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Mobile Worlds: Choice at the Intersection of Demographic and Environmental Change

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Abstract

Research on environmental change has often focused on changes in population as a significant driver of unsustainability and environmental degradation. Demographic pessimism and limited engagement with demographic realities underpin many arguments concerning limits to growth, environmental refugees, and environment-related conflicts. Re-engagement between demographic and environmental sciences has led to greater understanding of the interactions between the size, composition, and distribution of populations and exposure to environmental risks and contributions to environmental burdens. We review the results of this renewed and far more nuanced research frontier, focusing in particular on the way demographic trends affect exposure, sensitivity, and adaptation to environmental change. New research has explained how migration systems interact with environmental challenges in individual decisions and in globally aggregate flows. Here we integrate analysis on demographic and environmental risks that often share a root cause in limited social freedoms and opportunities. We argue for a capabilities approach to promoting sustainable solutions for a more mobile world.

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1. INTRODUCTION

Population change is a fundamental social process that has been well studied in and of itself, and to help explain a range of social phenomena such as cultural change, labor markets, public health, travel, urbanization, and conflict. Although it has long been known that social vulnerability to environmental change arises from the convergence of both environmental and social processes, population dynamics are largely ignored as a significant social phenomenon in this context (1).

Where it has been considered in environmental change research, population has most often been taken to be little more than the aggregate number of people, the growth of which has been said to surpass environmental carrying capacity (e.g., 2), in turn leading to negative consequences such as forced displacement or violent conflict (3). There has been no shortage of critiques of such pessimistic accounts of the relationship between population and the environment (4, 5). Although few ever agreed with neo-Malthusian explanations of environmental change, it has been argued that in past decades population researchers nevertheless chose to avoid research on such a controversial topic (1, 6, 7).

Although there have always been some population researchers engaged in empirical understanding of the relationships between population and the environment (e.g., 8, 9), consideration of a wide gamut of demographic issues and trends in relation to environmental change has re-emerged to provide greater explanation of contemporary and future environmental dilemmas and challenges (10, 11). A central pillar of this new engagement has been the contribution of demographers to scenarios used to chart the range of plausible future environmental changes, such as the Shared Socioeconomic Pathways used in the recent assessment report of the Intergovernmental Panel on Climate Change (12), and those used in the Millennium Ecosystem Assessment (13).

There is now a burgeoning field of research investigating the intersection of environmental risks with migration, fertility, mortality, and population structure (1, 14). Here we review this research and seek to extend its analysis of intersecting environmental and demographic trends and migration by adding a focus on the role of capabilities and freedoms and opportunities in improving people's choices about how many children they have, and where and how they live in a world that will be characterized by increasing mobility and changes in the environment.

2. ENVIRONMENTAL CHANGE, FERTILITY, AND MORTALITY

If nothing else, population research is concerned with mortality and fertility, and these are common elements in all research on population change. Until recently fertility has exceeded mortality in

most developing countries, and it continues to do so by some margin in much of Africa: hence, the world is set to become more populous. The United Nations estimates suggest there will likely be 9.7 billion in the world by 2050, with Africa's population expected to more than double, so that by 2050, 54% of the world's population will live in Asia, 25% in Africa, 8% in Latin America and the Caribbean, 7% in Europe, and 4% percent in North America (15). By 2100 there is expected to be approximately 11.2 billion people in the world, with the latter half of this century seeing a fall in populations in Asia, Europe, and Latin America and the Caribbean, and significant further increases in Africa. By the end of the century, Africa will be nearly as populous as Asia, with these two continents being home to 39% and 44% of the world's population, respectively (15). However, these population projections do not consider the effect of increased environmental change in future mortality and fertility (16).

Environmental change remains, and will likely increase as, an important element in mortality risks. It is estimated that preventable environmental factors now cause 12.6 million deaths per annum, or 23% of all deaths each year (17). Leading causes of death are cancers, cardiovascular diseases, respiratory infections and diarrheal diseases caused by air and water pollution, and infectious diseases such as malaria caused by changes in environmental vectors (17). Children under five are most at risk of mortality from environmental causes, particularly those in low-income countries. Climate change is expected to further increase child mortality in some developing regions, particularly due to undernutrition and waterborne diseases (18). Deaths per capita attributable to the environment are highest in sub-Saharan Africa, where people are more than 15 times more likely to die from infections and neonatal and nutritional diseases than those in high-income countries (17).

Natural disasters are not a significant cause of death relative to all preventable environmental causes, although they do receive a great deal of attention given that climate change seems likely to have an increasing influence (19). Between 1994 and 2013, geophysical disasters were responsible for 1.35 million deaths worldwide, with floods being the leading cause of disaster mortality (20). Population growth and economic development are major future drivers of disaster mortality as they increase risks through land use changes that amplify damages from natural perturbations; increase the exposure of people to these perturbations; and influence the degree to which infrastructure, human capital, and institutions reduce vulnerability. This is perhaps most clear in the distribution of disaster-related deaths, with people in developing countries more than three times more likely to die in a disaster than people in developed countries (20).

Demographic and development drivers will likely remain the dominant factors in future disaster mortality, although climate change will have an increasing effect, and climate-related disasters are increasing in frequency (20). For example, mortality due to storm surges is expected to increase due to a combination of rising sea levels, stronger winds, and increasing concentrations of populations in coastal areas (19).

Climate change has also been implicated in excess mortality associated with extreme heat events, which exacerbate cardiovascular and respiratory conditions, particularly among the elderly (18). There is evidence that climate change has already caused excess deaths in many northern hemisphere cities—for example, it has been implicated in the 2003 summer heatwaves in Europe, which are thought to have caused up to 70,000 excess deaths (21). Climate change is expected to significantly increase heat-related mortality in the future (18, 22). Excess heat is also linked to increased wildfires, which are a cause of excess mortality due to both direct effects as well as smoke (23, 24). Through these and other means, climate change alone is expected to increase deaths by up to 250,000 people per year by 2030 (25).

Are there significant effects of environmental change on fertility? Although observed fertility rates are well understood, there is little research on environmental risks directly on this

phenomenon. Fertility rates are highest in households in least developed countries where livelihoods are resource dependent, which creates incentives for a larger number of children for labor and for perceived security. High infant mortality rates and restrictions on women's access to education, work, and family planning services also contribute to high fertility (26). Economic development leading to livelihood diversification coupled with increasing female participation in schooling and work and improvements in maternal and child health and access to family planning are the key drivers of falling fertility. If environmental change affects fertility, then it is largely through its effects on economic development and health.

But is there evidence of more direct effects of environmental degradation on fertility? In theory, environmental degradation increases the labor needed to provide water, food, and fuel in resource-dependent livelihoods, suggesting a population-poverty spiral where more children born leads to more resource depletion, which in turn leads to higher birth rates (27). In practice, this relationship is far from straightforward and if it exists, it is likely to be small, with research showing the importance of children's ages and property rights institutions in such circumstances (28–30). A strategy to cope with long-term environmental deterioration involves promoting the early marriage of daughters, documented in Malawi, which is making younger the age at which women first give birth and delaying, or preventing, their access to further education, which both can lead to an increase in fertility (31).

There is also contested evidence on fertility-environment relations. Rovin et al. (32), for example, report that in peri-urban areas in Ethiopia population growth and climate change are changing traditional attitudes toward having large families, with perceptions that families with fewer children seem to be better positioned to deal with environmental challenges (although their ability to lower fertility is often constrained for reasons of cost or culture). Episodes of extreme food scarcity can lower fertility for several reasons and principal among these are higher demands on women's labor during times of hardship, which impact their ability to give birth (16). Recent research suggests that if environmental degradation increases the demand for migration this in turn increases parent's investments in child education, which results in lower fertility (33). The circular or longer-term migration of men or women in response to hardship may also decrease opportunities to reproduce.

There is some evidence that fertility is lower in summer and that summer temperature extremes lead to lower fertility (34, 35). There is also some suggestion that the seasonality of births in turn influences rates of childhood diseases and mortality (36, 37). Natural disasters also appear to lower fertility in the short term, at least for some affected populations (38, 39). There are, however, no direct studies on whether increased temperatures due to climate change will have any significant effect on fertility in and of itself: The observed relationship is weak and contingent on several uncertain variables, and troughs in fertility are followed by subsequent increases. There is little evidence that increasing disasters due to climate change have any significant effects on aggregate fertility, certainly compared to the effects on mortality.

