Published in
Climate change (Wiley Interdisciplinary Reviews) 1, issue 4, 517-524, 2010
which should be used for any reference to this work

Linking climate change, environmental degradation, and migration: a methodological overview

Etienne Piguet*

Empirical research focusing on the links between climate change, environmental degradation, and forced migration has risen significantly in recent years and uses an impressive variety of methods. The present article suggests a typology identifying six research method families: ecological inference based on area characteristics, individual sample surveys, time series, multilevel analysis, agent-based modeling (ABM), and qualitative/ethnographic studies. The main technical features and empirical results of each family of methods are presented and critically discussed. We conclude by calling for a coordinated international effort to improve the quality and variety of data that could be used with existing research methods and significantly improve our understanding of the migration-environment nexus.

Although a wide spectrum of estimates, ranging anywhere up to 1 billion 'climate refugees' by 2050, have been put forward by NGOs and advocacy organizations, the numbers 'circulating' in the media are nothing but rule of the thumb—more or less informed. It is clear among scholars that there are no established methods of providing overall quantitative predictions concerning the additional human migration that might be caused by climate change, and that there is truly no such thing as a climate or environmental migrant in the narrow sense of a migrant exclusively moving for environmental reasons. Except in extreme cases, population displacements are always the result of a multicausal relationship between environmental, political, economic, social, and cultural dimensions.[1–8] Environmental stressors do not impact equally on all individuals, households, and communities, and information related to climate change is not perceived in the same way everywhere and by everyone.[9,10] Even when confronted with severe environmental degradations, human beings and communities are resilient and have at least some minimum level of agency in deciding to migrate or to choose other adaptation strategies.[11] For these reasons, migration induced by climate change cannot be modeled in the same 'hardware modeling' way as the climate itself, and the idea of producing quantitative predictions of migration, assorted with probabilities of occurrence, is little more than a dream.[12–14]

Despite this major limitation, at least two research strategies appear scientifically relevant with respect to migration and climate change. The first is mainly descriptive and prospective. It focuses on the identification of the main regions threatened by environmental degradation (the so-called hotspots) and on integrated assessments of the vulnerability and resilience of their inhabitants, which provide insights into possible future migrations.[15,13,16] In several cases, environmental degradation scenarios could be incorporated in economic models that are then used to forecast migration, but these are as yet largely unbeaten tracks.[17] The second research strategy is analytical and attempts to disentangle the environmental impact from other migration drivers. Empirically, it questions the role and weight of environmental factors in already occurring human migration.

The present article deals exclusively with this last question and presents a critical assessment of the different methods used in its response. Such an attempt at a systematic methodological inventory is missing

*Correspondence to: Etienne.piguet@unine.ch

Etienne Piguet Institut de géographie IGG, Université de Neuchâtel, Espace L-Agassiz 1, 2000 Neuchâtel, Switzerland

so far in the literature dealing with the environment–migration nexus, as well as in more general syntheses of methods related to the population–environment relationship.[18] It is, however, rendered necessary by the growing scientific interest in the topic, the resultant recent upsurge in empirical research—in postdisaster situations for example—and the variety of methods used. We suggest a six-group typology of empirical studies and outline the variables used to capture environmental change and migration. We discuss the principal results and the pros and cons of the six methods, before briefly outlining future directions for data collection and empirical research. We do not consider here the inverse relationship, namely the impact of migration on the environment.[19–21]

