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Developments in modelling of climate change-related migration

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Abstract Climatic variability and change is known to influence human migration patterns. Researchers increasingly see migration as one of a range of potential means by which populations may adapt to the future impacts of climate change. Modelling of climate change-related migration is a relatively new undertaking. This article provides a brief overview of current scholarly understanding of climate change-related migration processes, identifies recent developments and current challenges in modelling, and suggests opportunities for enhancing future modelling efforts. Given the lack of reliable global datasets on environmentally related migration, regional and sub-regional modelling of climate change effects on migration is where most developments are likely to emerge in the short-run. Such models, which can draw on a range of GIS-based and statistical approaches, at present make use of fairly general assumptions about migration behavior, and therefore best serve as gauges of potential trends and migration hotspots, and not as absolute predictors of future migrant numbers. Models will become increasingly sophisticated as scholarly understanding of underlying factors influencing migration behavior, such as risk perception, social networks, and labor market connections, is improved. Obtaining reliable data for use in such models will remain a significant challenge in coming years. International policymakers seeking to expand the predictive capacity of models are encouraged to use existing mechanisms such as the UN Framework Convention on Climate Change to develop protocols and mechanisms for collecting and sharing reliable data on climate-related population movements.

1 Introduction

Scholars have long known that environmental conditions, including climatic variability and change, can and do influence human migration (e.g. Hugo 1996; Hunter 2005). In recent years, a range of estimates have appeared suggesting that climate change, sea level rise and

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related environmental impacts could lead to human population displacements and movements totalling in the hundreds of millions by mid-century (e.g. Myers 2002; Christian Aid 2007). Estimates such as these tend to be based on broad-brush assumptions about current and future trends in climate and population patterns (McLeman 2011a). While there exists a large and continually growing scholarly literature modelling the effects of climate change on the migration and distribution of non-human organisms, only in recent years have studies emerged seeking to systematically model human migration responses to climate. Studies that have sought to incorporate human migration into integrated assessments of climate change impacts are fewer still (Warren 2011).

This represents an important analytical hurdle for scholars to overcome. The current state of climate-migration modelling parallels the developmental history of other areas of climate impact modelling. The first generation of studies of climate change impacts on human systems were easily criticized for failing to incorporate reasonable assumptions about adaptation (Füssel and Klein 2006; Smit and Skinner 2002). For example, early research projecting the impacts of climate change on agricultural production such as the MINK studies by Easterling et al. (1992), contained coarse assumptions about farmer adaptation described as "dumb" farmer scenarios and "clairvoyant" farmer scenarios. These represented two extremes in adaptation, one where farmers never adapted but continually stuck with past practices even under changing conditions, and the other where farmers unfailingly intuited exactly which adaptations would maximize crop yields. The two extremes were intended to represent the breadth of possible outcomes, and subsequently led to more sophisticated modelling methods and outcomes. This is roughly the stage we are presently at in terms of capturing potential adaptive migration responses in climate change impact modelling. As will be elaborated below, scholars have become increasingly adept at identifying locations and environments where human populations are exposed to significant risks from climate change, such as droughts, extreme storms and rising sea levels. However, it is no more adequate to assume that such populations will remain stationary in the face of change or flee in droves, than it once was to assume that farmers never adapt or are clairvoyant. Migration is an important form of adaptation to climatic stresses that has occurred for millennia and continues to be practiced in many parts of the world today (Bardsley and Hugo 2010). Except in absolute worst case scenarios, migration rarely leads to wholesale abandonment of stricken areas, and when it does occur it has considerable economic and social implications for both source and destination (McLeman 2011b). Models that can capture the breadth of possible migration outcomes while incorporating reliable assumptions about adaptive behaviour represent the next stage in climate-migration modelling, one that scholars are just entering.