Overall, although there are reasons to consider that environmental change may have an effect on movement through stages of the demographic transition, this has yet to be seriously considered (16, 40). However, if, for example, climate change increases poverty in some already impoverished populations or access to fertility-reducing social opportunities such as education and family planning does not improve, then fertility may cease to decline and demographic transitions may be stalled (41). Given that in almost all world regions mortality has declined significantly and fertility has reached or nearly reached replacement levels, much evidence suggests the problem of stalled demographic transition is perhaps only likely in constrained regions of sub-Saharan Africa, where fertility levels are not expected to reach replacement levels until the end of the century (15).

3. POPULATION SIZE AND STRUCTURE

The intersection between population and environment relates to the detail and processes of demographic structures, applied at global and other scales. Advances in this area build on emerging insights from demography, migration, and life-course studies engaging with environmental science and analysis of environmental risks. This new emerging science has embraced methodological and epistemological pluralism, showing the way that gender, age, occupation, and human capital factors influence the vulnerability of individuals and populations to environmental change (11).

Although the aggregate global population is growing, migration patterns have their own dynamics, driven by regional economic trends, urbanization processes, and incentives and disincentives within political systems for movements of people. The scale of migration globally has kept pace with aggregate population growth, and hence the total number of people who migrate is increasing. In some regions, migration rates to cities have increased rapidly, whereas globally the propensity for international migration as a proportion of world population has been stable in recent decades. But with rising populations, and aging populations, the scale and complexity of migration have increased.

The causes of observed patterns of mobility are diverse, and environmental change plays a part. Changing economic structures toward service and industrial sectors are the principal drivers of the largest movements of people globally: from rural areas to towns and cities. But demographic changes also play a significant rise in the changing patterns of migration. As public health investment increases life expectancy and reduces mortality, and populations experience growth in young and adult populations, the expectations and real benefits of migration have risen. Social changes in gender equality, in the provision of public health, and in the reduced demand for labor in agriculture are all critical in explaining migration patterns.

Explaining aggregate migration flows, and more trickily, predicting changes in aggregate flows, is a contested area. As with demographic transitions, models of migration and mobility transitions have been posited as explaining natural progressions of migration trends. Zelinsky (42) popularized accounts of migration transitions, showing that in largely rural economies, migration was principally to land frontiers, followed subsequently by increasingly circular and permanent migration to urban areas, whereas international migration gathered pace only later when surplus labor from urban areas accumulated capital and skills. Migration transition models have been focused on bringing migration into accounts of demographic change. Such transition models have more recently been shown to be limited in explaining or predicting future migration patterns, or incorporating new drivers of mobility, such as reduction in the real costs of moving and the role of communications technologies in changing mobility patterns and demands (43, 44).

Most global scale analyses of environmental challenges, such as land use change, climate change, and habitat loss, have embedded within them data on the present and future distribution of the world's population. Demographic input to such global analyses, including population projections within the Representative Concentration Pathways and Shared Socio-economic Pathways, shows a range of global peak populations across the twenty-first century and identifies those population trends as a key driver of projected greenhouse gas emissions over the coming decades (12). In most of the narratives of future worlds, aggregate population peaks in the mid-twenty-first century. With these stabilized populations, it is migration and the completion of urbanization transitions that become the most important demographic parameters of environmental pressures and burdens.

The fine-grained differences in demographic shifts and of migration patterns have very different consequences for environmental sustainability and for who will be exposed to environmental risks. First, population changes and related migration alter the environmental footprint of households and of urban settlements and the land use around them. Demand for energy and resources changes

over one's life: Someone in their eighties has different consumption and mobility patterns than someone in their twenties, even at the same income levels. Older adults, for example, have reduced demand for travel and mobility, compared to the rest of the population. But the single most significant factor in population change for resource use, affected by both mobility and by aging, is the reduction of average household size in virtually all regions of the world. With the same population but living in a larger number of households, the environmental burden is increased. Kaye et al. (45), for example, showed that urban form and small household size directly affected biogeochemical flows and pollution loading. Liu et al. (46) argued that smaller household size is associated with urban sprawl with consequences for habitat loss and biodiversity, and Cardillo et al. (47) show that population density is a factor in localized extinction of carnivore populations in particular.

But urban migration and dense urban environments also offer opportunities for consolidated delivery of services, reduced demands on automobility, and the potential for sustainable futures. At the individual level, migration means forming new households, moving locations, and making significant investment decisions. Moving homes or having children, for example, has been shown to lead to consumption of durable goods but presents windows of opportunity for realignment of values and identity. Emerging ideas in this field focus on, for example, habit discontinuity that shows how individuals reposition their identity and consumption or travel patterns when they relocate, but within a limited time window.

Fine-grained changes in population structure affect pathways to sustainability but also alter social vulnerability to environmental risks. Aging populations, for example, change the dynamics of social risk. Cutter & Finch (48) showed how high dependency ratios and other outcomes of aging populations contribute to what they term the hazardscapes of the United States in the past four decades. Elderly populations are physiologically at risk from extreme heat, for example, and are increasingly exposed to such risks within cities (49, 50). Although there is some evidence of adaptation and responses to heatwave risks, projected future population aging will result in a significant escalation of exposure. Watts et al. (22) show that aging populations will be a more influential driver of heat-related mortality than changing patterns of extreme temperatures, with the net effect being a 12-fold increase in the exposure of elderly populations to heat stress over the coming decades, particularly concentrated in cities in Asia.

Do changing structures enable societies to better overcome environmental risks through adaptation? Emerging research shows how life course affects adaptive behavior: with elderly populations tending to inoculate themselves from disasters through recourse to their past experiences and practices (51). At the same time, there is emerging evidence that adoption of new technologies that can reduce risk tends to be greater in younger populations (52). The differences between generations may not always be harmonious: In a study from the high-latitude Canadian north, Laidler et al. (53) showed how tensions between younger and older people about customary practices around hunting came to undermine their ability to sustain collective action to conserve resources. Population structure also changes the distribution of values that inform social constructions of vulnerability: For example, younger people may be more predisposed and able to migrate from highly vulnerable places, whereas older people heavily discount future risks (54, 55). Hence, aging populations and other structural changes directly affect the ability of societies to collectively adapt to risk.

4. MIGRATION

4.1. Present and Future Migration Flows

For the purposes of this review, we take Brown & Bean's (56) definition of migration as being movement of at least one year in duration and that involves crossing an administrative border—although this need not mean crossing a national border. This is distinct from the concept of

mobility, which includes far more ubiquitous and quotidian movements over shorter distances and durations. Although mobility may also be affected by environmental change, the vast majority of the research focuses on the links between environmental change and migration—perhaps because migration is the more common term, and because there is better data about migration than there is about mobility.

Research on environmental migration tends to fetishize migration, and ignore its nature and scale (57). The extent to which environment matters in migration cannot be understood independently of the larger context of migration. The majority of migration studies show that population movements are utterly normal, rational, and unthreatening to host societies. They also show that migration is overwhelmingly an economic process, that it is transformational to the lives of those who move, and that the benefits accrue principally to the middle classes. For example, of the estimated 232 million international migrants in the world, most come from countries represented in the Organisation for Economic Co-operation and Development (OECD) or middle-income countries, and almost all move to cities in other OECD economies (58). There is estimated to be a further 740 million internal migrants, most of whom, like international migrants, seek improved social opportunities through education in cities. These numbers include, for example, more than 200 million rural Chinese who have moved to cities in search of work since 1980 (59).

Because migration is principally driven by economic motives, the vast majority of moves are to cities where it is perceived there are improved job prospects and social opportunities such as education. It has been estimated that three million people move to cities every week, and more than half of the world's population now lives in cities (60). Almost all of these cities are located in coastal areas, thereby increasing the number of people exposed to climate change–induced sea-level rise and storms. Neumann et al.'s (61) modeling suggests an increase of up to 320 million more people living on coastal lands less than 10 m above sea level by the year 2030, rising to 760 million more by 2060 (baseline year is 2000). The largest share of this increase is expected to be in Asia, but the most rapid increase relative to the present is expected to be in Africa (61).