TYPE 1: ECOLOGICAL INFERENCE BASED ON AREA CHARACTERISTICS

The central idea of ecological inference is to reconstruct individual behavior from group-level data. The word 'ecological' indicates that the unit of analysis is not an individual but a group of people, usually corresponding to a geographical area. The hypothesis here is that if the environment plays a role in migration decisions, the environmental characteristics of a specific geographic area should be correlated with the migratory characteristics of that same area during the same period of time (or after a certain time lag). To give an example: there should be a correlation between the intensity of natural disasters in the municipalities of a country and the emigration rates of these municipalities. One can trace back to Durkheim's work on suicide[22] this general approach to inferring causal relationships. Considering that many factors impinge on migration, contemporary researchers nowadays use multivariate methods to control the effect of socioeconomic or political confounding variables so as to isolate the specific impact of the environment. Whereas, many existing studies explicitly target the environmental dimension of migration in a direct way, interesting results also stem from studies intended at analyzing migration determinants in a more general context, albeit one that includes environmental explanatory variables.[23,24] Numerous studies enhance their sample by using pooled data at different time periods: for one single variable such as, for example, pluviometry, the characteristics observed in one area during period 1 constitute one observation while the characteristics observed during period 2 constitute another, etc.

Based on different types of environmental indicators including rain, drought, floods, tropical cyclones, etc., most studies that apply ecological inference deduce a significant impact of the environment on emigration (Saldana-Zorilla between Mexican municipalities,[25] Munshi between Mexican provinces and the United States,[23] Naudé in sub-Saharan Africa,[26] Van der Geest in Ghana,[27] Henry et al. in Burkina Faso,[28] Chopra and Gulati in India,[29] Barrios[30] and Reuveny[31] among developing countries, and Afifi and Warner across 172 countries of the world[32]), but the level of correlation varies greatly across these works, and environmental variables always appear as only one driving force of migration among others. In the case of interprovincial migration in Burkina Faso, for example, they add only 5% to the explanation of migration measured by a coefficient of determination (R^2).[28] No correlation at all has been found when the dependent migration variable is limited to asylum requests lodged in Europe. This specific kind of migration is explained, to a significant extent, by other factors such as the political situation in zones of departure.[24]

As those results testify, ecological inference is a very fruitful approach. Ecological variables are often much easier to collect than individual data and allow for a good level of comparability between studies. Two limitations should be mentioned. The first lies in the paucity of the environmental variables used: most indicators are very basic and concern either rainfall or natural disasters, leaving aside more elaborate indicators of climate change or environmental degradation. This limitation could be overcome by a more systematic exploitation of existing data collected by organizations such as the World Meteorological Organization, the Centre for Research on the Epidemiology of Disasters, the International Earth Science Information Network, etc., and by the identification of key environmental variables related to migration which could be better collected at a world or regional level.

A second limitation is more directly related to the method itself and the fact that exposures and responses are only measured for spatial aggregates rather than for individuals. This alludes to the well-known problem of 'ecological fallacy': correlations measured at the aggregated level might not hold true at the individual level.[33] In other words, nothing guarantees that the very people who emigrated and contributed to a negative migration balance in an area under environmental stress, for example, are the same individuals who experienced that environmental stress and took a decision to migrate accordingly. One could argue that the problem of ecological fallacy remains less severe in environmental/migration studies than in studies linking two purely individual characteristics (such as literacy and origin) because

the environmental variables themselves are not based on aggregated individual characteristics. One must nevertheless bear in mind that in interpreting the above empirical results, any consideration regarding the mechanisms at stake should be done at the level of the area and not at that of the individuals. In the same vein, ecological inference makes it very difficult to differentiate the impact of environmental variables between population subgroups, in relation to gender or socioeconomic status for example, unless one can use specific migration data for these groups. All of these difficulties are reinforced, especially in Low Income Countries, by the varying size and shape of the spatial units employed and by the fact that they might cut across meaningful cultural, economic, social, and environmental boundaries.

