSIBLE INTERNAL CLIMATE MIGRATION SCENARIOS UP TO 2050

Pessimistic/ Reference (RCP8.5/SSP4)	**More inclusive development** (RCP8.5/SSP2)	**More climate-friendly** (RCP2.6/SSP4)

The Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP) Data

Table 3.3: Matrix of climate, crop and water model combinations used in this report.

	Crop simulation			
Water simulation	**GCM1, LPJmL (crop)**	**GCM1, GEPIC**	**GCM2, LPJmL (crop)**	**GCM2, GEPIC**
HadGEM2-ES, LPJmL (water)	Model 1			
HadGEM2-ES, WaterGAP2		Model 2		
IPSL-CM5A-LR, LPJmL (water)			Model 3	
IPSL-CM5A-LR, WaterGAP2				Model 4

Figure B.1: ISIMIP average index values during 2010-50 against 1970-2010 baseline for water availability, from LPJmL/water (left) and WaterGap (right), forced with the HadGEM2-ES climate model (top four maps) and IPSL-CM5A (bottom four maps) under RCP2.6 and RCP8.5, East Africa

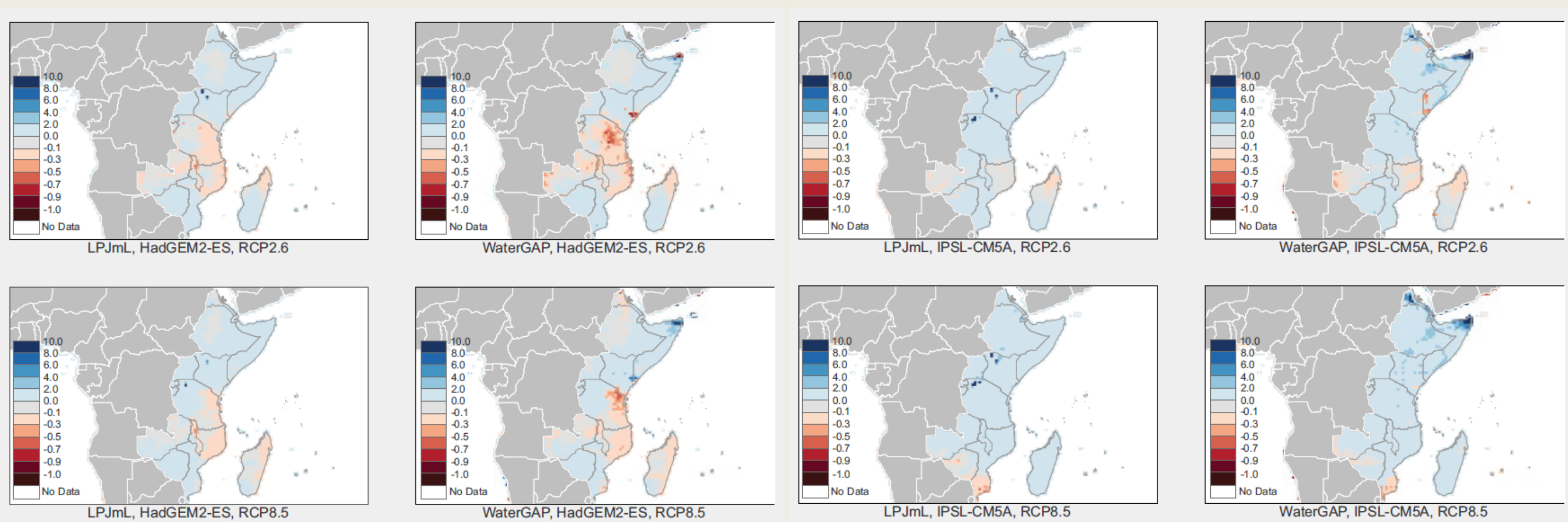


Figure 3.4: Flowchart of modeling steps

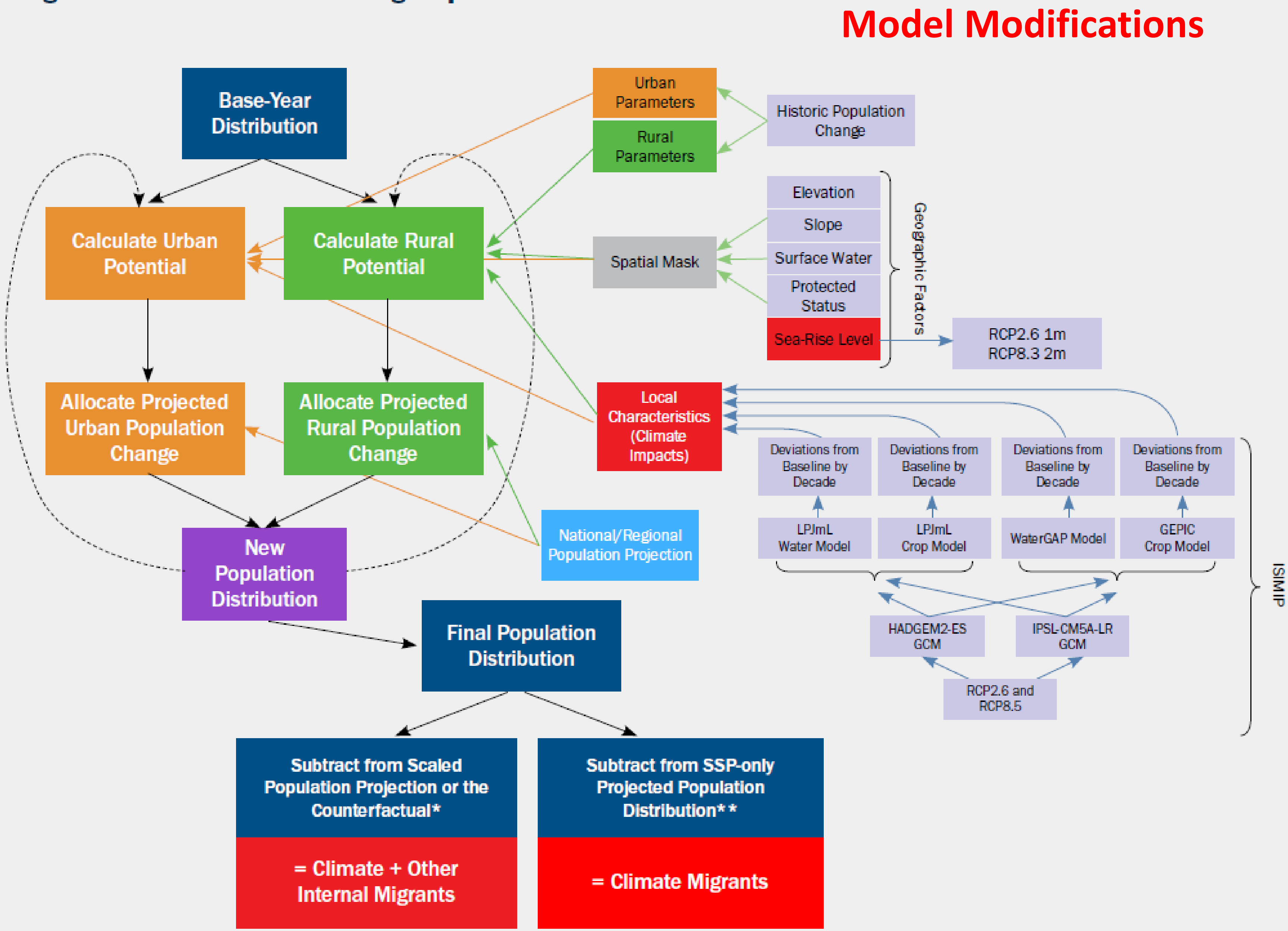
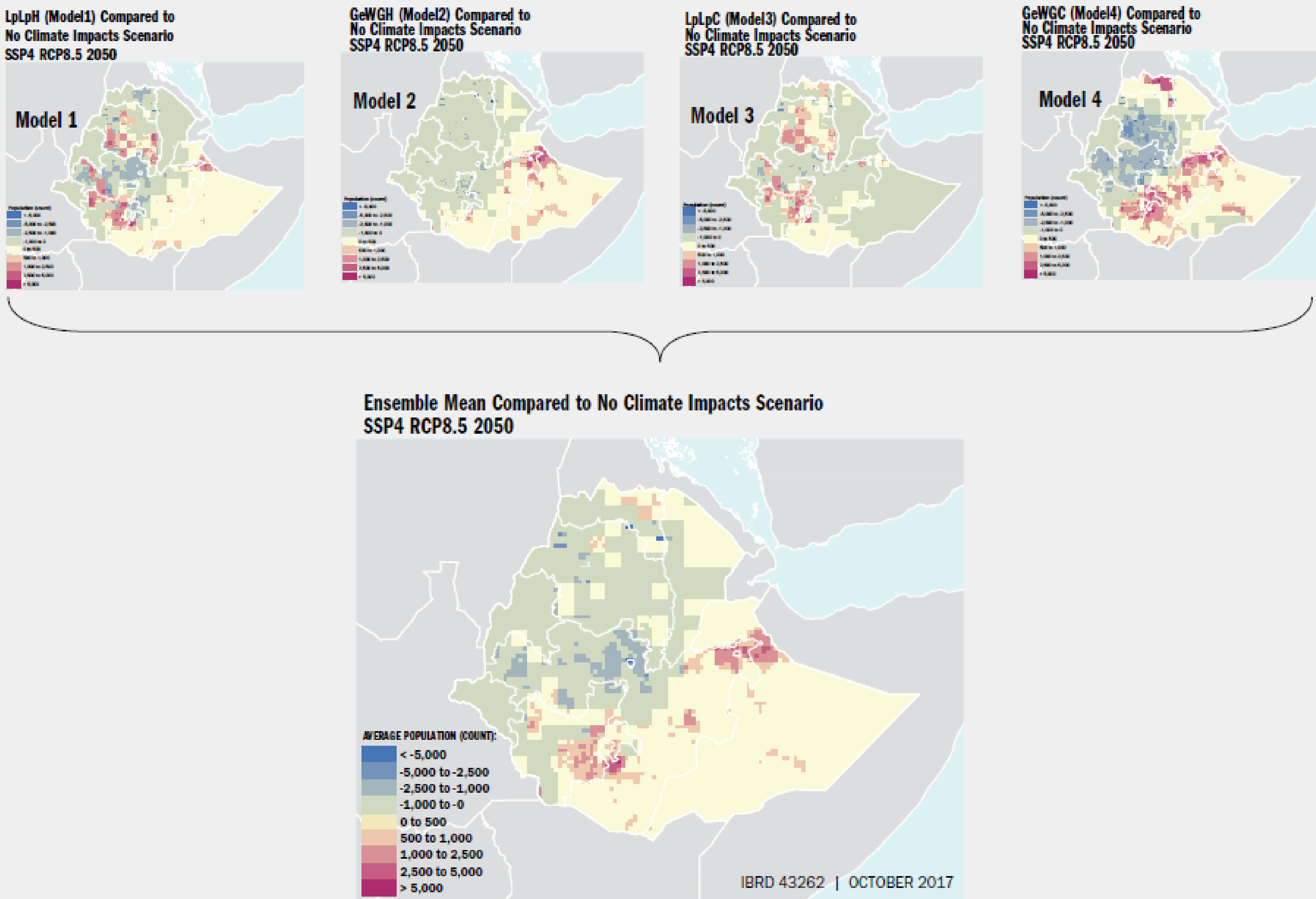
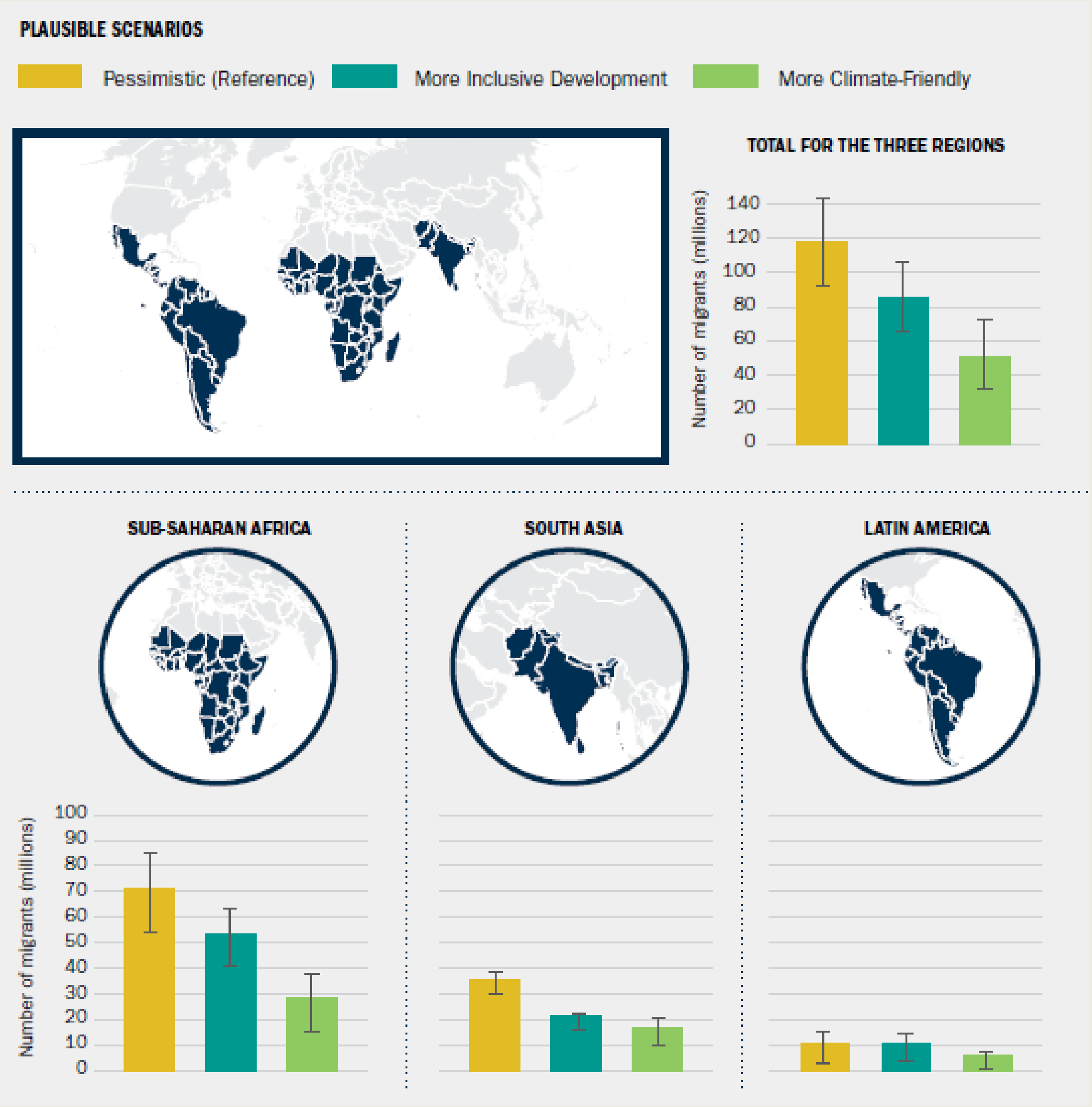