These patterns of migration cannot be understood without considering demographic and economic changes. The projected global population growth of approximately 25% from present is likely to be heavily concentrated in the cities of the less developed economies of Africa and South Asia (57). There are now 76 countries that have below replacement levels of fertility, and most of these are developed economies whose labor demands and aging populations cannot be supported without migrant labor (12, 57). At the same time the incomplete demographic transitions in parts of South Asia, Sub-Saharan Africa, and the Middle East and North African regions will see populations continue to grow rapidly, potentially outstripping the provision of public goods and services and employment, creating both pressures for migration and increasing vulnerability to environmental change (57). These demographic and economic asymmetries will continue to drive migration from rural to urban areas and from middle-income to OECD economies.

How will changes in population and economy translate into migration system changes? The Foresight (62) report "Migration and Global Environmental Change" developed global migration scenarios consistent with global population projections and learning from transition theories of migration and mobility, as shown in **Figure 1**. In those scenarios, the principal drivers of migration flows are the scale of economic growth alongside the nature of governance. Scenarios where governance within countries and across nations is fragmented and conflictual lead to higher aggregate global populations and to higher risks of involuntary displacement and trapped populations. More inclusive governments, greater diffusion of internet access, and accountability for planning processes lead to scenarios of lower aggregate populations and less undesirable forms of migration.

Environmental change may influence the time-honored process of searching for work in cities if it changes peoples' assessment of the relative benefits and costs of migrating. Because power

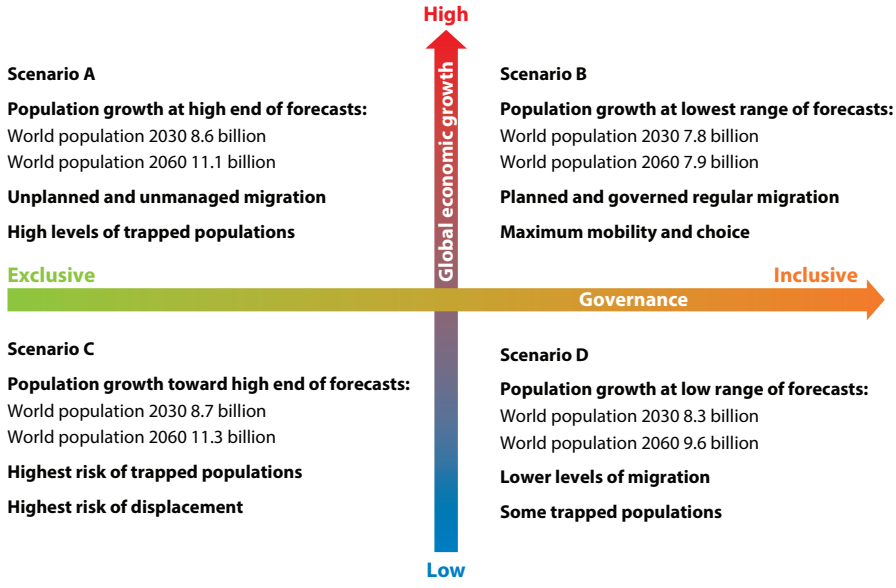

Figure 1

Narratives of alternative future migration trends at global scale over the decades until 2080 are driven by the redistribution and rate of economic growth and by the inclusiveness or fragmented nature of the governance of migration and international cooperation. The narratives demonstrate significant divergence in distributions of populations, in levels of internal and international migration, and in levels of immobility and hence trapped populations. Figure adapted from Reference 62.

and capital are concentrated in cities, efforts to sustainably manage urban environments and to adapt them to climate change are relatively greater than those in rural areas, and at the same time relatively greater dependence on natural resources makes rural areas more vulnerable to environmental change (63, 64). Thus, environmental change is likely to increase the disparities in wealth and social opportunities that drive rural to urban migration.

The extent that environmental change contributes to migration is most evident in the case of disasters, which are a significant cause of displacement (62). The Internal Displacement Monitoring Centre (65) estimates that since 2008 an average of 22.5 million people have been displaced each year due to hydroclimatic disasters. When holding the effect of population growth constant, the likelihood of a person being displaced by such disasters has increased by 60% in the past 40 years across the world. Such involuntary displacement is categorically different to migratory flows of choice and causes people to move short distances for short periods of time. Virtually all studies of displacement from environmental hazards show that the vast majority of populations return to their homes when possible (57, 66–68).

4.2. Drivers and Consequences of Migration

Diverse environmental hazards have different displacement dynamics. Long duration crises, such as drought, affect choice and mobility over many years, depriving households of the assets to engage in successful long-distance migration, and increasing short-term temporary movements. These offsetting trends demonstrate the need to disaggregate migration by choice from displacement movements. Research on drying in the Sahel, for example, shows the ways in which migration is

an integral part of adaptation to drought, although always in association with political, economic, demographic, and social factors (69–71). Consistent with the broader pattern of migration, such moves are most often to urban areas and occur in developing economies with high population growth rates (72–74).

Fear of violence and persecution is a further important factor driving involuntary displacement. Approximately 10% of the world's international migrants are refugees: people who cross an international border as they flee persecution (75). However, more than twice this number remain within their own countries when fleeing violence, and these are classified as internally displaced people (IDPs) (75). The links between environmental change and contemporary armed conflicts are tenuous and uncertain, so today's refugees and IDPs cannot be categorized in any meaningful sense as environmental refugees. Moreover, there is little direct evidence of impacts to date of rates of IDPs and refugees as a consequence of climate change impacts on violence: Environmental changes have at best a weak influence on violence (76–78).

Conversely, if environmental change does increase migration, this in itself is not likely to lead to an increase in armed conflict (79). Refugees fleeing armed conflicts that cross into neighboring countries tend to increase the risk of armed conflict in their new destinations (80)—but the effect is not present for other types of international migrants. In terms of migrants within countries, where armed conflict, poverty, insecure property rights, and weak conflict resolution institutions are present, migration can increase the risk of conflict (81–83), although in most cases internal migration has little effect (84, 85). A critical factor is the role of the state in avoiding "othering" of migrants, in conflict resolution, and in supporting the rights of both migrants and host communities (86–89).

Although migration generally yields benefits for migrants and their families, this is not always the case and benefits may be slow to accrue. There is significant evidence that migrants, and particularly those who are poor and less socially connected, are vulnerable to exploitation and discrimination, as well as to environmental changes (62, 90–93). Given the combined effects of increasing urbanization and environmental change, urban planning and resilience are also critical to the welfare and security of most of the world's future population.

It is widely recognized that migration systems amplify social differentiation, with the option for migration as a livelihood choice restricted to those with social, human, and financial capital. International migration, in particular, reinforces social and economic structures because migration itself is costly: It requires money as well as social networks and skills, and the further the move the more resources are required. Migration is therefore a response to environmental change that is far less available to the poor and socially marginal. It may be then that in some low-income and highly vulnerable rural areas environmental changes create poverty immobility traps such that the poorest of the poor, who cannot afford to utilize migration as an adaptation strategy, instead become yet poorer with declining access to ecosystem goods and services.

4.3. Policy, Choice, and Nonlinearity

An emerging theme of the research on environmental migration is planned resettlement, whereby governments move communities through compulsorily buying their residences, or provide incentives for populations to move. Governments have engaged in large-scale resettlement for reasons such as making way for dams, infrastructure, and urban development projects. But with the prospect of significant risks from climate change making coastal areas in particular potentially uninhabitable, resettlement is emerging as an increasingly important theme of climate change policy globally, for example, through the Warsaw International Mechanism on Loss and Damage. Countries such as China have also begun to implement resettlement activities in the context of

climate risks. Research has sought to elaborate principles and strategies to minimize harm to populations that are resettled, and there is a progressing normalization of resettlement. But there are few examples where resettlement, even with best-practice processes, has not resulted in net losses in material well-being and psychosocial welfare among resettled populations (94–99). Least-worst outcomes occur when resettlement is a community-driven rather than top-down process, there is adequate time for preparation, payments for work go to affected communities, communities remain intact, property rights are transferred, host communities are not disadvantaged, and existing decision-making processes within communities are respected (95, 100, 101). Climate change opens the possibility of resettlement being imposed for other pre-existing economic and political motives. Hence, research has increasingly framed resettlement around rights, choice, and freedom of populations, seeking to secure resettlement processes that are community driven and respect basic human rights (100).