TYPE 2: INDIVIDUAL SAMPLE SURVEYS

This second approach differs from the first precisely because it is aimed at considering processes at the level of individuals or households. Data on environmental pressure and socioeconomic context are collected through relatively large surveys (from a few hundred to several thousand cases). The surveys either inquire about past migrations (reconstitution of biographies)[34] or take the form of a panel in which households are contacted several times and questioned about the migration of one, or several, of their members during the intervals.[35–37] This information is then used as a dependent variable in regression models[35,37] or to compute simple cross-tabulations.[36]

Environmental variables are captured either by asking direct questions in the survey or by collecting information at the local level. One of the most cited studies using this approach is based on two surveys (1982 and 1989) conducted in rural Mali with a pool of 7079 individuals and 309 households before and after a series of droughts that affected the country.[36] The results document no increase in international emigration but shorter-cycle migration from food-short to food-surplus zones. Most of the other studies using similar methods also emphasize the complexity and indirect linkages between migration and environmental variables: Paul questions 291 respondents from eight tornado-affected villages in Bangladesh and discovers that none of their household members had migrated because of the 2004 tornado, that respondents were unaware of any outmigration within their localities, and that one-third of respondents even suspected that outsiders had been flocking into the tornado-affected areas in the hope of benefiting from disaster relief schemes. These results led him to provocatively entitle his paper 'Evidence against disaster-induced migration'.[34] Halliday[37] utilizes panel data among 739 rural households in El Salvador. He shows in a multivariate model that adverse agricultural conditions did increase migration to the United States during the nineties but that the 2001 earthquakes—in accordance with Paul concerning the counterintuitive impact of sudden disaster—actually reduced net migration to the United States. Finally, an impressive 108-month long panel study conducted between 1997 and 2006 in 151 Nepalese neighborhoods of the Chitwan valley[35,38] shows that whereas the quality of drinking water has no impact on population displacements, deforestation, population pressure, and agricultural decline do indeed produce elevated rates of local population mobility, but no significant increases in interregional or international migration. These results partly contradict a previous study using the same method in the same area but with a smaller sample and over a shorter time span.[39]

One main weakness of the aforementioned studies is that environmental change is only very incompletely captured. In certain cases, the information on environmental evolution is limited to one single documented event (hurricane, drought, etc.) and the analysis compares 'before' and 'after' situations.[36,34] In other instances, the environmental situation at the beginning of the period is used as a predictor of all future migrations.[35,38] Halliday does ask questions about agricultural shocks in all three waves of his panel survey, but the level of detail is limited to 'harvest loss' and 'livestock loss'.[37] On the whole, none of the studies based on sample surveys draws on detailed environmental evolutions captured along the whole period under review, and it thus remains difficult to disentangle environmental variables from other contextual effects. Just as ecological inference can be subject to ecological fallacy (cf. section *Type 1: Ecological Inference Based on Area Characteristics*), we see that analyses strictly centered on individual data are symmetrically subject to the so-called atomistic fallacy of missing the context in which behavior takes place.[40] Although the studies just mentioned do lead to some very valuable results, this is an important shortcoming that is not intrinsically linked to the method itself but to its implication on data collection. It could be overcome by designing large panel questionnaires including, over a sufficiently long period of time, a broader array of environmental questions, or by combining local information on environmental evolutions with repeated waves of questionnaires.[41] Such research strategies are costly but, as demonstrated by the Nepalese case mentioned above, they may lead to very valuable new insights.

Several more sophisticated methods have been tested to overcome the failures of the two families of methods we have just referred to; we group them in three families.

TYPE 3, 4, AND 5: TIME SERIES, MULTILEVEL ANALYSIS, AND AGENT-BASED MODELING

Time series, multilevel analysis, and agent based modeling (ABM) are three very different approaches, yet all seek to bridge the gap between individual and ecological data or, in other words, to avoid both ecological and atomistic fallacies.