Figure 3.3: Illustrative example for Ethiopia: Combining four model outputs into one ensemble

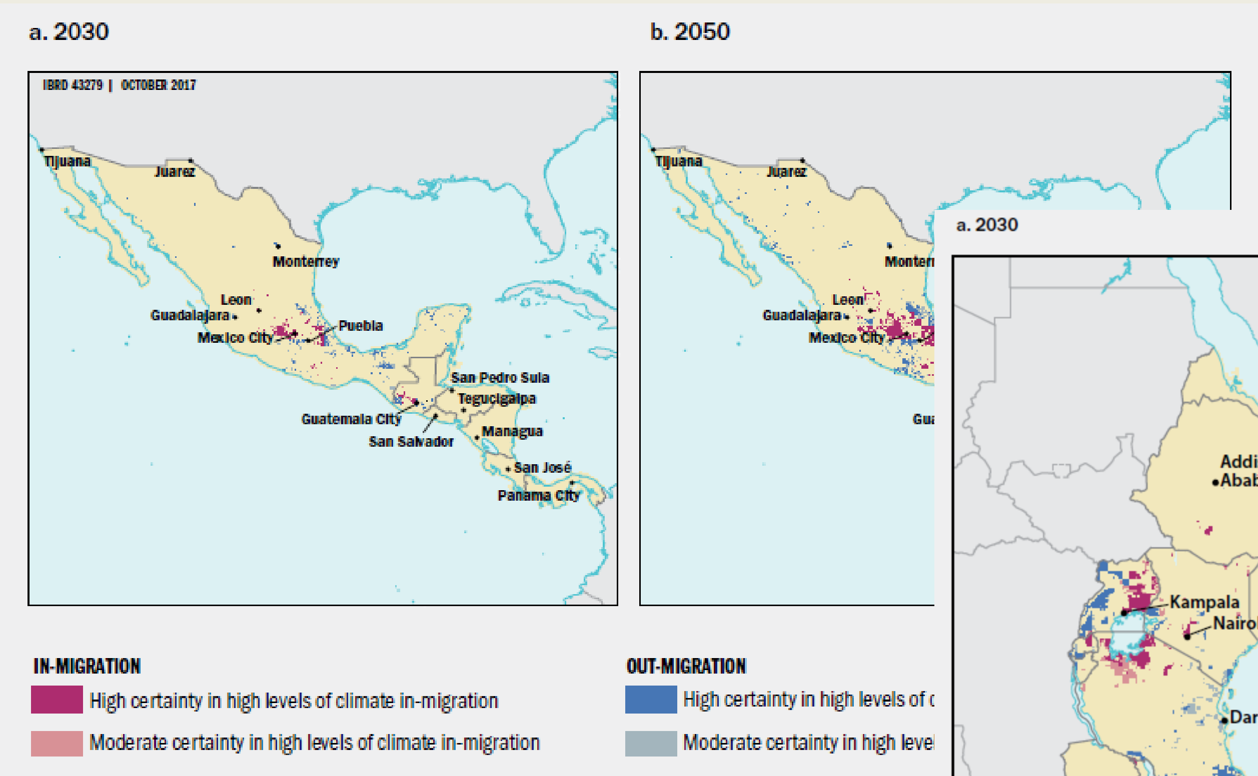


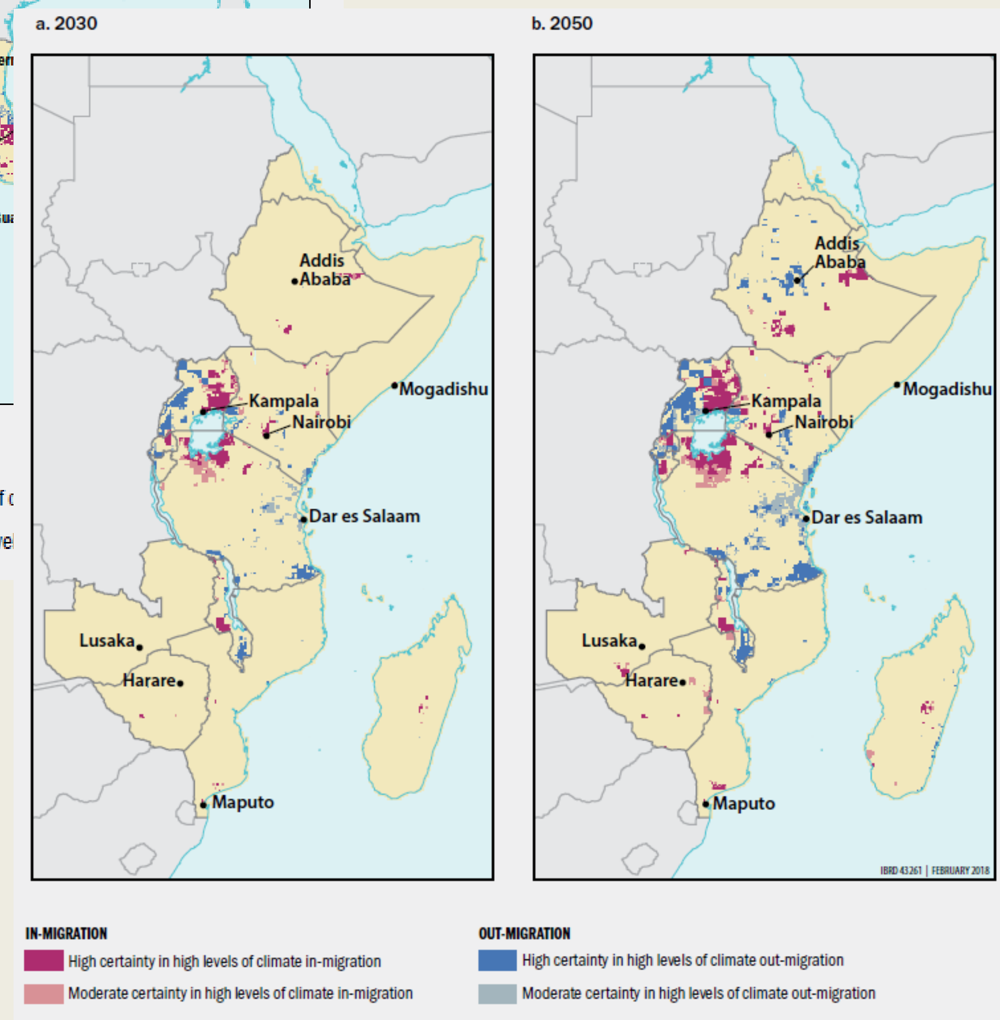
Headline numbers

- Up to 140 million internal migrants by 2050 in the three regions
- The largest numbers are in Africa, suggesting high climate sensitivity in that region
- Numbers are lower for SSP2: more inclusive development, and lowest for the climate-friendly RCP2.6 scenario