A final theme of this research focuses on the ways in which more voluntary mobility and migration can enhance adaptation to environmental change (93, 100). The use of migration as a strategy to adapt to environmental change is well understood and observed across an array of countries (e.g., 70, 102–107). There is significant evidence of the benefits of movement to environmentally vulnerable populations in the form of remittances of money, but also goods, services, and knowledge, and through risk sharing among extended social networks (108). Often such movements are from individuals who leave to seek work to diversify household income. The capacity of households to support such a move depends on their endowments, which in poor areas are often based on natural capital. There is considerable evidence that the more capital households have the longer the distance of migration in response to environmental change, and that conversely, when environmental change undermines endowments then migration may be restricted in range, and in many cases not possible (103, 109–112). Migration to seek work in response to stress is not restricted to one gender: There are increasing opportunities for migration for adult women in industrial sectors such as garments and electronics in emerging economies such as Bangladesh. Such changing gender opportunities themselves may be altering choices and patterns of migration in response to environmental risks.

Although migration generally has significant benefits to the households and communities from which migrants originate, there are important exceptions (113, 114). This draws attention to the need for migration to be a choice that optimizes benefits rather than one that minimizes risks, and therefore the need to reduce the drivers of vulnerability (115). Thus, upholding rights and freedoms to enable people to stay in place is as important as upholding their rights and freedom to move. As Felli & Castree (116) note, although migration may be a means to adaptation to environmental change it is no substitute for investments in adaptation such that people have the right to choose whether to migrate. This point is important, for many studies show that many people affected by environmental change cannot or do not wish to migrate (117–121).

Anticipating migration therefore requires understanding future changes in demographic, economic, and political processes alongside changes in environmental processes. Of these macro processes, the demographic and environmental drivers are best understood as they are path dependent and somewhat predictable—at least at large spatial scales (57, 122). The political-economic drivers of migration are far more nonlinear and contingent. For example, it has been observed that trade agreements and neoliberal reforms can undermine agricultural livelihoods, which in turn increase vulnerability to environmental shocks and the propensity to utilize migration as an adaptation strategy (123). Another example is the consequences of the United Kingdom's exit from the European Union on migration within Europe, the effects of which have yet to be seen but are sure to be significant (124). Finally, proposed heavy restrictions on migration from Mexico to the United States will have deep repercussions for social vulnerability in Mexico, where migration has long

been a major livelihood adaptation strategy (125, 126). Indeed, insofar as economic integration through trade helps overcome poverty and facilitates international migration, the seeming turn toward more isolationist economic positions in the United Kingdom and United States does not augur well for those economies and migration circuits that are entwined with these two countries.

So, migration is multicausal and environmental change is rarely if ever its major driver, particularly of international migration (127). There are diverse pathways including resource constraints, declining access to markets and goods and services, and the direct impacts of extreme events that mediate between environmental change and migration, and in situ adaptation rather than migration is most often the dominant response to these changes. Where migration is induced by these direct and indirect effects of environmental change, it most often includes movements within countries, and movements of a more cyclical nature, rather than movements to another country (93, 128).

Therefore, despite exaggerated claims in the media about the influence of environmental change on migration, the scholarly literature tends to be far more cautious. Few if any scholars accept Myers' estimates that climate change alone would likely displace more than 200 million people by 2050, with many noting they have almost no empirical basis (108, 129, 130). Such estimates are based on exposure to risk and fail to account for adaptation and the multicausal nature of migration (100).

Furthermore, there is therefore little support for, and indeed widespread scholarly critique of, the concept of environmental refugees, despite its appeal (131, 132). The concept has been critiqued for being alarmist (133), counterproductive to addressing either the problem of environmental migration or the challenges facing refugees (134), and "erroneous as a matter of law" (135).

Given the multicausal and multifaceted nature of migration as a social system, many studies have critiqued the representation of environmental migrants in popular and scholarly discourse, and demonstrated the political implications of representing populations in this way. For example, Bettini (133) argues that apocalyptic narratives of environmental refugees ultimately serve to depoliticize the issue, rendering its management a matter of technique rather than one of addressing underlying inequalities. Several studies have explored the discordant temporalities between the focus of environmental migration narratives on very distant futures and the far more short-term concerns of citizens and decision makers. For example, Arnall & Kothari (136) show that contrary to local elites, ordinary people in the Maldives are not concerned about future environmental migration. Methmann & Oels (137) and Barnett (138) worry about the effect of catastrophic futures on commitments to adaptation, asking if environmental migration narratives deny the possibility of and undermine commitments to adaptation, thereby making migration more likely. Baldwin (139) suggests the focus on environmental migration ultimately serves to displace anxieties about powerlessness in the face of climate change into a more specific issue that can possibly be managed, and hence serves to increase agency and make climate change an issue of humanity.

5. FREEDOM, CHOICE, AND DEMOGRAPHIC FUTURES

It is often said that demography is destiny and that there is little that can be humanely done to affect the trajectory of the world's population. To be sure, much of the future growth in the world's population is biologically inevitable, but governments and private investors have significant leverage on the size and distribution of the future population, through affecting the quality of future lives and future societies, which drive demographic choice. Protecting and enhancing human capabilities through the promotion of rights and freedoms and adaptation are central to avoiding human insecurity from future demographic and environmental changes. Capabilities, rights, and

freedoms are implicit in much of the research on both demographic change and social vulnerability to environmental change. With this review of the evidence, we show that capability, choice, and freedom should be central to any efforts to mediate the drivers and consequences of demographic and environmental changes.

Capabilities are commonly defined, following the work of Sen (140), as the conditions and entitlements that enable people to do things. Capabilities, following the work of Nussbaum, include bodily health and integrity and an ability to imagine, reason, feel, play, affiliate with others, and hold property. They emerge through the provision of social opportunities such as education and health care; rights such as those regarding personal security and property; and freedoms such as the freedom of mobility, to seek work, and to associate with others (140). Capabilities are therefore enabled by bureaucratic, legal, cultural, and customary institutions that set the norms and rules of social conduct and that are created and sustained by governments, private actors, and civil society. The institutions that enable capabilities are not fixed: They are produced and reproduced by actors who may choose to use their agency to create, sustain, or undermine them. In other words, societies have choices about the outcomes of demographic and environmental change.

Social opportunities and freedoms such as access to health care, education, security, and work lead to falling birth rates, and can therefore catalyze demographic transitions (140). The rights of women to not have children are as important as their rights to have them, and supporting these reproductive rights through voluntary family planning programs, access to contraception, and maternal and child health care can help reduce poverty, improve women's and children's health, enhance social opportunities for women, and slow population growth (141–143). Improving female access to schooling is a key policy intervention that can help empower women and their decisions about reproduction, and it has been shown to lower fertility (144). Improving health care for women and children and women's working conditions as well as abolishing discrimination in women's access to work also contribute a great deal (145–147). Major investments in family planning alone could lower fertility in Africa such that there are 1 billion fewer people by the turn of the century than the business-as-usual scenario. Increasing the proportion of official development assistance spent on family planning from 1 to 2% would likely have this effect.

Many studies also highlight the importance of voluntary family planning as an adaptation strategy, and this is a strategy vulnerable populations have themselves identified (9, 32, 41, 143). It has been shown that access to family planning enhances women's freedoms, and reduces their vulnerability to environmental change. More broadly, lowering fertility produces a demographic dividend for economies by reducing the number of dependents workers have to support, in turn allowing for increased savings, investment, and productivity gains—all of which enhance their capacity to curb and adapt to environmental change (148). Women's empowerment also leads to reduced consumption; for example, O'Neill et al. (149) suggest that slowing population growth can contribute up to 25% of the reduction in greenhouse gas emissions necessary to avoid dangerous climate change.

There is a growing body of evidence focused on human capital and its role in reducing social vulnerability to disasters. This is one of the key contributions of new demographic research on climate change, which has shown that improving education improves public health outcomes and reduces mortality from disasters (150–152). Improving education also enhances the benefits (and minimizes the risks) from migration by increasing the choices available to migrants about where to move, and it improves their chances of successful establishment in new destinations. Recent research suggests that climate change further increases the benefits of education by improving migration opportunities, and thus parents may invest more in education and seek to have fewer children (33).