Although similar to type 1 methods, time series analyses substitute data on temporal evolutions in a given area for data on spatial units. The measure of the degree of correlation over time between, for example, monthly pluviometry and migration, allows this approach to establish if, and to what extent, migration patterns are explained by the evolution of environmental parameters, controlling for other factors that might evolve during the period. Unfortunately, the two studies at our disposal to have taken this route both used a limited number of variables and periods that make it difficult to draw significant results: Van der Geest[27] simply compares time series of north–south internal migration and average annual rainfall in Ghana and obtains the counterintuitive result that migration is reduced at times of most pronounced environmental stress. Kniveton et al. analyze the relationship between climate variability in Mexico and migration to the United States in the drought prone states of Zacatecas and Durango for the 40-year period between 1951 and 1991.[5] They show in the case of Durango (Zacatecas presenting no significant correlations) that the greater the rainfall, the larger the emigration. This result contradicts the conclusions reached by Munshi, also for Mexico, with type 1 method.[23] Although these two studies clearly pave the way for promising developments, their conclusions should be handled carefully: no real control variables have been used, and migrant numbers are low and statistically not very significant. As noted by Kniveton et al., one major limitation of this approach can also be found in the absence, for much of the world, of monthly or quarterly migration flow data time series, which would enable us to link changes in the environment at time '*t*' with migration at subsequent periods.[5]

Another approach, that we shall call 'multilevel', combines ecological data (including, e.g., satellite imagery), individual data from household surveys and, in certain cases, time series. Multilevel methodologies appeared quite recently in numerous disciplines of the social sciences with the aim of analyzing explanatory factors at various levels of aggregation (individual, household, classroom, geographical area, etc.) or, more generally, disentangling the specific impact of different contextual scales.[42] These methods appear well suited to the study of human–environment interactions in geography as they allow for a significant expansion of the range of variables analyzed and thus enhance the precision of the analysis.[43] They have, as yet, been applied to migration by only a very limited number of authors. Henry et al.[12] are actually the only ones to fully apply a multilevel approach to migration in the case of Burkina Faso. They collected migration histories among 3911 individuals and environmental data at the community level in about 600 places of origin mentioned by the migrants. The environmental indicator consists of rainfall data covering the 1960–1998 period and the dependent variable is the risk of the first departure of a migrant from his village. Findings suggest that people from drier regions are more likely to engage in both temporary and permanent migration to other rural areas, but that short-term moves to distant destinations decrease with rainfall deficits. Three other studies can be mentioned as they introduce contextual characteristics of the region of departure as additional information related to households in a 'type 2' survey study (one can also mention an older paper on Mexican–US migration[44]). The first study, in Nicaragua, shows that a household highly exposed to Hurricane Mitch has a higher probability of having a member abroad than a household with similar adaptive capacity but living in a nonexposed area.[45] The second, in Ethiopia, shows a positive impact between the (perceived) local vulnerability to a food crisis and emigration among 2000 households of 40 village communities.[46] The third, in Ecuador, collects events histories, including migration information at local, internal, and international level, from 1995 to 2006 among 279 households. This person–year dataset is completed by time-varying contextual variables including, among other control variables and predictors of migration, environmental information about precipitations and 'unusual harvests'.[47] Overall, the results show that environmental conditions play a role for all three types of migration, but are most significant for local and internal mobility.

Although the multilevel approach appears very promising, one drawback of the method is the use of a predefined hierarchy of spatial units (usually the administrative units at which level the data is collected) that might not reflect the spatial distribution of the phenomenon at stake. To give an example,

one half of a unit—say a district—might be exposed to landslides whilst the other is not. This weakness could only be overcome by defining small enough statistical units to capture the spatial variation of the environmental degradation. This is the case, for example, in the aforementioned study on Ecuador, where precipitations were measured with a 1 km resolution. Another drawback is the difficulty to collect reliable contextual information apart from the most basic climatic data such as pluviometry. Another—not yet completed—Ecuador case study seems extremely promising in overcoming these limitations[41].

ABM has recently been advocated by several researchers in the field of environment and migration. According to Kniveton et al. who use ABM in a case study on Burkina Faso[48]: 'A solution to the complexity of climate-migration linkages is to use agent-based models to simulate the behavioral responses of individuals and households to climate signals, as well as relevant interactions between these social actors'.[5,47] The central idea is to identify or hypothesize the rules of behavior that lead to migration decisions in a context of multiple stimuli. A computer simulation then allows researchers to observe the outcome on a population of agents over time and to modify the contextual parameters. One of the great strengths of ABM versus other methods is that it can easily take into account heterogeneities of behavior between agents (e.g., according to gender) or bounded rationalities (the fact that the rationality of individuals is limited by their level of information, cognitive abilities, and amount of time available to make decisions), and that interactions between agents and retroaction loops can be dealt with (e.g., if a certain number of agents decide to emigrate, the remaining agents face an increased incentive to leave too).