This article summarizes key linkages between climate change and migration, followed by an overview of recent developments in modelling the influence of climate change on human migration, along with some of the associated challenges, barriers and opportunities. Much of the research described in this article has been identified through a systematic search of English language scholarly publications and conference proceedings contained in the ISI Web of Science database, which has been shown to be particularly useful for such purposes (Berrang-Ford et al 2011). This search was conducted using the combined search terms "climate change" and "migration model*" to create an inventory that was then visually narrowed down to separate studies pertaining to human migration from those pertaining to migration of other species. A small number of completed and in-progress research examples taken from non-peer-reviewed "gray literature" are also included here on the basis of their citation or association with authors and organizations in the peer reviewed works identified.

2 Linkages between climate change and migration

It is well established that changes in environmental conditions, including changes in climate, can influence human population dynamics, of which migration is one aspect (Lutz et al 2002). Research suggests that human distribution, settlement and migration patterns in prehistoric and classical times were in many instances influenced by changes and variability in global and regional climate, with well-known syntheses of such cases including works by Diamond (2005), Fagan (2008), Lamb (1982) and Linden (2006). The twentieth century witnessed a number of climate-related events that are believed to have had a significant influence on migration, including the Dust Bowl migration on the North American Great Plains during the 1930s, drought events in the East African Sahel in the 1980s, and hurricanes Mitch and Katrina in the Caribbean basin in the last fifteen years (see McLeman and Hunter 2010 for a review of these and other events; also Leighton 2006 for migration events related to drought and desertification in recent decades).However, although there is clearly a linkage between climate and migration, climate and other environmental conditions are only some of any number of potential factors that may enter into the migration decision-making process of individuals and households at any given time (McLeman and Smit 2006). Isolating and interpreting the relative influence of climatic variables from other concurrent and pre-existent factors in migration movements is therefore not always possible (see Foresight (2011) for a detailed collective study of the linkages between environment and migration). Even where a climate-related "signal" has clearly been a proximate influence on the migration decision of the household, the reasons given for migration after the fact may be described differently by the migrants, such as having been economically or socially motivated (e.g. see Holzschuh's classic 1939 study of reasons given by more than 6,500 migrants who left the southern Great Plains during the 1930s Dust Bowl).

Popular discussions of climate-related migration are often framed in terms of "environmental refugees", a term coined by El-Hinnawi (1985) to describe people who are involuntarily displaced in response to environmental conditions or events such as floods, droughts and so forth. Scholars increasingly tend to avoid the term, given the lack of international legal recognition of such a category of persons (Johnson and Krishnamurthy 2010). A range of climatic events and conditions are known from past experience to stimulate distress migration, and many of these are expected to increase in terms of frequency and severity in various regions as a result of climate change (Solomon et al. 2007; Parry et al. 2007) (Table 1). However, involuntary or distress migration represents only one end of a continuum of possible climate-migration outcomes, the other end being environmental amenity migrants who voluntarily seek better quality environmental conditions (e.g. "snowbird" migration of retirees from northern US to the sunbelt) (McLeman 2010). Many other possibilities exist between the extremes of environmental refugee and amenity-seeker, and in many instances it may be difficult to distinguish environmental influences from political, economic, social, and similar cultural factors that influence migration behavior (Hunter 2005; Massey et al. 2010; Suhrke 1994). For example, the potential range of effects of climate on labor migration patterns is sometimes overlooked in discussions of climate change; while the impacts of climate change may reduce income possibilities in some regions or sectors and open up opportunities in new ones, such as economic development emerging in a warming Arctic (McLeman 2011a).

In the scientific community, human impacts of climate change are typically described in terms of *vulnerability*, which is in turn seen as being a function of the *sensitivity* of a given population, region or system to the types of climatic disturbances to which it may be exposed (often simply described as *exposure*), and the *capacity* of the population *to adapt*

Table 1 Expected impacts of anthropogenic climate change reported by IPCC and potential associations with future population displacements/migrations (adapted from McLeman 2011a; McLeman and Hunter 2010)