The evidence presented throughout this review has shown how capabilities and rights are central to migration. Lack of choice defines involuntary displacement. Choice is limited in coerced

resettlement. Choice is central to individual decisions on migration and their destination. As a matter of principle, people should have the right to remain living where they choose to, and so this suggests that a right to adaptation in place is as important as a right to migration (135, 153). Capabilities, rights, and freedoms, such as the capacity for reason enhanced by education, the capacity to work that is enabled by health care and the right to work, and rights to social security and suffrage, are also essential determinants of adaptive capacity, as they enable people to respond in ways that suit their needs and values (154–156). For example, when their freedom of mobility is restricted pastoralists fare less well during droughts (157). When access to primary health care is restricted, rates of infection rise during extreme events (22). Similarly, when people are denied access to homelands by new developments and land grabbing, their vulnerability to environmental change increases (158).

By the same token, many people can and may choose to utilize mobility as a form of adaptation, and so freedom of movement within and across borders will be an increasingly important determinant of demographic and environmental futures (108). As reviewed above, migration policies offer a unique opportunity to facilitate adaptation precisely because they expand the choices available to households (100). There is growing interest in utilizing migration policies for this purpose. For example, Australia's Seasonal Worker Policy was originally designed to help support economic development in the Pacific Islands but is now increasingly being seen as a means to facilitate adaptation in the region (159). Importantly, the Australian and also the New Zealand seasonal worker schemes are generally effective at protecting the rights of migrant workers, and this contributes greatly to the benefits of these schemes for migrants and their families (159).

More broadly, migration is always most beneficial for migrants and their communities of origin and destination when they are afforded the same rights and opportunities as people in their host communities (113, 160). When migrants have de jure or de facto citizenship they are better able to improve their human capital and start new enterprises, which contributes to the economy and taxation revenue, as well as increases migrant incomes and therefore remittances to their communities of origin (161). Such rights also include the right to leave and return from the new country, which increases the development of transnational networks and the benefits they provide to both source and destination areas. Finally, respect for human rights is also the sine qua non of least-worst resettlement processes, even though such processes are more likely in countries where human rights are not well protected (162).

Most internal migration in response to environmental change will be to urban areas. When people move from disadvantaged and environmentally sensitive rural areas to sustainable cities with resilient infrastructure and universal access to social opportunities and freedoms, their vulnerability to climate (and other stresses) falls (163, 164). When such movements result in increasing exposure and discrimination, then social vulnerability may increase. Given that rural to urban migration continues apace, and that almost all future population growth will be located in cities, investing in the resilience of cities must now be a high priority (165, 166). The outcomes of the intersection of demographic changes and climate change are therefore heavily dependent on the choices that national and urban governments, investors, and aid donors make about how to invest and where to invest. Much evidence suggests that urban settlements in high-population-growth countries are, in many senses, the crucible of risk for climate change in the coming decades (167).

6. CONCLUSIONS

Throughout this review we have sought to advance a more constructive and avowedly nondeterministic and pluralist science of demography and environmental change. Across the field of demographic research related to migration, population structures, and their interactions with

climate change, there is an implicit theme of choice. Our review highlights that negative potential spirals of population-environment interactions such as exposed and trapped populations, large-scale displacement, and breaches in basic human rights are by no means inevitable. Rather, rights- and capabilities-based approaches to adaptation in vulnerable populations can accelerate the demographic transition and increase the choices people need to adapt to environmental change.

Much of the evidence we have reviewed in effect highlights that a world in which rights, freedoms, and opportunities are protected is a world in which people and the societies they belong to flourish. Such societies will also likely have more sustainable rates of population growth and consumption and minimal vulnerability to environmental change. Hence, there are multiple dividends to all people from institutionalizing rights, freedoms, and opportunities in all countries, and to do so is to choose a more peaceful and sustainable path through the intersection of demographic and environmental change. Demography is destiny only if we allow it to be.

SUMMARY POINTS

1. Demographic trends such as migration, fertility choice, and aging populations interact with environmental risks to produce new and unforeseen societal challenges.
2. Migration is an effective response to environmental change and degradation and is observed globally in historical and contemporary societies and settings.
3. Elements of population size and structure, such as aging populations, dependency ratios, and population density in cities, are important determinants of environmental burden and risk.
4. Both limited social freedoms and inequality of opportunity constrain demographic responses to environmental risks and challenges, including in the observed lack of mobility in vulnerable populations.
5. Interventions and regulatory change that enhance freedom of movement would lead to reduced exposure to and impact of environmental degradation on vulnerable populations.

FUTURE ISSUES

1. The net environmental burden of aggregate migration flows requires significant multimethod and multiscale research, given the many common unevidenced assumptions that migration drives resource depletion and social conflict.
2. New multiscale research focuses on the relative role of environment on the interacting demographic parameters of migration, fertility choice, and social identity.
3. Research on the social consequences of migration flows would benefit from the incorporation of place-based knowledge and perspectives on community, identity, loss, and belonging.
4. The challenges of immobility require greater focus, given the potential for enhanced migration as an element of sustainable development.
5. The likely increased interventions for planned relocation of communities require greater scrutiny, particularly regarding their political economy, rights, and justice implications.

DISCLOSURE STATEMENT

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LITERATURE CITED

1. Piguet E. 2013. From "primitive migration" to "climate refugees": the curious fate of the natural environment in migration studies. *Ann. Assoc. Am. Geogr.* 103:148–62
2. Ehrlich P, Ehrlich A. 1990. *The Population Explosion*. New York: Simon & Schuster
3. Kaplan R. 1994. The coming anarchy. *Atlantic Mon.* 273:44–76
4. Boserup E. 1990. Economic and demographic relationships in development. *Popul. Dev. Rev.* 16:775–79
5. Dalby S. 1996. The environment as geopolitical threat: reading Robert Kaplan's 'Coming Anarchy.' *Ecumene* 3:472–96
6. Gage AJ. 2015. The next best time for demographers to contribute to climate change research. *Vienna Yearbook Popul. Res.* 13:19–22
7. McDonald P. 2015. Engagement of demographers in environmental issues from a historical perspective. *Vienna Yearbook Popul. Res.* 13:15–17
8. Bongaarts J, O'Neill BC, Gaffin SR. 1997. Global warming policy: population left out in the cold. *Environment* 39:40–43
9. O'Neill BC, MacKellar FL, Lutz W. 2001. *Population and Climate Change*. Cambridge, UK: Cambridge Univ. Press
10. Hayes AC, Adamo SB. 2014. Introduction: understanding the links between population dynamics and climate change. *Popul. Environ.* 35:225–30
11. Muttarak R, Lutz W, Jiang L. 2015. What can demographers contribute to the study of vulnerability? *Vienna Yearbook Popul. Res.* 13:1–13
12. Samir K, Lutz W. 2017. The human core of the shared socioeconomic pathways: population scenarios by age, sex and level of education for all countries to 2100. *Glob. Environ. Change* 42:181–92
13. O'Neill BC. 2005. Population scenarios based on probabilistic projections: an application for the Millennium Ecosystem Assessment. *Popul. Environ.* 26:229–54
14. Dasgupta PS, Ehrlich PR. 2013. Pervasive externalities at the population, consumption, and environment nexus. *Science* 340:324–28
15. United Nations. 2015. *World population prospects: the 2015 revision, key findings and advance tables*. Work. Pap. ESA/P/WP.241, Dep. Econ. Soc. Aff., UN, New York. **https://esa.un.org/unpd/wpp/publications/files/key_findings_wpp_2015.pdf**
16. Grace K. 2017. Considering climate in studies of fertility and reproductive health in poor countries. *Nat. Clim. Change* 7:479–85
17. Prüss-Üstün A, Wolf J, Corvalán C, Bos R, Neira M, eds. 2016. *Preventing Disease Through Healthy Environments: A Global Assessment of the Burden of Disease from Environmental Risks*. Geneva: World Health Organ.