ABM is not a new method in migration studies. It has been famously used in the past to analyze segregation processes (e.g., the preference of an ethnic group to live in a homogeneous neighborhood along co-ethnic lines) leading to intraurban migration.[49] Until now, however, one can note that only very tentative studies have used ABM in the field of environment-migration relations, and that no convincing results have been published so far. One can wonder if the method will really fulfill its promises for two reasons. First, preexisting knowledge about the ways in which people react to environmental stress and, more specifically, about the reactions of specific subgroups is very limited and makes it difficult to create the rules of behavior necessary for ABM. Second, the routine behaviors themselves (i.e., rules and regularities developed over a certain period of time) might not be so common in the field of environmentally induced migration, where many stimuli consist of sudden events with which populations have never had to cope before. These two points render the situation of environmental migration quite different from the classical fields of application of ABM.[50] ABM retains clear potential nevertheless. It forces researchers to explicitly formalize their hypotheses about the mechanisms at stake and could be fruitfully combined with participative methods involving local populations in the process of building the model (as a game play process), as was the case, without an explicit link to migration, in a recent experiment in Kiribati.[50]

We have just examined five families of methods specifically geared at answering the question of the exact weight of the environment on migration by using a variety of statistical tools and data. Let us now briefly introduce one last approach, which mainly uses qualitative method.

TYPE 6: QUALITATIVE/ ETHNOGRAPHIC METHODS

Qualitative methods have been by far the most widely used research design in recent years. The number of existing ethnographic local field studies performed since 2005 can be estimated at around 50 worldwide,[51] nearly one half in the context of the EACH-FOR program.[52] These studies use either interviews or small sample questionnaires among inhabitants of threatened areas, contacts with privileged informants, or, in some cases, literature sources on historical analogs.[53–55]

Providing an exhaustive list and summary of all these case studies is beyond the scope of the present paper. One can note that these qualitative approaches are well established and raise far fewer methodological and data difficulties than the quantitative methods described in the previous chapters (which does not mean they are easier to use!). As a general observation, one can note that most case studies strongly support the multicausality hypothesis regarding migration. Whereas numerous authors simply confirm that the environment plays a role in migration in many parts of the world, others are challenging the idea that climate change is already a central driver of migration, even in areas such as Tuvalu that are considered to be at the forefront in terms of environmental deterioration.[56]

Although, by definition, they are not in a position to provide a quantitative measure of the weight of environmental factors on migration, such studies offer invaluable insights into people's attitude toward, and their perception and representation of, climate change in general and the migration option in

particular; a central dimension if one wants to gather a coherent and complete theory of migration related to environmental change.[57]

CONCLUSION: WAYS FORWARD

It is only through a better understanding of the ways in which migration intervenes as a coping strategy responding to environmental degradation that local and regional scenarios of the migratory consequences of climate change will be conceivable and might, eventually, be aggregated to deliver overall predictions. In doing so, it should be kept in mind that migration is only but one of a range of responses to environmental degradation. It can be a last resort solution but can also be a complementary, efficient individual choice to promote *in situ* adaptation at the household or community level. Studies should thus not treat migration outcomes in isolation but connect them with nonmigration responses.

This methodological review has identified six families of methods, some in their infancy, others well established, that can all contribute to the aim of better understanding the migration–environment nexus. The inventory also underlines that the empirical research has often been pursued in isolation by a fairly limited number of authors. Meta-studies that could assess the migratory impact of different factors on the basis of a collection of studies are as yet impossible. This is largely due to the lack of data available to measure migration behavior and environmental evolutions at temporally and spatially comparable scales.