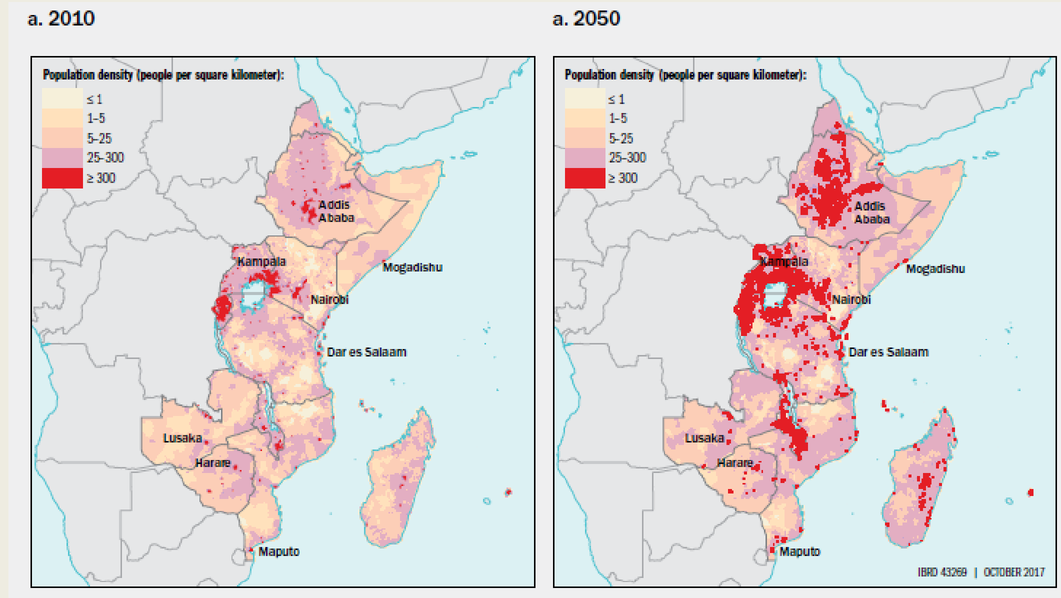
Spatial patterns

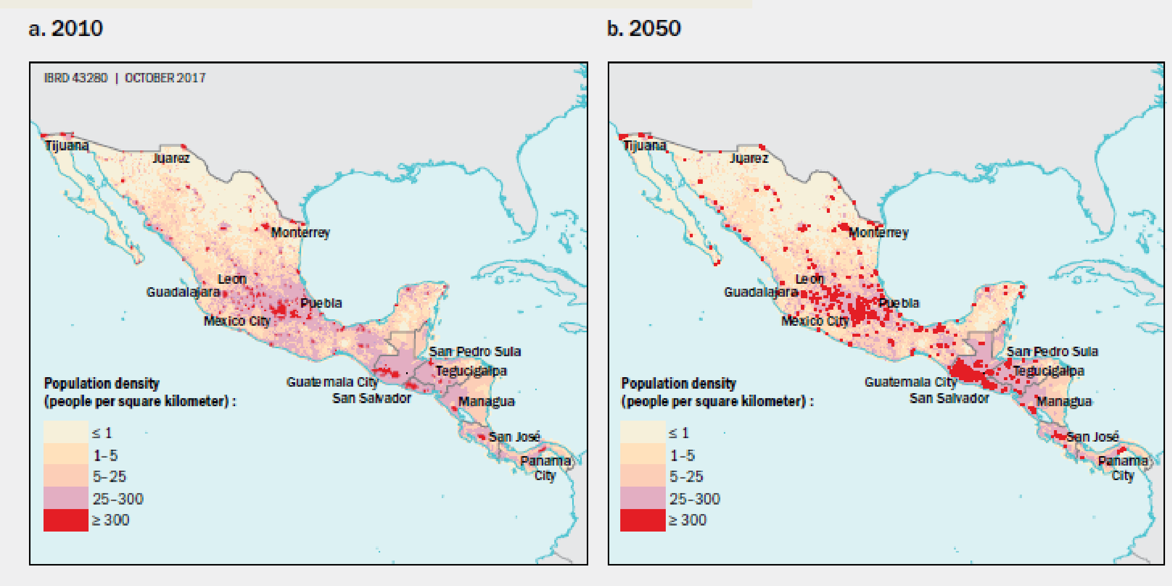




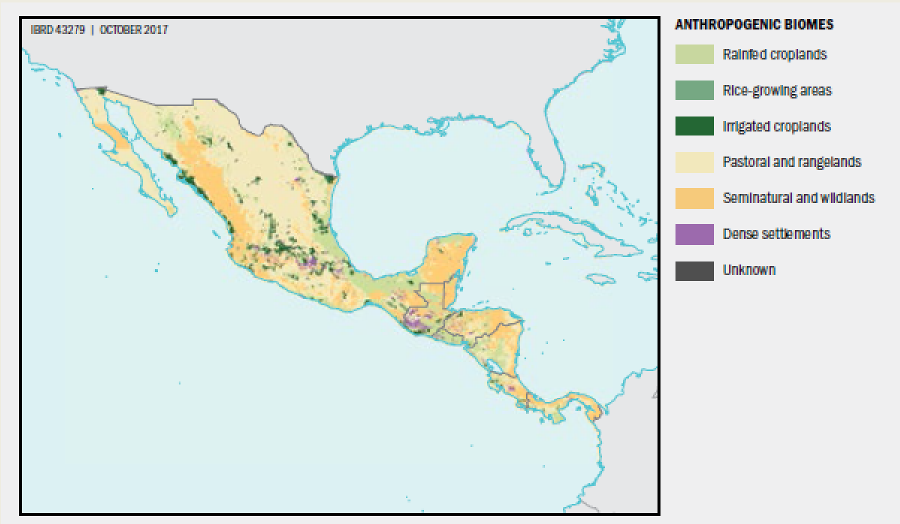
Urbanization

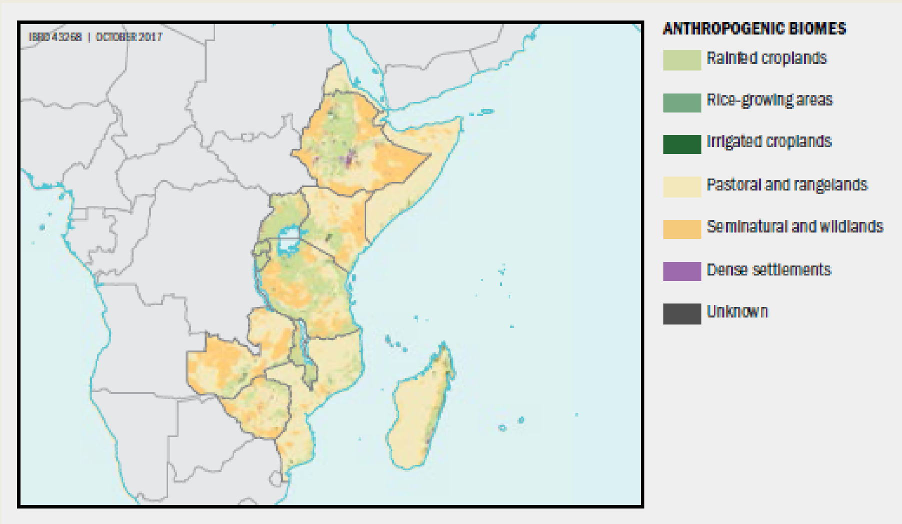
Urban Threshold: >=300 persons per sq. km.