18. Smith KR, Woodward A, Campbell-Lendrum D, Chadee DD, Honda Y, et al. 2014. Human health: impacts, adaptation, and co-benefits. In *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. CB Field, VR Barros, DJ Dokken, KJ Mach, MD Mastrandrea, et al., pp. 709–54. Cambridge, UK: Cambridge Univ. Press
19. Lloyd SJ, Kovats RS, Chalabi Z, Brown S, Nicholls RJ. 2016. Modelling the influences of climate change-associated sea-level rise and socioeconomic development on future storm surge mortality. *Clim. Change* 134:441–55
20. Centre for Research on the Epidemiology of Disasters (CRED). 2015. *The Human Cost of Natural Disasters 2015*. Brussels: CRED
21. Robine J-M, Cheung SLK, Le Roy S, Van Oyen H, Griffiths C, et al. 2008. Death toll exceeded 70,000 in Europe during the summer of 2003. *C. R. Biol.* 331:171–78
22. Watts N, Adger WN, Agnolucci P, Blackstock J, Byass P, et al. 2015. Health and climate change: policy responses to protect public health. *Lancet* 386:1861–914
23. Johnston FH, Henderson SB, Chen Y, Randerson JT, Marlier M, et al. 2012. Estimated global mortality attributable to smoke from landscape fires. *Environ. Health Perspect.* 120:695–701
24. Whittaker J, Haynes K, Handmer J, McLennan J. 2013. Community safety during the 2009 Australian 'Black Saturday' bushfires: an analysis of household preparedness and response. *Int. J. Wildland Fire* 22:841–49
25. Hales S, Kovats S, Lloyd S, Campbell-Lendrum D, eds. 2014. *Quantitative Risk Assessment of the Effects of Climate Change on Selected Causes of Death, 2030s and 2050s*. Geneva: World Health Organ.
26. Casterline JB, Lazarus RT. 2010. *Determinants and Consequences of High Fertility: A Synopsis of the Evidence*. Washington, DC: World Bank
27. Dasgupta PS. 1995. Population, poverty and the local environment. *Sci. Am.* 272:40–45
28. Brauner-Otto SR, Axinn WG. 2017. Natural resource collection and desired family size: a longitudinal test of environment-population theories. *Popul. Environ.* 38:381–406
29. de Sherbinin A, VanWey LK, McSweeney K, Aggarwal R, Barbieri A, et al. 2008. Rural household demographics, livelihoods and the environment. *Glob. Environ. Change* 18:38–53
30. Filmer D, Pritchett LH. 2002. Environmental degradation and the demand for children: searching for the vicious circle in Pakistan. *Environ. Dev. Econ.* 7:123–46
31. Chamberlain G. 2017. Brides of the sun: This is what climate change looks like. *The Guardian*, Nov. 23. **https://www.smh.com.au/world/brides-of-looks-like-20171122-gzqdt9.html**
32. Rovin K, Hardee K, Kidanu A. 2013. Linking population, fertility, and family planning with adaptation to climate change: perspectives from Ethiopia. *Afr. J. Reprod. Health* 17:15–29
33. Shayegh S. 2017. Outward migration may alter population dynamics and income inequality. *Nat. Clim. Change* 7:828–32
34. Barreca A, Deschenes O, Guldi M. 2015. *Maybe next month? Temperature shocks, climate change, and dynamic adjustments in birth rates*. NBER Work. Pap. 21861
35. Lam DA, Miron JA. 1996. The effects of temperature on human fertility. *Demography* 33:291–305
36. Dorélien AM, Ballesteros S, Grenfell BT. 2013. Impact of birth seasonality on dynamics of acute immunizing infections in Sub-Saharan Africa. *PLOS ONE* 8:e75806
37. Martinez-Bakker M, Bakker KM, King AA, Rohani P. 2014. Human birth seasonality: latitudinal gradient and interplay with childhood disease dynamics. *Proc. R. Soc. B* 281:20132438
38. Lin C-YC. 2010. Instability, investment, disasters, and demography: natural disasters and fertility in Italy (1820–1962) and Japan (1671–1965). *Popul. Environ.* 31:255–81
39. Seltzer N, Nobles J. 2017. Post-disaster fertility: Hurricane Katrina and the changing racial composition of New Orleans. *Popul. Environ.* 38:465–90
40. Livi-Bacci M. 2015. What we can and cannot learn from the history of world population. *Popul. Stud.* 69:S21–28
41. Costello A, Abbas M, Allen A, Ball S, Bell S, et al. 2009. Managing the health effects of climate change. *Lancet* 373:1693–733
42. Zelinsky W. 1971. The hypothesis of the mobility transition. *Geogr. Rev.* 61:219–49

43. Skeldon R. 2012. Migration transitions revisited: their continued relevance for the development of migration theory. *Popul. Space Place* 18:154–66
44. Porter G. 2016. Mobilities in rural Africa: new connections, new challenges. *Ann. Am. Assoc. Geogr.* 106:434–41
45. Kaye JP, Groffman PM, Grimm NB, Baker LA, Pouyat RV. 2006. A distinct urban biogeochemistry? *Trends Ecol. Evol.* 21:192–99
46. Liu J, Daily GC, Ehrlich PR, Luck GW. 2003. Effects of household dynamics on resource consumption and biodiversity. *Nature* 421:530–33
47. Cardillo M, Purvis A, Sechrest W, Gittleman JL, Bielby J, Mace GM. 2004. Human population density and extinction risk in the world's carnivores. *PLOS Biol.* 2:e197
48. Cutter SL, Finch C. 2008. Temporal and spatial changes in social vulnerability to natural hazards. *PNAS* 105:2301–6
49. Åström DO, Bertil F, Joacim R. 2011. Heat wave impact on morbidity and mortality in the elderly population: a review of recent studies. *Maturitas* 69:99–105
50. Hajat S, Kovats RS, Lachowycz K. 2007. Heat-related and cold-related deaths in England and Wales: Who is at risk? *Occup. Environ. Med.* 64:93–100
51. Norris FH, Murrell SA. 1988. Prior experience as a moderator of disaster impact on anxiety symptoms in older adults. *Am. J. Community Psychol.* 16:665–83
52. Wolf J, Allice I, Bell T. 2013. Values, climate change, and implications for adaptation: evidence from two communities in Labrador, Canada. *Glob. Environ. Change* 23:548–62
53. Laidler GJ, Ford JD, Gough WA, Ikummaq T, Gagnon AS, et al. 2009. Travelling and hunting in a changing Arctic: assessing Inuit vulnerability to sea ice change in Igloolik, Nunavut. *Clim. Change* 94:363–97
54. Khasiani SA. 1991. A model of migration motivations: migration valuations and migration dispositions among rural youth in Kenya. *Eastern Afr. Econ. Rev.* 7:27–38
55. Fincher R, Barnett J, Graham S. 2015. Temporalities in adaptation to sea-level rise. *Ann. Assoc. Am. Geogr.* 105:263–73
56. Brown SK, Bean FD. 2005. International migration. In *Handbook of Population*, ed. DL Poston, M Micklin, pp. 347–82. New York: Kluwer Acad. Publ.
57. Hugo G. 2011. Future demographic change and its interactions with migration and climate change. *Glob. Environ. Change* 21:S21–33
58. International Organization for Migration (IOM). 2015. *World Migration Report 2015*. Geneva: IOM
59. Liang Y, Guo M. 2015. Utilization of health services and health-related quality of life research of rural-to-urban migrants in China: a cross-sectional analysis. *Soc. Indic. Res.* 120:277–95
60. López Moreno E, Bazoglu N, Mboup G, Warah R. 2009. *State of the World's Cities Report 2008/9: Harmonious Cities*. London: Earthscan
61. Neumann B, Vafeidis AT, Zimmermann J, Nicholls RJ. 2015. Future coastal population growth and exposure to sea-level rise and coastal flooding—a global assessment. *PLOS ONE* 10:e0118571
62. Foresight. 2011. *Migration and global environmental change: future challenges and opportunities*. Rep., UK Gov. Off. Sci., London
63. Hallegatte S, Henriet F, Corfee-Morlot J. 2011. The economics of climate change impacts and policy benefits at city scale: a conceptual framework. *Clim. Change* 104:51–87
64. Hughes L, Rickards L, Stock P, Steffen W, Rice M. 2016. *On the Frontline: Climate Change & Rural Communities*. Canberra: Clim. Counc. Austr.
65. Internal Displacement Monitoring Centre (IDMC). 2015. *Global Estimates 2015: People Displaced by Disasters*. Geneva: IDMC
66. McLeman RA, Hunter LM. 2010. Migration in the context of vulnerability and adaptation to climate change: insights from analogues. *Wiley Interdiscip. Rev. Clim. Change* 1:450–61
67. Piguet E. 2008. *Climate change and forced migration*. Res. Pap. 153, United Nations High Comm. Refug., Geneva
68. Perch-Nielsen S, Bättig M, Imboden D. 2008. Exploring the link between climate change and migration. *Clim. Change* 91:375–93