Expected biophysical changes (derived from Solomon et al 2007; Parry et al. 2007)	Regions at risk	Possible linkages to migration
Decreased snow and sea ice cover	Arctic	Economic migrants arriving to take advantage of newly accessible resources, transportation routes
Higher average river runoff and water availability; more heavy precipitation events	High latitudes, some wet tropical areas	Periodic flood-related displacements
Lower average river runoff and water availability; more droughts in dryland areas	Mid- to low-latitudes and dry tropics; drought-prone continental areas; areas receiving mountain snowmelt	Water scarcity, drought, & decreased crop productivity may lead to migration, especially higher rates of rural-urban migration in developing regions
Coastal hazards: erosion, extreme storms, sea level rise	Low-lying coastal regions, deltas, small islands, atolls	Need to relocate coastal settlements & infrastructure; possible salinization of water supplies and soils

(Adger 2006; Parry et al. 2007; Smit and Wandel 2006). Past experience shows some types of settlement locations are more exposed to migration-inducing climate events than others, such as low-lying coastal areas and small islands; river valleys and deltas; dryland areas; regions where precipitation is highly seasonal; and, high latitudes and high altitudes (McLeman and Hunter 2010). In the context of vulnerability, migration may be seen as one of a variety of potential actions by which exposed individuals or households adapt to climatic exposures (Bardsley and Hugo 2010; McLeman and Smit 2006; Perch-Nielsen et al. 2008; Tacoli 2009). There are past examples of state-organized or state-sponsored population relocations in response to climate-related events, such as in drought-stricken East Africa in the 1980s and in the Canadian provinces of Alberta and Saskatchewan during Depression-era droughts (Ezra and Kiros 2001; Marchildon et al. 2008; McLeman and Ploeger 2012). However, most climate-related migration occurs as the result of autonomous responses by households and individuals, and consequently takes on many different shapes and forms (McLeman and Smit 2006). A single climate event may stimulate a variety of possible migration responses in terms of destination, duration, and participation, as was seen, for example, following Hurricane Katrina (Fussell et al. 2010). This heterogeneity in migration response reflects the fact that migration, climate-related or otherwise, is not a simple stimulus-response event, but is moderated by a range of social, economic, and cultural processes operating across multiple scales and time-frames (e.g. Castles and Miller 2009).

The greatest amount of climate-related migration presently occurs at intra-national or intra-regional scales, and it is expected this will continue to be the case in coming decades (Adamo and Izazola 2010; Gemenne 2011; Massey et al 2010; Nelson 2010). While it is often the sudden-onset, high-magnitude events leading to large pulses of distress migration that capture the most media and scholarly attention, the cumulative contribution of ongoing localized events across regions is also significant in terms of overall flows of climate-related migration (Gutmann and Field 2010; Saldaña-Zorrilla 2008). In developing regions, where economic systems and livelihoods are closely tied to agriculture and natural resources, increased frequencies of extreme climatic events and conditions are expected to accelerate already growing levels of rural-to-urban migration (Hunter 2005; Mendelsohn et al. 2007; McLeman and Hunter 2010). People at the lower end of the socio-economic spectrum, particularly landless laborers and tenant farmers, are among those most easily displaced (Massey et al 2010). However, access to economic and social capital may limit their potential to engage in migration as an adaptation strategy and the range of potential migration destinations available to them (McLeman and Smit 2006). Landowners, business operators and others at the upper end of the socioeconomic spectrum may also experience economic hardship, but may be more likely to resist migration because their household capital is tied to land and other assets that are not transportable (McLeman and Smit 2006). Migration is not always permanent or indefinite in such circumstances. Cyclical intra-regional migration in response to seasonal variability in precipitation and periodic droughts has long been practiced in Sudano-Sahelian Africa and rural South Asia and this practice can be expected to continue (Bassett and Turner 2007; Deshingkar and Start 2003; Hampshire 2002; Mortimore and Adams 2001; Nyong et al. 2006).