The collation of results and the combination of methods applied on more relevant datasets thus appear promising avenues in order to overcome the limitations of single approaches. The most illuminating and original studies that we have referred to make use of data especially developed through time consuming collection processes involving qualitative as well as quantitative methods. Comparable efforts shall hopefully be intensified. A complementary strategy would be to add relevant questions about environmental change and migration to existing censuses or large sample surveys.[41] With this objective, official producers of statistics at the national and international levels should be actively involved in order to lay the foundations for a large coordinated international data production effort. This effort will need to be informed by the methodological discussions that have long taken place in migration studies around questions such as longitudinal versus cross-sectional studies, studies in the origin or the destination, etc.[3,58,59]

In any case, a climate/migration module, inspired by methodological discussions from both mainstream migration studies and environmental studies, should definitely be introduced in future international research efforts on climate change.

ACKNOWLEDGEMENTS

I would like to thank Raoul Kaenzig, Laurence Crot, and Fabrice Lehmann for their help in preparing this article.

REFERENCES

1. Adamo S. Addressing Environmentally Induced Population Displacements: A Delicate Task. Background Paper for the Environment Research Network Cyberseminar on Environmentally Induced Population Displacements; 2008. Available at: http://www.populationenvironmentresearchorg. Accessed March 24, 2010.
2. Barnett J, Webber M. *Accommodating Migration to Promote Adaptation to Climate Change*. Stockholm: Commission on Climate Change and Development; 2009.
3. Brettell CB, Hollifield JF. *Migration Theory—Talking Across Disciplines*. London: Routledge; 2007.
4. Hugo G. *Migration, Development and Environment*. Geneva: IOM International Organization for Migration; 2008.
5. Kniveton D, Schmidt-Verkerk K, Smith C, Black R. *Climate Change and Migration: Improving Methodologies to Estimate Flows*. Migration Research Series. Vol. 33. Geneva: International Organization for Migration; 2008.
6. Perch-Nielsen S, Bättig MB, Imboden D. Exploring the link between climate change and migration. *Clim Change* 2008, 91:375–393.
7. Piguet E. Climate change and forced migration. New Issues in Refugee Research. *United Nations High Commissioner for Refugees Research Paper*; 2008, 153.
8. Tacoli C. Crisis or adaptation? Migration and climate change in a context of high mobility. *Environ Urban* 2009, 21:513–525.