69. Black R, Adger WN, Arnell NW, Dercon S, Geddes A, Thomas D. 2011. The effect of environmental change on human migration. *Glob. Environ. Change* 21:S3–11
70. Rain DR. 1999. *Eaters of the Dry Season: A Circular Migration System in the West African Sahel*. Boulder, CO: Westview Press
71. Mortimore MJ, Adams WM. 2001. Farmer adaptation, change and 'crisis' in the Sahel. *Glob. Environ. Change* 11:49–57
72. Marchiori L, Maystadt J-F, Schumacher I. 2012. The impact of weather anomalies on migration in sub-Saharan Africa. *J. Environ. Econ. Manag.* 63:355–74
73. Naudé W. 2009. Natural disasters and international migration from Sub-Saharan Africa. *Migr. Lett.* 6:165–76
74. Nawrotzki RJ, DeWaard J, Bakhtsiyarava M, Ha JT. 2017. Climate shocks and rural-urban migration in Mexico: exploring nonlinearities and thresholds. *Clim. Change* 140:243–58
75. Intern. Displac. Monit. Cent. (IDMC). 2017. *IDMC's Global Internal Displacement Database (GIDD)*. Geneva: IDMC. **http://www.internal-displacement.org/database/**
76. Buhaug H, Nordkvelle J, Bernauer T, Böhmelt T, Brzoska M, et al. 2014. One effect to rule them all? A comment on climate and conflict. *Clim. Change* 127:391–97
77. Gemenne F, Barnett J, Adger WN, Dabelko GD. 2014. Climate and security: evidence, emerging risks, and a new agenda. *Clim. Change* 123:1–9
78. Salehyan I. 2014. Climate change and conflict: making sense of disparate findings. *Political Geogr*. 43:1–5
79. Brzoska M, Fröhlich C. 2016. Climate change, migration and violent conflict: vulnerabilities, pathways and adaptation strategies. *Migr. Dev.* 5:190–210
80. Salehyan I. 2008. The externalities of civil strife: refugees as a source of international conflict. *Am. J. Political Sci.* 52:787–801
81. Mwesigye F, Matsumoto T. 2016. The effect of population pressure and internal migration on land conflicts: implications for agricultural productivity in Uganda. *World Dev*. 79:25–39
82. Reuveny R. 2007. Climate change-induced migration and violent conflict. *Political Geogr*. 26:656–73
83. Vlassenroot K, Huggins C. 2005. Land, migration and conflict in eastern Democratic Republic of Congo. In *From the Ground Up: Land Rights, Conflict and Peace in Sub-Saharan Africa*, ed. C Huggins, J Clover, pp. 115–94. Pretoria, S. Afr.: Inst. Secur. Stud.
84. Ghimire R, Ferreira S, Dorfman JH. 2015. Flood-induced displacement and civil conflict. *World Dev*. 66:614–28
85. Raleigh C, Jordan L, Salehyan I. 2008. *Assessing the Impact of Climate Change on Migration and Conflict*. Washington, DC: World Bank
86. Black R, Sessay MF. 1998. Refugees and environmental change in West Africa: the role of institutions. *J. Int. Dev.* 10:699–713
87. Mitchell MI. 2011. Insights from the cocoa regions in Côte d'Ivoire and Ghana: rethinking the migration–conflict nexus. *Afr. Stud. Rev.* 54:123–44
88. Suhrke A. 1997. Environmental degradation, migration, and the potential for violent conflict. In *Conflict and the Environment*, ed. NP Gleditsch, pp. 255–72. Dordrecht: Springer
89. Unruh JD. 2004. Migration induced legal pluralism in land tenure. Implications for environmental change. In *Environmental Change and its Implications for Population Migration*, ed. J Unruh, M Krol, N Kliot, pp. 101–18. Dordrecht: Kluwer Acad. Publ.
90. Chatterjee M. 2010. Slum dwellers response to flooding events in the megacities of India. *Mitig. Adapt. Strateg. Glob. Change* 15:337–53
91. Kwankye SO, Anarfi JK, Tagoe CA, Castaldo A. 2007. *Coping strategies of independent child migrants from northern Ghana to southern cities*. Work. Pap. T-23, Dev. Res. Cent. Migr. Glob. Poverty, Univ. Sussex, Brighton
92. Zulu EM, Beguy D, Ezeh AC, Bocquier P, Madise NJ, et al. 2011. Overview of migration, poverty and health dynamics in Nairobi City's slum settlements. *J. Urban Health* 88:185–99
93. Black R, Bennett SRG, Thomas SM, Beddington JR. 2011. Climate change: migration as adaptation. *Nature* 478:447–49
94. Arnall A. 2014. A climate of control: flooding, displacement and planned resettlement in the Lower Zambezi River valley, Mozambique: a climate of control. *Geogr. J.* 180:141–50

95. Bronen R, Chapin FS. 2013. Adaptive governance and institutional strategies for climate-induced community relocations in Alaska. *PNAS* 110:9320–25
96. Cunsolo-Willox A, Harper SL, Ford JD, Landman K, Houle K, Edge VL. 2012. "From this place and of this place:" climate change, sense of place, and health in Nunatsiavut, Canada. *Soc. Sci. Med.* 75:538–47
97. Fernandes W. 2000. *From Marginalization to Sharing the Project Benefits*. Washington, DC: World Bank
98. Gebauer C, Doevenspeck M. 2015. Adaptation to climate change and resettlement in Rwanda. *Area* 47:97–104
99. Wilmsen B, Webber M. 2015. What can we learn from the practice of development-forced displacement and resettlement for organised resettlements in response to climate change? *Geoforum* 58:76–85
100. Barnett JR, Webber M. 2010. *Accommodating Migration to Promote Adaptation to Climate Change*. Washington, DC: World Bank
101. de Sherbinin A, Castro M, Gemenne F, Cernea MM, Adamo S, et al. 2011. Preparing for resettlement associated with climate change. *Science* 334:456–57
102. Bylander M. 2015. Depending on the sky: environmental distress, migration, and coping in rural Cambodia. *Int. Migr.* 53:135–47
103. Findley SE. 1994. Does drought increase migration? A study of migration from rural Mali during the 1983–1985 drought. *Int. Migr. Rev.* 28:539–53
104. Koubi V, Spilker G, Schaffer L, Bernauer T. 2016. Environmental stressors and migration: evidence from Vietnam. *World Dev.* 79:197–210
105. Nawrotzki RJ, DeWaard J. 2016. Climate shocks and the timing of migration from Mexico. *Popul. Environ.* 38:72–100
106. Thiede B, Gray C, Mueller V. 2016. Climate variability and inter-provincial migration in South America, 1970–2011. *Glob. Environ. Change* 41:228–40
107. Warner K, Afifi T. 2014. Where the rain falls: evidence from 8 countries on how vulnerable households use migration to manage the risk of rainfall variability and food insecurity. *Climate Dev.* 6:1–17
108. Tacoli C. 2009. Crisis or adaptation? Migration and climate change in a context of high mobility. *Environ. Urban.* 21:513–25
109. Gray CL. 2009. Environment, land, and rural out-migration in the southern Ecuadorian Andes. *World Dev.* 37:457–68
110. Lewin PA, Fisher M, Weber B. 2012. Do rainfall conditions push or pull rural migrants: evidence from Malawi. *Agric. Econ.* 43:191–204
111. Massey DS, Axinn WG, Ghimire DJ. 2010. Environmental change and out-migration: evidence from Nepal. *Popul. Environ.* 32:109–36
112. Meze-Hausken E. 2000. Migration caused by climate change: How vulnerable are people in dryland areas? A case-study in Northern Ethiopia. *Mitig. Adapt. Strateg. Glob. Change* 5:379–406
113. Kothari U. 2003. Staying put and staying poor? *J. Int. Dev.* 15:645–57
114. Barnett J. 2012. On the risks of engineering mobility to reduce vulnerability to climate change: insights from a small island state. In *Climate Change and Human Mobility*, ed. K Hastrup, K Fog Olwig, pp. 169–89. Cambridge, UK: Cambridge Univ. Press
115. Suckall N, Fraser E, Forster P. 2017. Reduced migration under climate change: evidence from Malawi using an aspirations and capabilities framework. *Climate Dev.* 9:298–312
116. Felli R, Castree N. 2012. Neoliberalising adaptation to environmental change: Foresight or foreclosure? *Environ. Plan. A* 44:1–4
117. Adams H, Adger WN. 2013. The contribution of ecosystem services to place utility as a determinant of migration decision-making. *Environ. Res. Lett.* 8:015006
118. Arnall A, Thomas DSG, Twyman C, Liverman D. 2013. Flooding, resettlement, and change in livelihoods: evidence from rural Mozambique. *Disasters* 37:468–88
119. McNamara KE, Gibson C. 2009. 'We do not want to leave our land': Pacific ambassadors at the United Nations resist the category of 'climate refugees.' *Geoforum* 40:475–83
120. Mortreux C, Barnett J. 2009. Climate change, migration and adaptation in Funafuti, Tuvalu. *Glob. Environ. Change* 19:105–12
121. Paul BK. 2005. Evidence against disaster-induced migration: the 2004 tornado in north-central Bangladesh. *Disasters* 29:370–85