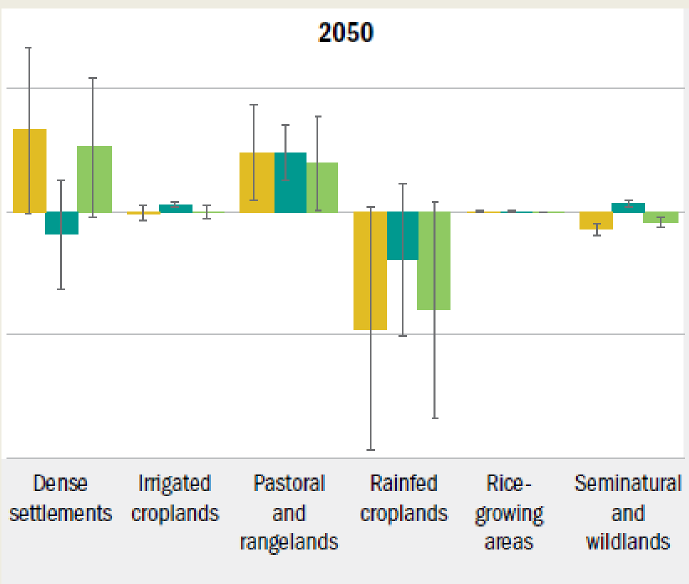


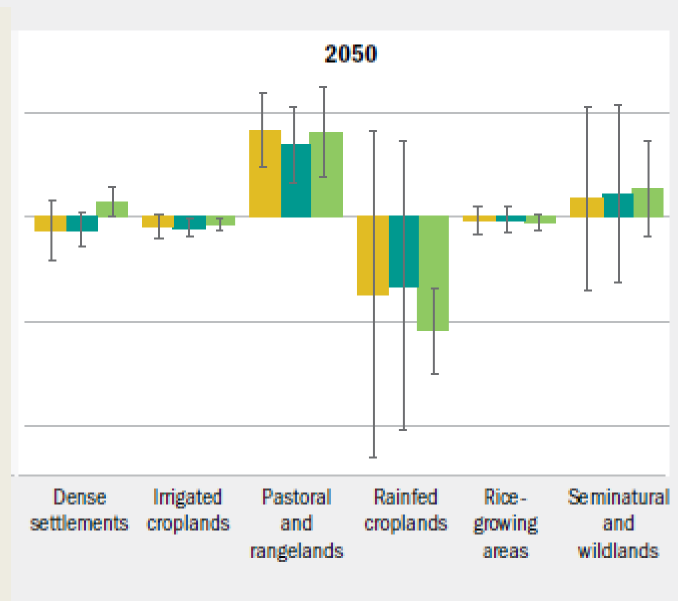


Livelihood Systems



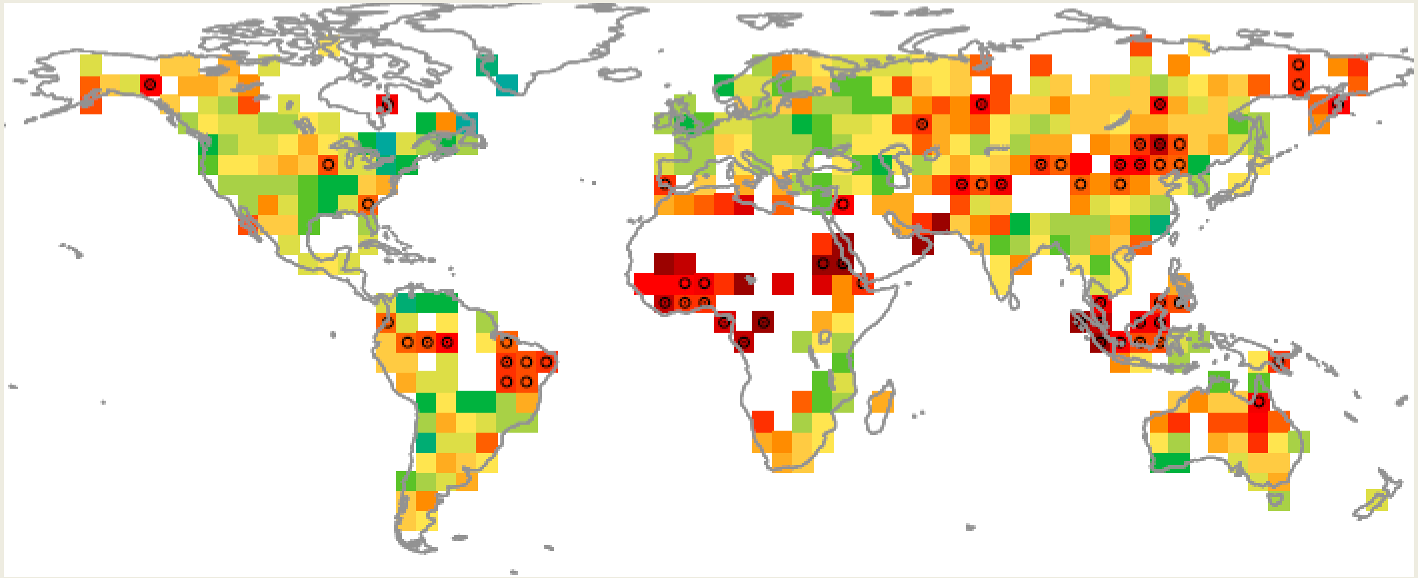






West Africa

The “canary in the cage” of climate change



Observed climate change hotspots, Turco et al. 2016 *GRL*

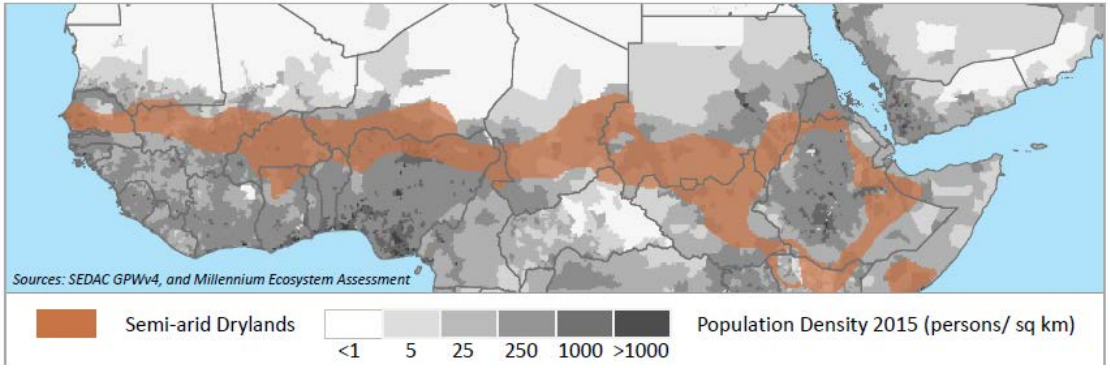