9. Dessai S, Adger WN, Hulme M, Turnpenny J, Kohler J, et al. Defining and experiencing dangerous climate change—an editorial essay. *Clim Change* 2004, 64:11–25.
10. Marx SM, Weber EU, Orlove BS, Leiserowitz A, Krantz DH, et al. Communication and mental processes: experiential and analytic processing of uncertain climate information. *Glob Environ Change* 2007, 17:47–58.
11. Grothmann T, Patt A. Adaptive capacity and human cognition: the process of individual adaptation to climate change. *Glob Environ Change* 2005, 15:199–213.
12. Henry S, Schoumaker B, Beauchemin C. The impact of rainfall on the first out-migration: a multi-level event-history analysis in Burkina Faso. *Popul Environ* 2004, 25:423–460.
13. Kniveton D, Smith C, Black R, Schmidt-Verkerk K. Challenges and approaches to measuring the migration-environment nexus. In: Laczko F, Aghazarm C, eds. *Migration, Environment and Climate Change: Assessing the Evidence*. Geneva: International Organization for Migration (IOM); 2009, 41–111.
14. Perch-Nielsen S. Understanding the Effect of Climate Change on Human Migration - The Contribution of Mathematical and Conceptual Models. Diploma Thesis, Department of Environmental Sciences ETH, Zurich; 2004.
15. Black R, Kniveton D, Skeldon R, Coppard D, Murata A, et al. *Demographics and climate change: future trends and their policy implications for migration*. Working Paper, Brighton, Development Centre on Migration, Globalisation and Poverty, University of Sussex; 2008, T-27.
16. Warner K, Ehrhart C, de Sherbinin A, Adamo S, Chai-Onn T. *In Search of Shelter—Mapping the Effects of Climate Change on Human Migration and Displacement*. CARE/CIESIN/UNHCR/UNU-EHS/World Bank; 2009.
17. Barbieri AF, Confalonieri UEC. Climate change, migration and health: exploring potential scenarios of population vulnerability in Brazil. In: Piguet E, Pécoud A, de Guchteneire P. eds., *Migration and Climate Change*. Paris; Editions de l'UNESCO; 2010, (In preparation).
18. Lutz W, Prskawetz A, Sanderson WC. *Population and Environment. Methods of Analysis in Supplement to Population and Development Review*. Vol. 28. New York: The Population Council; 2002.
19. Black R. *Refugees, Environment and Development*. London: Longman; 1998.
20. Carr D. Population and deforestation: why rural migration matters. *Prog Hum Geogr* 2009, 33:355–378.
21. Hugo G. Environmental concerns and international migration. *Int Migr Rev* 1996, 30:105–131.
22. Durkheim E. *Le suicide (1897)*. Paris: PUF; 1995.
23. Munshi K. Networks in the modern economy: Mexican migrants in the U.S. labor market. *Q J Econ* 2003, 118:549–599.
24. Neumayer E. Bogus Refugees? The determinants of asylum migration to Western Europe. *Int Stud Q* 2005, 49:389–410.
25. Saldaña-Zorrilla S, Sandberg K. Impact of climate-related disasters on human migration in Mexico: a spatial model. *Clim Change* 2009, 96:97–118.
26. Naudé W. *Conflict, Disasters and No Jobs—Reasons for International Migration from Sub-Saharan Africa*. United Nations University, WIDER, Research Paper; 2008, 85.
27. Van der Geest K. *North–South migration in Ghana: what role for the environment?* Paper presented at the International Conference on Environment, Forced Migration and Social Vulnerability, Bonn, 9–11 October 2008.
28. Henry S, Boyle P, Lambin EF. Modelling inter-provincial migration in Burkina Faso: the role of socio-demographic and environmental factors. *Appl Geogr* 2003, 23:115–136.
29. Chopra K, Gulati SC. *Migration, Common Property Resources and Environmental Degradation*. New Delhi/Thousand Oaks/London: Sage; 2001.
30. Barrios S, Bertinelli L, Strobl E. Climatic change and rural–urban migration: the case of sub-Saharan Africa. *J Urban Econ* 2006, 60:357–371.
31. Reuveny R, Moore WH. Does environmental degradation influence migration? Emigration to developed countries in the late 1980s and 1990s. *Soc Sci Q* 2009, 90:461–479.
32. Afifi T, Warner K. *The Impact of Environmental Degradation on Migrations Flows across Countries*. United Nations University, EHS, Working Paper; 2008, 5.
33. Robinson WS. Ecological correlations and the behavior of individuals. *Am Sociol Rev* 1950, 15:351–357.
34. Paul BK. Evidence against disaster-induced migration: the 2004 tornado in north-central Bangladesh. *Disasters* 2005, 29:370–385.
35. Bohra-Mishra P, Massey DS. Environmental Degradation and Out-Migration: New Evidence from Nepal. In: Piguet E, Pécoud A, de Guchteneire P. eds., *Migration and Climate Change*. Paris; Editions de l'UNESCO; 2010, (In preparation).
36. Findley SE. Does drought increase migration? A study of migration from rural Mali during the 1983–85 drought. *Int Migr Rev* 1994, 28:539–553.
37. Halliday TJ. Migration, risk and liquidity constraints in El Salvador. *Econ Dev Cultural Change* 2006, 54:893–925.
38. Massey DS, Axinn WG, Ghimire DJ. *Environmental change and out-migration: evidence from Nepal*. Population Studies Center Research Report; 2007, 07–615.

39. Shrestha S, Bhandari P. Environmental security and labor migration in Nepal. *Popul Environ* 2007, 29:25–38.

40. Gray PS, Williamson JB, Karp DA. *The Research Imagination: An Introduction to Qualitative and Quantitative Methods*. Cambridge: Cambridge University Press; 2007.