122. Lutz W, Muttarak R. 2017. Forecasting societies' adaptive capacities through a demographic metabolism model. *Nat. Clim. Change* 7:177–84
123. McLeman R, Schade J, Faist T. 2016. *Environmental Migration and Social Inequality*. Dordrecht: Springer
124. Vargas-Silva C. 2016. EU migration to and from the UK after Brexit. *Intereconomics* 51:251–55
125. Feng S, Krueger AB, Oppenheimer M. 2010. Linkages among climate change, crop yields and Mexico–US cross-border migration. *PNAS* 107:14257–62
126. Hunter LM, Murray S, Riosmena F. 2013. Rainfall patterns and US migration from rural Mexico. *Int. Migr. Rev.* 47:874–909
127. Millock K. 2015. Migration and environment. *Annu. Rev. Resour. Econ.* 7:35–60
128. McLeman R. 2014. *Migration and Climate Change*. Cambridge, UK: Cambridge Univ. Press
129. Brown O. 2008. *Migration and Climate Change*. Geneva: Int. Organ. Migr.
130. Piguet E. 2010. Linking climate change, environmental degradation, and migration: a methodological overview. *Wiley Interdisciplin. Rev. Clim. Change* 1:517–24
131. Lonergan S. 1998. The role of environmental degradation in population displacement. *Environ. Change Secur. Proj. Rep.* 4:5–15
132. Gemenne F. 2011. Why the numbers don't add up: a review of estimates and predictions of people displaced by environmental changes. *Glob. Environ. Change* 21:S41–49
133. Bettini G. 2013. Climate barbarians at the gate? A critique of apocalyptic narratives on 'climate refugees.' *Geoforum* 45:63–72
134. Martin S. 2010. Climate change, migration, and governance. *Glob. Gov.* 16:397–414
135. McAdam J. 2011. Swimming against the tide: why a climate change displacement treaty is not the answer. *Int. J. Refugee Law* 23:2–27
136. Arnall A, Kothari U. 2015. Challenging climate change and migration discourse: different understandings of timescale and temporality in the Maldives. *Glob. Environ. Change* 31:199–206
137. Methmann C, Oels A. 2015. From 'fearing' to 'empowering' climate refugees: governing climate-induced migration in the name of resilience. *Sec. Dialogue* 46:51–68
138. Barnett J. 2017. The dilemmas of normalising losses from climate change: towards hope for Pacific atoll countries. *Asia Pac. Viewp.* 58:3–13
139. Baldwin A. 2017. Climate change, migration, and the crisis of humanism: climate change, migration and humanism. *Wiley Interdisciplinary Rev. Clim. Change* 8:e460
140. Sen A. 1999. *Commodities and Capabilities*. Oxford: Oxford Univ. Press
141. Bongaarts J, Sinding S. 2011. Population policy in transition in the developing world. *Science* 333:574–76
142. Cook RJ, Dickens BM, Fathalla MF. 2003. *Reproductive Health and Human Rights*. Oxford: Oxford Univ. Press
143. Das Gupta M. 2014. Population, poverty, and climate change. *World Bank Res. Obs.* 29:83–108
144. Martin TC. 1995. Women's education and fertility: results from 26 Demographic and Health Surveys. *Stud. Fam. Plan.* 26:187–202
145. Benería L, Berik G, Floro M. 2015. *Gender, Development and Globalization: Economics as if All People Mattered*. London: Routledge
146. Dankelman I. 2010. *Gender and Climate Change: An Introduction*. London: Routledge
147. Striessnig E, Lutz W, Patt AG. 2013. Effects of educational attainment on climate risk vulnerability. *Ecol. Soc.* 18:16
148. Bloom DE, Canning D, Fink G, Finlay JE. 2009. Fertility, female labor force participation, and the demographic dividend. *J. Econ. Growth* 14:79–101
149. O'Neill BC, Dalton M, Fuchs R, Jiang L, Pachauri S, Zigova K. 2010. Global demographic trends and future carbon emissions. *PNAS* 107:17521–26
150. Lutz W, KC S. 2011. Global human capital: integrating education and population. *Science* 333:587–92
151. Lutz W, Muttarak R, Striessnig E. 2014. Universal education is key to enhanced climate adaptation. *Science* 346:1061–62
152. Muttarak R, Lutz W. 2014. Is education a key to reducing vulnerability to natural disasters and hence unavoidable climate change? *Ecol. Soc.* 19:42
153. Polack E. 2009. A right to adaptation: securing the participation of marginalised groups. *IDS Bull.* 39:16–23

154. Barnett J. 2010. Human rights and vulnerability to climate change. In *Human Rights and Climate Change*, ed. S Humphreys, pp. 257–71. Cambridge, UK: Cambridge Univ. Press
155. Holland B. 2012. Environment as meta-capability: why a dignified human life requires a stable climate system. In *Ethical Adaptation to Climate Change: Human Virtues of the Future*, ed. A Thompson, J Bendik-Keymer, pp. 145–64. Cambridge, MA: MIT Press
156. Schlosberg D. 2012. Climate justice and capabilities: a framework for adaptation policy. *Ethics Int. Aff.* 26:445–61
157. Hum. Rights Watch (HRW). 1992. *Indivisible human rights: the relationship between political and civil rights to survival*. Rep., Hum. Rights Watch, New York
158. Golay C, Biglino I. 2013. Human rights responses to land grabbing: a right to food perspective. *Third World Q.* 34:1630–50
159. Bedford R, Bedford C, Wall J, Young M. 2017. Managed temporary labour migration of Pacific Islanders to Australia and New Zealand in the early twenty-first century. *Aust. Geogr.* 48:37–57
160. Jacobsen K. 2002. Livelihoods in conflict: the pursuit of livelihoods by refugees and the impact on the human security of host communities. *Int. Migr.* 40:95–123
161. Horst C. 2006. Refugee livelihoods: continuity and transformations. *Refugee Surv. Q.* 25:6–22
162. Kalin W. 2008. *Guiding principles on internal displacement*. Stud. Transnat. Legal Policy 38, Am. Soc. Int. Law, Washington, DC
163. Roberts D. 2010. Prioritizing climate change adaptation and local level resilience in Durban, South Africa. *Environ. Urban.* 22:397–413
164. Satterthwaite D. 2011. How urban societies can adapt to resource shortage and climate change. *Philos. Trans. R. Soc. A* 369:1762–83
165. Parnell S, Walawege R. 2011. Sub-Saharan African urbanisation and global environmental change. *Glob. Environ. Change* 21:S12–20
166. Revi A, Satterthwaite DE, Aragón-Durand F, Corfee-Morlot J, Kiunsi RBR, et al. 2014. Urban areas. In *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, ed. CB Field, VR Barros, DJ Dokken, KJ Mach, MD Mastrandrea, et al., pp. 535–612. Cambridge, UK: Cambridge Univ. Press
167. Viguié V, Hallegatte S. 2012. Trade-offs and synergies in urban climate policies. *Nat. Clim. Change* 2:334–37

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