Mapping and Modeling the Flow of Climate Change Migrants

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SciencesPo

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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.
When we come to the Mediterranean Sea, of course,

I take a train, I arrive in London.

At Breda, I spent four days looking for work without finding anything.
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.”

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. “

## Estimated Magnitudes of Migration & Displacement

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

*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

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

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**Speed of Event**

- Slow Onset
- Fast Onset

**Long-Term Migration Response**

- Higher Certainty
- Lower Certainty
Dynamic Economic Model of coastal inundation \( \rightarrow \) population shifts, \( \Delta \) GDP

trade and migration endogenous but zero “hard” adaptation

Mean losses in total cell real GDP in 2200 under RCP 4.5


634m people in the 10m LECZ

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...

Agent Based Models

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

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

Aggregate migration of community

Result:

Agent Based Models
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

**Pastoralism is a livelihood based on:**

**Production**
- Climate
- Rainfall
- Land access
- Pasture
- Pasture rejuvenation

**Sale and consumption**
- Livestock
- Cash assistance
- Remittances
- Drought IDPs

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)

**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, 1/8<sup>th</sup> degree
- **NO CLIMATE ASSUMPTIONS**

Future Impacts: Multisectoral Hotspots of Impacts

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>
<thead>
<tr>
<th>Crop simulation ➔ Water simulation ↓</th>
<th>GCM1, LPJmL (crop)</th>
<th>GCM1, GEPI</th>
<th>GCM2, LPJmL (crop)</th>
<th>GCM2, GEPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>GCM1, LPJmL (water)</td>
<td>#1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GCM1, WaterGAP2</td>
<td></td>
<td>#2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GCM2, LPJmL (water)</td>
<td></td>
<td></td>
<td>#3</td>
<td></td>
</tr>
<tr>
<td>GCM2, WaterGAP2</td>
<td></td>
<td></td>
<td></td>
<td>#4</td>
</tr>
</tbody>
</table>
CROP MODELS

Gravity Models

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

WATER MODELS
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

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

<table>
<thead>
<tr>
<th>Country or region</th>
<th>Total number of IDPs as of 31 December 2015 (conflict)</th>
<th>New displacements in 2015 (conflict)</th>
<th>New displacements in 2015 (disasters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abyei Area</td>
<td>82,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Afghanistan</td>
<td>1,174,000</td>
<td>335,000</td>
<td>71,000</td>
</tr>
<tr>
<td>Albania</td>
<td>4,200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Algeria</td>
<td>19,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angola</td>
<td>5,600</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Argentina</td>
<td>36,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Armenia</td>
<td>8,400</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>5,700</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Azerbaijan</td>
<td>564,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bahamas</td>
<td>2,800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bangladesh</td>
<td>426,000</td>
<td>531,000</td>
<td></td>
</tr>
<tr>
<td>Belize</td>
<td>300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bhutan</td>
<td>2,900</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bolivia</td>
<td>11,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bosnia and Herzegovina</td>
<td>98,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Botswana</td>
<td>300</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>59,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bulgaria</td>
<td>800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burkina Faso</td>
<td>3,700</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burundi</td>
<td>99,000</td>
<td>23,000</td>
<td>3,100</td>
</tr>
<tr>
<td>Cabo Verde</td>
<td>200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cambodia</td>
<td>8,900</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cameroon</td>
<td>124,000</td>
<td>71,000</td>
<td>11,000</td>
</tr>
</tbody>
</table>
Very large flows from Kathmandu to other districts immediately after the earthquake...

Nepal Population Estimates as of 10th June 2015

<table>
<thead>
<tr>
<th>Nepal Population Estimates</th>
<th>Pre-earthquake population</th>
<th>Population outflow (above normal)</th>
<th>Population inflow (above normal)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.8m</td>
<td>+180,000 (110,000 - 260,000)</td>
<td>-55,000 (-33,000 - 77,000)</td>
</tr>
</tbody>
</table>

Key findings:
1. An estimated 390,000 people moved more than normal from the Kathmandu, Bhaktapur and Lalitpur districts, with Kathmandu Valley being the most densely populated area in Nepal and home to 2.8 million people.
2. Kathmandu Valley is here defined as the districts of Kathmandu, Bhaktapur and Lalitpur. Kathmandu Valley is one of the most densely populated areas in Nepal and home to 2.8 million people.
3. Above normal flows from Kathmandu Valley to other districts.

Population Displacements

What is “normal” mobility? Anomaly detection

![Graph showing number of unions with significant increase/decrease of daily flow over time with Mahasen highlighted.]

Internal Migration

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