Figure 3.2.2 Temperature change in degrees Celsius per decade from 1951-2013.

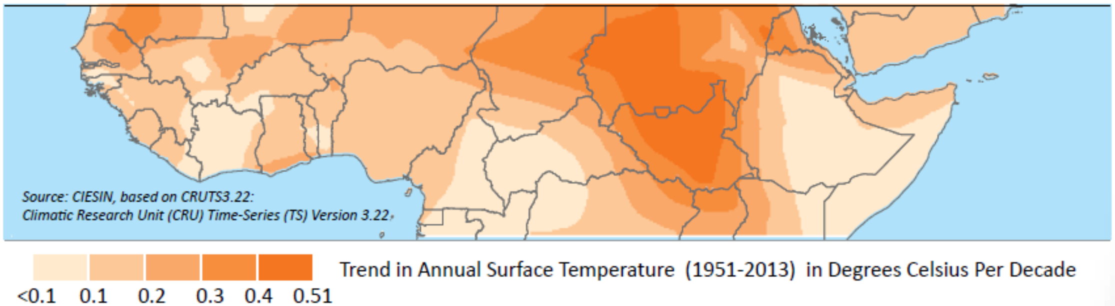


Figure 3.2.3 Coefficient of variation of rainfall from 1951-2013 (in percent of the long term average).

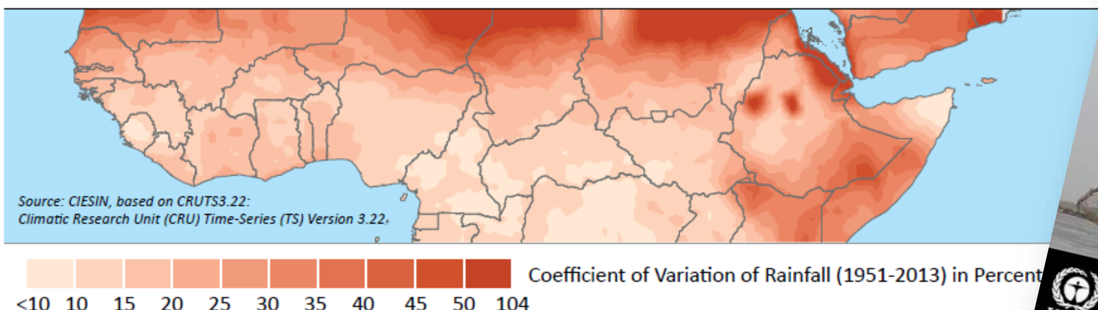
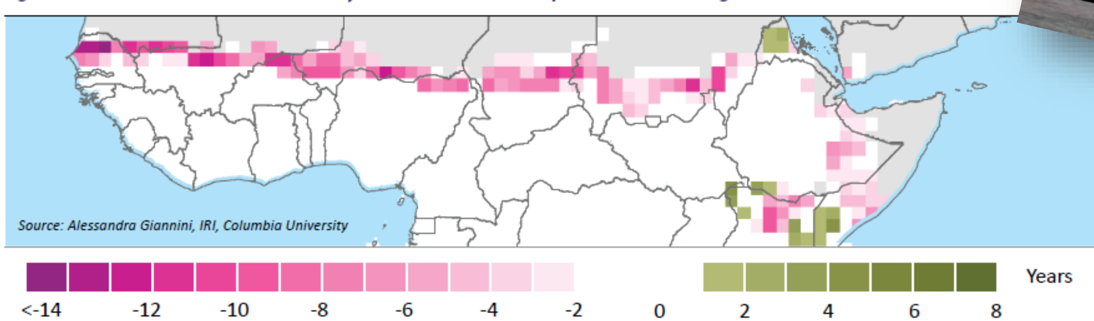
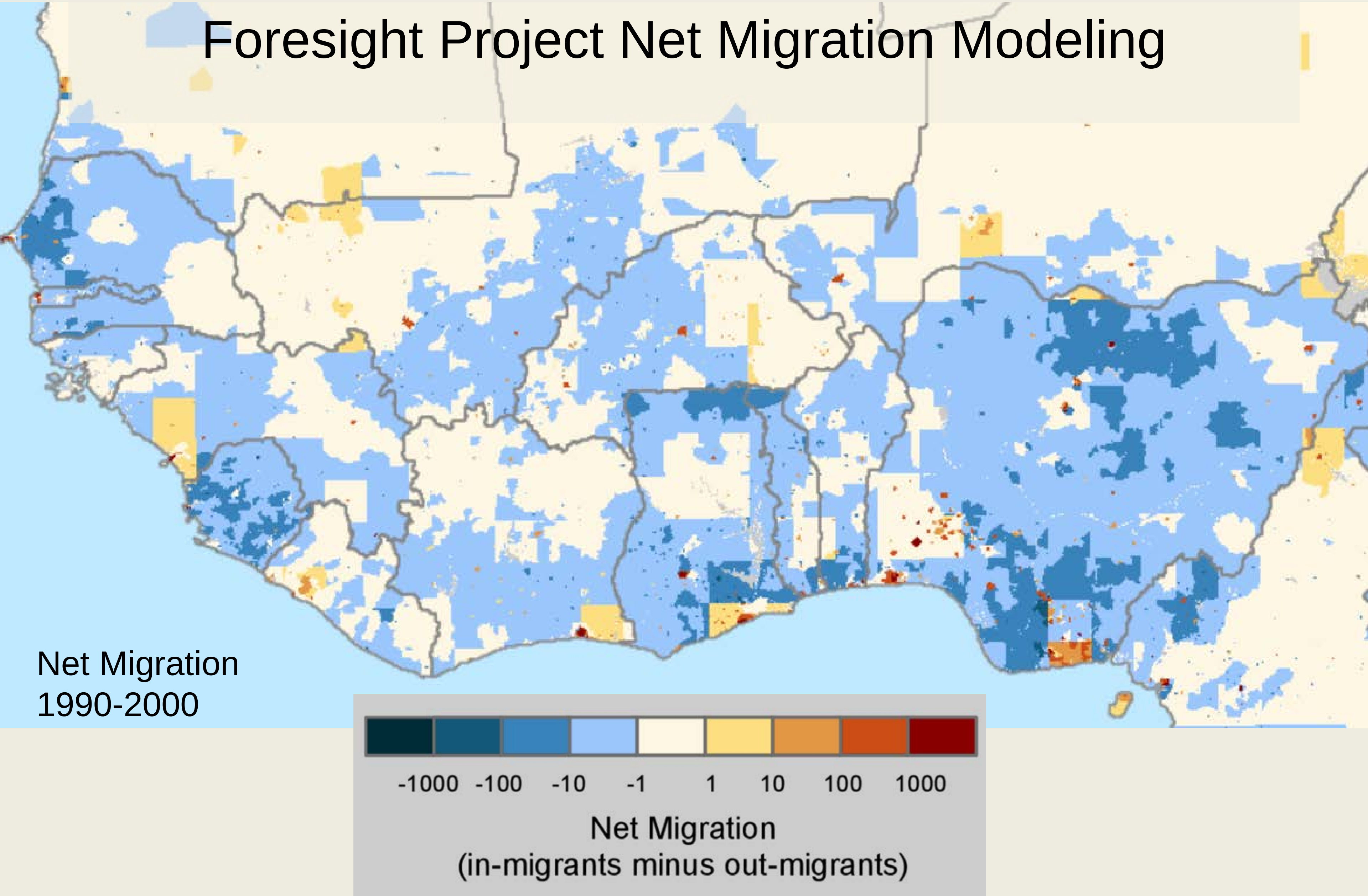