International movements of people are also expected to increase in response to climate change, particularly along established migration routes and making use of social networks and transnational communities (McLeman and Hunter 2010). Such beliefs are consistent with experiences in the US in recent decades, where migrant numbers from Mexico have increased in periods when drought conditions existed in rural Mexico (Feng et al. 2010), and where 1998s Hurricane Mitch was followed by a surge in unauthorized Honduran migrant arrivals (Fig. 1). Popular media have suggested that anthropogenic climate change has already begun causing migration from small Pacific islands to Australia and New Zealand, but there currently exists no peer-reviewed research to support this suggestion (Mortreux and Barnett 2009). Interviews with residents of Tuvalu carried out as part of the EU/UNU-led EACHFOR project on environmental migration found that concerns about climate change mix with other economic and social motivations with respect to future migration intentions (Gemenne and Shen 2009).

3 Modelling climate change-related migration

Modelling of climate change-related migration is very much an emergent area of research, with no peer-reviewed studies found in the ISI Web of Knowledge dating prior to the last

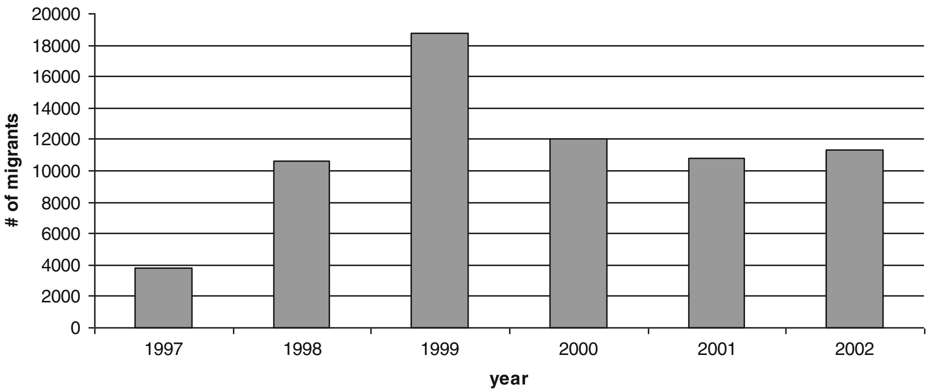

Fig. 1 Honduran nationals subject to deportation identified by US Immigration and Naturalization Service pre- and post-Hurricane Mitch (Oct-Nov 1998). Data source: US Department of Homeland Security (2011)

decade. Generalized macro-economic models suggest that even small changes in climatic conditions can translate into multi-fold effects on migration patterns (Marchiori and Schumacher 2011), so this is clearly a research area that is overdue for attention from those with experience in economic, demographic and other types of modelling. Existing models have yet to incorporate the developments with respect to climate-migrations linkages described in section 2 above, with lack of reliable population data constituting a significant and ongoing challenge for would-be modellers. Global data on population movements are often coarse in nature, and datasets that link population change to environmental stimuli are particularly unavailable (Brown 2008). No global monitoring program presently exists for capturing all environmentally-related population movements across international borders or internal movements. The Population Division of the UN Department of Economic and Social Affairs estimates the world's current annual migrant population at slightly more than 200 million (UN DESA 2010); it is not known what proportion migrate for environmental reasons. The United Nations High Commission for Refugees (UNHCR) provided protection or assistance for 10.55 million refugees worldwide, and another 14.7 million involuntarily displaced within their own borders at the end of 2010 (UNHCR 2011). Because environmental stimuli do not qualify as valid reasons for seeking refugee protection, these statistics do not capture people who are involuntarily displaced for climate-related reasons, and the UNHCR offers no other estimates for such categories of people. The UN's International Strategy for Disaster Reduction and the Centre for Research on the Epidemiology of Disasters (CRED) provide annual estimates of the number of people affected by natural disasters affecting 100 people or more per event, broken down by type of disaster (of which some, but not all, are climatic in nature). A 2009 report by the UN Office for the Coordination of Humanitarian Affairs (OCHA) and the International Displacement Monitoring Centre suggests a methodology for monitoring future climate-related disaster displacements by combining data from a number of sources, including CRED's EM-DAT database, the Dartmouth Flood Observatory, Red Cross/Red Crescent Disaster Management Information Systems, and OCHA's ReliefWeb.