41. Bilsborrow RE. Collecting data on the migration-environment nexus. In: Laczko F, Aghazarm C, eds. *Migration, Environment and Climate Change: Assessing the Evidence*. Geneva: International Organization for Migration (IOM); 2009, 115–196.

42. Kreft IGG. Introduction: hierarchical linear models: problems and prospects. *J Educ Behav Stat* 1995, 20:109–113.

43. Zolnik EJ. Context in human geography: a multilevel approach to study human–environment interactions. *Prof Geogr* 2009, 61:336–349.

44. Janvry Ad, Sadoulet E, Davis B, Seidel K, Winters P. *Determinants of Mexico–US migration: the role of household assets and environmental factors*. Department of Agricultural and Resource Economics, UC Berkeley, Working Paper Series; 1997, 853.

45. Carvajal L, Pereira I. Evidence on the link between migration, climate disasters, and human development. In: *Paper presented at the International Conference on Environment, Forced Migration and Social Vulnerability, Bonn, 9–11 October, Munich*; 2008.

46. Ezra M, Kiros G-E. Rural Out-migration in the drought prone areas of Ethiopia: a multilevel analysis. *Int Migr Rev* 2001, 35:749–771.

47. Gray CL. Environment, land, and rural out-migration in the southern Ecuadorian Andes. *World Dev* 2009, 37:457–468.

48. Smith C, Kniveton D, Black R, Wood S. Climate Change, Migration and Agent-Based Modelling: Modelling the Impact of Climate Change on Forced Migration in Burkina Faso; 2008. Manuscript available at: http://wwwinformaticssussexacuk/users/cds21/publications/ (Accessed December 21, 2009).

49. Schelling TC. *Micromotives and Macrobehavior*. New-York: Norton; 1978.

50. Gilbert N. *Agent-Based Models*. London: Sage; 2007.

51. Piguet E, Pécoud A. Introduction. In: Piguet E, Pécoud A, de Guchteneire P. eds., *Migration and Climate Change*. Paris; Editions de l'UNESCO; 2010, (In preparation).

52. Jäger J, Frühmann J, Grünberger S, Vag A. EACH-FOR—Environmental Change and Forced Migration Scenarios: Synthesis Report; 2009.

53. Arenstam Gibbons SJ, Nicholls RJ. Island abandonment and sea-level rise: an historical analog from the Chesapeake Bay, USA. *Glob Environ Change* 2006, 16:40–47.

54. McLeman R, Mayo D, Strebeck E, Smit B. Drought adaptation in rural eastern Oklahoma in the 1930s: lessons for climate change adaptation research. *Mitig Adapt Strat Glob Change* 2008, 13:379–400.

55. McLeman R, Smit B. Migration as an adaptation to climate change. *Clim Change* 2006, 76:31–53.

56. Mortreux C, Barnett J. Climate change, migration and adaptation in Funafuti, Tuvalu. *Glob Environ Change* 2009, 19:105–112.

57. Piguet E. Re-embedding the environment into migration theory. Paper presented at the Conference Remaking migration theory: intersections and cross-fertilisations of the Population Geography Research Group of the RGS-IBG, University of Brighton and University of Sussex 2009, 13th–14th May, submitted for publication.

58. Bilsborrow RE. *International Migration Statistics: Guidelines for Improving Data Collection Systems*. Geneva: International Labour Office; 1997.

59. Bilsborrow RE, Oberai AS, Standing G. *Migration Surveys in Low Income Countries: Guidelines for Survey and Questionnaire Design*. London: Croom Helm; 1984.

FURTHER READING

Laczko F, Aghazarm C. eds., *Migration, Environment and Climate Change: Assessing the Evidence*. Geneva: International Organization for Migration (IOM); 2009.

Piguet E, Pécoud A, de Guchteneire P. *Migration and Climate Change*. Paris: Editions de l'UNESCO; 2010, in preparation.