Figure 3.2.4 Difference in the number of years that received adequate rainfall for sorghum and millet.



Zommers et al. 2016. *Loss & Damage: The Role of Ecosystem Services*. Nairobi: UNEP.

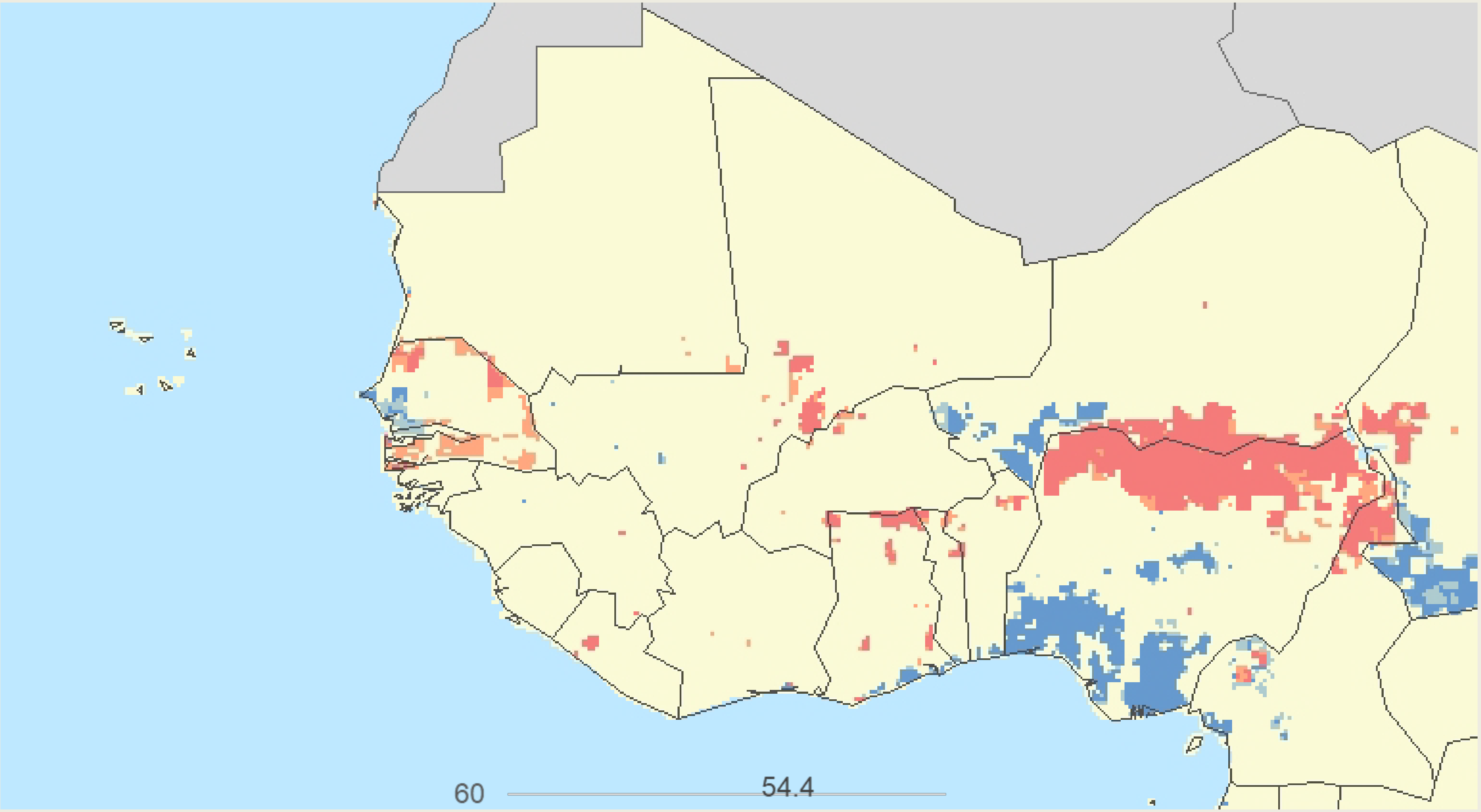
Foresight Project Net Migration Modeling