Datasets such as these provide crude proxy figures from which it is possible to make global estimates of involuntary climate change-related migration, one component of the potential spectrum of climate-related migration. It is important to note, however, that not all of those affected by disasters become migrants; many resume their former place of residence as soon as it is safe to do so. Furthermore, many environmentally induced movements of people are driven by small-scale, frequent or repetitive events that may not show up in disaster reporting (Gutmann and Field 2010). Researchers have shown better success in modelling climatic impacts on migration patterns at regional and sub-regional levels, where they have been able to develop datasets that include linked environmental information and population and migration data over particular time periods, with Burkina Faso, Mexico, Nepal, and Amazonian Brazil being just some examples (Barbieri et al. 2010; Feng et al. 2010; Kniveton et al. 2008; Massey et al. 2010; Parry et al. 2010). These disparate datasets are not necessarily linkable to create larger scale models, do not cover similar time periods, and sometimes rely on data that are not maintained on an ongoing basis. In summary, reliable and comprehensive global forecast models of climate change migration numbers and patterns are still many years off.

One early area of development in modelling that continues to be used can be loosely described as spatial vulnerability modelling, which uses techniques influenced by those developed in natural hazards vulnerability research (e.g. Clark et al. 1998; Cutter et al. 2000; Wilhelmi and Wilhite 2002). These types of models identify areas or populations potentially exposed to particular impacts of climate change by using geographic information systems

(GIS) to combine output from general circulation models (GCMs) or regional climate models (RCMs) with various types of population, agro-economic and/or resource data (e.g. Byravan et al. 2010; Mcgranahan et al. 2007; O'Brien et al. 2004; Polsky 2004; Vorosmarty et al. 2000). From these, assumptions are then made about the potential for population displacement and migration, as was done for several regions in Warner et al (2009), and in studies of coastal populations exposed to mean sea level rise by Byravan et al. (2010), Hinkel et al. (2010) and McGranahan et al. (2007). Such modelling techniques can also be used to identify potential sites where climate change-related scarcities might interact with resource scarcity and/or political instability to potentially stimulate conflict (Busby et al. 2010; Wolfe et al. 2003), which could in turn have feedback effects on migration in affected areas.

Spatial vulnerability models often use a straight-line assumption that an increase in exposure to a particular climatic stress stimulates a corresponding increase in the potential for displacement and/or migration (Piguet 2010). This assumption is not consistent with the broader scholarly understanding of the various ways by which migration movements develop (see Castles and Miller (2009) for an introduction to the broader migration scholarship), nor is it reflected in past examples of climate-related migration, which have shown climate-related migration to be heavily moderated by intervening economic, social and cultural variables, and which occur in conjunction with or as subsequent to other forms of adaptation (McLeman and Smit 2006; Massey et al. 2010). For example, McLeman et al (2010) combined regional climate data and census information to create a GIS model that sought to replicate drought-related migration patterns known to have occurred in western Canada in the 1930s. While the model successfully captured spatial associations between population change and drought for that particular decade at regional scales, the resolution was poorer at local levels, where the influence of non-climatic factors such as farm-level soil conditions and rural social networks had particular effects on shaping household migration decisions (Gilbert and McLeman 2010; McLeman and Ploeger 2012). Moreover, the model has not yet been able to reproduce drought migration patterns in subsequent decades for the same region. This is because institutional and economic structures changed substantially over subsequent decades, requiring incorporation of additional data and modification of the underlying assumptions of causality built into the model. This example also shows how enhancing the predictive capacity of spatial vulnerability models benefits from "ground-truthing" through complementary qualitative field research to identify the factors and interactions that transform vulnerability to migration.

A second type of modelling that may hold promise for quantifying climate change-related migration is hazard analysis modelling, which focuses on capturing the migration behavior of individuals or particular population groups (Barber et al. 2000). Somewhat confusingly, the use of the term "hazard" with respect to this modelling method does not relate to environmental hazard stimuli but is simply a generic term denoting any potential life-course event (e.g. having a child, changing jobs, migrating, etc) that is contingent upon other variables, one of which could conceivably be changes in climatic or environmental conditions. In general migration research, this type of modelling has been used to understand the timing of migration events in response to particular stimuli (or *time-hazard modelling* (e.g. Odland and Shumway 1993)) and in identifying potential migration stimuli operating across multiple scales (i.e. multi-level hazard modelling (e.g. Massey and Espinosa 1997)). The types and quantity of data necessary to apply this type of modelling to climate change migration are not widely available at present, although it has been applied in sub-regional studies of other types of environmental migration, such as the impacts of land degradation on rural migration in Nepal (e.g. Massey et al. 2010) and links between land use/land cover change and migration in an agricultural valley in Chile (Berger 2004). A research group at the University of Sussex, England, is currently developing a multi-level hazard method described as *agent-based modelling* to develop forecasts of climate change migration, a method which derives multiple hypotheses about migrant behaviour from known migration data to create computer simulations (Smith et al. 2008; Kniveton et al. 2008). The researchers have been attempting to apply the method to drought migration in Burkina Faso, where sufficient longitudinal data exists; results have yet to appear in scientific literature. Another project involving Angus et al. (2009) is applying similar methods to modelling climate change-related migration in Bangladesh, again with peer-reviewed journal reports yet to come forth as I write.

Other statistical approaches to modelling climate change-related migration have emerged in the last few years. Feng et al. (2010) used historical crop data for Mexican agriculture and census data to calculate the semi-elasticity of international migration from various Mexican states in response to crop yield change. This information was then combined with various future crop yield scenarios generated by Rosenzweig and Iglesias (2006) to estimate that coming decades could see a more-than 4 % increase in Mexican migration to the US due to climate change impacts on Mexican agriculture. Barbieri et al. (2010) have sought to estimate the effects of climate change-related crop yield changes on future migration patterns in northeastern Brazil. Their method begins with extracting from pre-existing regional demographic scenarios economic influences on forces that shape demographic trends such as household income, employment, gross product, and level of consumption of families. These are then projected into the future. They then calculate from modelled climate data future agricultural performance, re-run the regional migration demographic scenarios to generate regional migration scenarios under climate change, and then downscale to a local level through disaggregation. Both the Feng et al. (2010) and Barbieri et al. (2010) studies make use of fairly broad assumptions about migration behavior, and should be used as gauges of potential future climate-migration trends as opposed to absolute predictions.

4 Future challenges and opportunities

An ongoing challenge that will continue into the foreseeable future is the acquisition of reliable datasets on climate-related migration, particularly at larger scales. The United Nations Department of Economic and Social Affairs Statistical Division (UNDESASD) presently collects information on international migration as reported by national governments, with the International Labour Organization (ILO) compiling statistics on international labour movement, the United Nations High Commissioner reporting refugee and asylum-seeker statistics, and the United Nations Population Division generating estimates of international migrant stocks based on data received from UNDESASD. Through the 2010 World Population and Housing Census Programme being coordinated by UNSD, it is hoped that census data will be available for most of the world's population by 2014; UNDESASD reports that by July 2011, 155 countries had completed at least one census since 2005. Once completed, this exercise can be expected to generate global data on international migrants similar to that reported in UNDESASD's 2002 Demographic Yearbook, which reported global data from 1985–2000 censuses on such topics as place of birth, age, sex and rural/urban residence of foreign-born populations (UNDESASD 2002).

A variety of challenges exist in terms of using national migration reporting and census data to track migration across jurisdictions, such as the irregularity of timing and frequency between countries, and the use of different definitions and standards of measurement

(UNDESASD 2004; Poulain and Herm 2011). The reliability of census data can be influenced by coverage errors (such as over-counting or undercounting sub-populations) and content errors attributable to the methods of collection and processing of data. The success of UNDESASD's efforts to encourage common standards in the 2010 Census round remains to be seen. As noted above, most climate-related migration is believed to occur within countries as opposed to internationally, so even should data across countries be difficult to reconcile, there will still be opportunities to drill into national data to analyze trends and patterns. Even assuming a greater reliability in global international migration and census data in coming years, this data has yet to be linked to climate information at corresponding scales, and this could be the subject of coordinated efforts among researchers to develop improved methods and common standards for doing so.