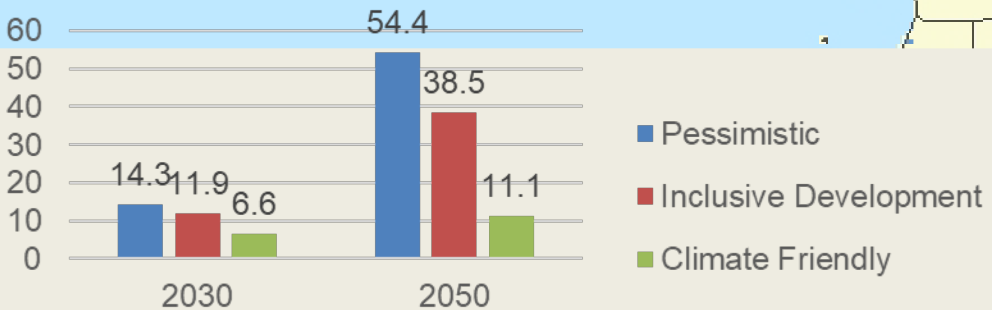


Net Migration
1990-2000

Data available at http://sedac.ciesin.columbia.edu/data/set/popdynamics-global-est-net-migration-grids-1970-2000

Groundswell Results





I posed this question to the PERN* community:

Is the Sahel in fact likely to be more adapted to future climate impacts than other regions of Africa because of past use of migration as an adaptive response to climate variability (especially drought)?

* Population-Environment Research Network of Future Earth and the International Union for the Scientific Study of Population

PERN

Agreeing with:

“For many systems, frequent levels of stress also lead to adaptations to that stress.”

- "in risk-prone environments where the state has little to offer, surprisingly adaptable livelihood systems can evolve. In the savannah of West Africa, for example, people have had to deal with climatic variability and environmental stresses since time immemorial, and most of the time they have done so quite successfully. **Human mobility has a very central place in the adaptive strategies of farmers and pastoralists in this region**.“ *– Kees van der Geest (2011), UNU-EHS*
- I do believe these communities might be better adapted to the impacts of future CC: **I have this feeling for communities of Northeastern Region of Brazil** (at least, for the ones that did not migrate to other areas during drought periods).

  – Luci Hidalgo Nunes, UNICAMP

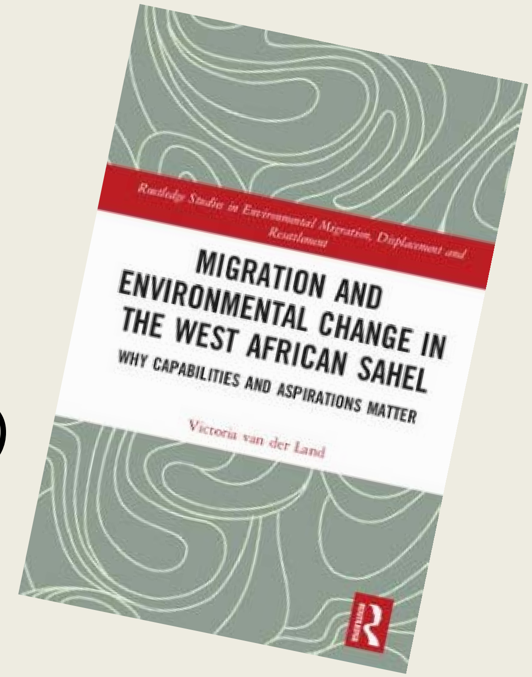
Qualified Agreement with:

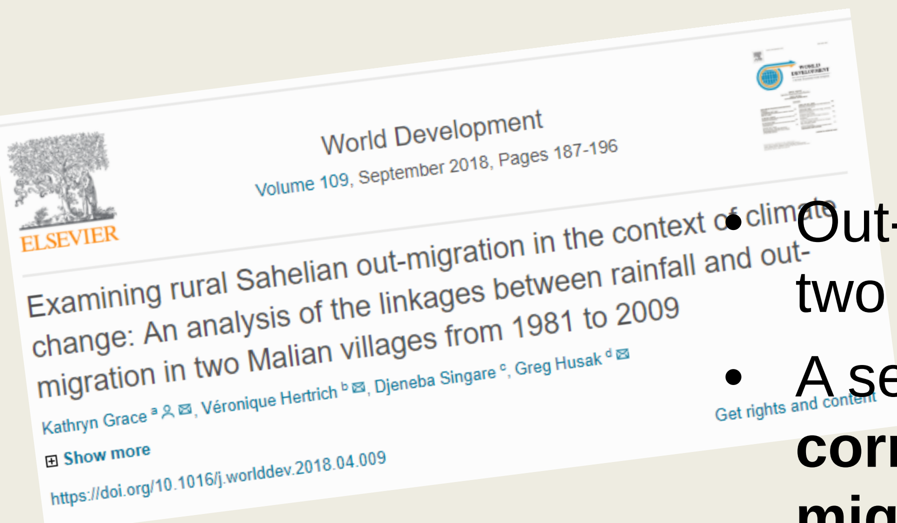
"For many systems, frequent levels of stress also lead to adaptations to that stress."

- Mobility is indeed inherent in the culture of most Sahelian communities and serves as important livelihood strategy. The natural environment is just one out of many reasons for mobility…. My team is currently working on a systematic meta-analysis on adaptation strategies in African drylands to identify the role of migration next to many other strategies. According to our results it seems **migration plays a central role in adaptation processes**, **but agricultural strategies are far more important**. Against this background I'm a bit hesitant to reason that communities with a migration culture are better prepared for the expected cc than non-mobile societies, perhaps they are prepared just differently. – *Kathleen Hermans, Helmholtz Centre for Environmental Research*

Conflicting evidence on the connection between drought / environmental factors and migration

Critiquing the assumption that environmental stress is the dominating migration driver, I **demonstrate the important role of individual aspirations and social processes, such as educational opportunities and the pull of urban lifestyles**. – *Victoria van der Land (2018)*




World Development
Volume 109, September 2018, Pages 187-196
ELSEVIER
Examining rural Sahelian out-migration in the context of climate change: An analysis of the linkages between rainfall and out-migration in two Malian villages from 1981 to 2009
Kathryn Grace [a], Véronique Hertrich [b], Djeneba Singare [c], Greg Husak [d]
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- Out-migration is a common practice in the two Malian villages.
- A season with **poor rainfall is not correlated to increased levels of out-migration** but may impact duration or destination.

– *Katherine Grace* et al *(2018)*

Agreeing with:

"*The impacts of stress, however, may be more problematic when the frequency or magnitudes of stress change at rates beyond which the system can adapt and still maintain its underlying structure*"

- I find it a bit difficult to understand how it helps the communities adapt in a future context given the scale of expected changes, together with abrupt, non-linear and surprise events. – *Suruchi Bhadwal, TERI*
- I spent a lot of time living and working in Niger in the late 1990s and early 2000s. **I am skeptical that migration will be an effective adaptation strategy**. It would have certainly been one in the past, but with the rapid population growth across the Sahel (highest in the world) and the (relatively new) insecurity that has come about in the Sahel dating back to the collapse of Libya and the rise of AQIM and Boko Haram, migration is increasingly challenging, particularly for herders such as the Fulani. – *Kristen Paterson, PRB*