The prospects for linking migration data and climate information at regional, national and sub-national scales are promising in the near term. In addition to census data, other administrative data sets related to border crossings, labour movements and household characteristics may provide opportunities for extracting migration data (Poulain and Herm 2011), which may in turn be combined with national-level environmental reporting and climate data. Work by Black et al (2011) suggests that sufficient statistical data can be generated in countries such as Ghana and Bangladesh to support agent-based modelling of climate-related migration, although their work highlights the high degree of complexity in resolving the specific linkages between particular climatic stimuli and potential migration responses. The rich database of the Mexican Migration Project (MMP) operated out of Princeton University, which includes rainfall data, could be combined with other environmental datasets for modelling broader climate-migration linkages in that region (see also Hunter et al. 2011a for ongoing work in that region). Other datasets likely exist for other regions, and there may also be opportunities for building modelling elements into ongoing empirical studies of population and environment in particular locales. For example, a team from the University of Colorado-Boulder and University of the Witwaterrand has begun incorporating GIS-based detection of local vegetation change into studies of migration behavior in an existing a health and demographic surveillance site in South Africa (Hunter et al. 2011b).

With greater interest and attention being given to modelling the connections between climate and migration, it can be expected that the next decade will see rapid growth in terms of the number and variety of models available, and the emergence of new modelling techniques and methods. We should also see increasing sophistication of models in terms of their ability to capture a wider range of causal variables and influences. The uneven quality and quantity of global data means that regional and sub-regional modelling is likely to develop more quickly and reliably than global scale modelling. Even without reliable global models and estimates, there will still be a considerable appetite for reliable regional models, scenarios and forecasts among policy makers and researchers in a variety of fields.

Recent scholarly developments in this field, such as the EU-funded Environmental Change and Forced Migration Scenarios project (http://www.each-for.eu) and the UK Government Office for Science Foresight Project on Environmental Migration (http://www.bis.gov.uk) have provided needed boosts to empirical research on the underlying connections between climatic stimuli, intervening socio-economic factors and migration decision-making outcomes at various scales, from the individual on up. A greater understanding of the factors responsible for differential migration responses within populations is important for improving the human behavioural assumptions in models and thereby strengthening their predictive capacity. Some under-studied factors with the potential for having significant impacts on modelling include: the role of perception of environmental risk as a precursor to adaptive responses (see Massey et al 2010); the influence of social networks and social capital play on in situ adaptation and adaptive migration destination selection (Gilbert and McLeman 2010; Massey et al. 2010), and the potential effects of climate change on intraregional and international labor migration patterns (Banerjee 2010; Feng et al. 2010). I anticipate considerably more research to unfold in all of these areas in coming years.

One area beyond the influence of individual researchers, but where international policy-makers have an opportunity to play an important role in facilitating future research, is in the creation of protocols and mechanisms for generating global statistics on internal and international migration undertaken for environmental reasons. As noted earlier, existing datasets relating to refugees and disaster displacements provide only rough and unreliable proxies for measuring the effects of climate change on migration, and census data lacks connection to environmental data. Protocols for a global environmental migration data collection initiative could be modelled on UNDESASD's guidelines for census and migration data, with the mandate for data collection enacted through an existing international agreement such as the UN Framework Convention on Climate Change (UNFCCC). The resources to carry out data collection and the tasking of potential coordinating agencies would necessarily be subject to debate and negotiation, but in the context of other actual and proposed expenditures under various UNFCCC-related initiatives the resource need would be comparatively modest. Such an initiative would be a particularly useful step forward in transforming discussion of future climate change migration from informed speculation to evidence-based policy-planning.

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