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Migration and Adaptation to Climate Change

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Abstract

Migration is one of a variety of ways by which human populations adapt to environmental changes. The study of migration in the context of anthropogenic climate change is often approached using the concept of vulnerability and its key functional elements: exposure, system sensitivity and adaptive capacity. This article explores the interaction of climate change and vulnerability through review of case studies of dry-season migration in the West African Sahel, hurricane-related population displacements in the Caribbean basin, winter migration of 'snowbirds' to the US Sun-belt, and 1930s drought migration on the North American Great Plains. In doing so, general causal, temporal and spatial dimensions of climate migration are identified, followed by a discussion of the potential global scale of future climate change-related migration and implications for gender equity and human security.

With the rise of scientific evidence of anthropogenic climate change, increasingly detailed scientific inquiries have been made into future climatic influences on global migration patterns [1-8]. Environmental changes, of which climate change represents one example, have long been recognized as having the potential to influence human migration and settlement patterns. The relationship between environmental change and migration is, however, rarely experienced in a simple stimulus-response fashion, but is instead modified and shaped by the interaction of environmental changes or events with human social, economic and cultural processes [6,9]. In the field of climate change research, the study of interactions between climate and migration are increasing situated within the context of human vulnerability to climate change, which is in turn identified as being a function of exposure to the impacts of climate change, the sensitivity of communities or socio-economic systems to such impacts, and the capacity of those exposed to adapt [10]. Migration responses to climate change may therefore be treated as one of a range of

possible ways by which people may adapt to adverse impacts of climate change or take advantage of resultant opportunities.

Through consideration of known climate-related migration patterns in a variety of environmental settings, this article examines how interactions of climate-related environmental changes and human social, economic and cultural systems have given rise to adaptive migration. Using case studies drawn from West Africa, the North American Great Plains, the US Sun-belt and the Caribbean basin, we identify, in general terms, causal, temporal and spatial dimensions associated with climate-related migration. In coming decades, such migration is likely to be concentrated in regions where high levels of exposure to adverse impacts intersect with natural resource-dependent livelihoods, and will likely have significant implications for equity and human security, particularly in developing regions. That said, since migration is so closely tied to adaptive capacity, there remains considerable opportunity to moderate the scale of eventual climate migrations through proactive adaptive capacity building.

Migration in the context of vulnerability and adaptation

Vulnerability

The concept of vulnerability provides a basis for understanding the spatial and temporal patterns of climate-related migration, as well as its consequences for societal well-being. In the climate change research community, vulnerability has been defined as being “The degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes” [10: p883]. The nature and characteristics of vulnerability vary considerably across geographic and ecological regions. Vulnerability also differentially characterizes social systems and, indeed, even households within particular systems. These differentials are shaped by a variety of factors including the particular nature of climate impacts; the degree of exposure to such impacts; the sensitivity of human systems to such changes; and the capacity of the exposed population and its socio-economic systems to adapt [10-12]. (EDITORS: YOU WILL WANT TO PUT A LINK TO THE WIRE ARTICLE ON VULNERABILITY IN THIS FIRST PARAGRAPH)

Migration is but one possible form of adaptation within a broader set of potential adaptive responses that individuals and households make when sensitive systems are exposed to changing or stressed environmental conditions [6-8]. Certain types of socio-economic systems are inherently more sensitive to climate-related environmental changes and are, therefore, more likely to engender adaptive migration. Sensitive systems include those characterized by agricultural and natural resource-dependence and those within low-lying coastal settlements, small island states, and other settings where exposure to climate-related risks is high and human livelihood possibilities are limited.

Climate-related exposures most commonly associated with migration fall into two general categories: *sudden-onset events* and *slow-onset changes* in environmental conditions. *Sudden-onset events* take place over short periods of time. These include tornadoes, hurricanes, floods, wildfires and extreme wind, rain or snow events. Sudden-onset events have the potential to cause considerable damage to infrastructure and property, as well as resulting in loss of life, and are therefore often associated with distress migration. In these cases, exposed persons may attempt to flee before the event occurs or evacuate during or post-event. Conversely, *slow-onset* changes in conditions, such as droughts, land degradation or oscillations in precipitation patterns, typically do not stimulate permanent relocation as a first-order household adaptation. They may, however, stimulate changes in temporary migration as a short-term adaptation.

Below, we review several known climate-related migrations. We suggest past events such as these provide useful insights into climate-migration and its important characteristics, thereby

facilitating understanding of how anthropogenic climate change is likely to influence future population movements. Such an approach is consistent with Glantz's (1991) application of historical analogues to climate adaptation studies and Gutmann's (2009) consideration of Hurricane Katrina within the broader historical context of natural hazards, among other studies of this nature [13,14].

Case examples of adaptive migration

Dry-season migration in the West African Sahel

For generations, rural households in the West African Sahel have incorporated a variety of migration strategies to adapt to rainfall's seasonality and the effects of periodic droughts. A north-south rainfall gradient creates annual variations in rainfall levels and timing, thereby lessening crop predictability and generating substantial uncertainty for rural resource-based livelihoods in the region [15]. In response, pastoralists undertake an annual north-south movement of their herds in conjunction with the seasonal availability of forage [16]. Sedentary agriculturalist households undertake a range of adaptive migration strategies to reduce the impacts of dry conditions on household well-being in a process sometimes referred to as "eating the dry season" [17]. Young men, and in some cultural groups young women as well, will often leave their rural homes during dry periods, when there is less work to be done. Many of these young adults migrate to regional urban centres to seek employment and send remittances from earned income back to their rural homes [17-19]. Other areas within the region may experience high levels of rural-to-rural migration, as households move to other rural villages to adapt to local environmental conditions [20]. During prolonged dry periods, young children may be sent out of the drought-affected area to stay with relatives elsewhere, further reducing pressure on household resources [21, 22]. The goal of these various seasonal migrations is similar: to reduce pressure on household food reserves and diversify livelihood opportunities when environmental conditions are unfavourable.

Although temporary migration takes multiple forms, drought conditions within West Africa do not necessarily yield permanent relocation from rural to urban centres [20]. Moreover, while there exists an ongoing movement of migrants from West Africa to Europe, drought does not necessarily lead to sudden increases in levels of migration along these established transnational migrant networks [23,24]. There are logical reasons for these patterns. When household incomes shrink due to severely dry conditions, a lack of financial capital may restrict migration options and result in shorter distance, intra-regional temporary relocation. Conversely, after a successful harvest, households may be better able to afford longer-distance migration of one of its members, but it must be ready and able to forego the absence of that household member's labour the agricultural season resumes. In each case, the household must assess a range of potential opportunities and losses that may be experienced due to migration. In such contexts, migration in a variety of forms becomes an important adaptation strategy within the broader objective of minimizing household vulnerability to environmental scarcity.

Hurricane-related migration in the Caribbean region

Hurricanes have the potential to cause large scale destruction to property, infrastructure, as well as loss of human life. They are a common phenomenon in the Caribbean basin, with Hurricanes Mitch in 1998 and Katrina in 2005 offering two well-known examples that led to large scale population displacements and a range of migration responses. They also show how underlying conditions of socio-economic inequity, institutional neglect of infrastructure, civil conflicts and other phenomena that exacerbate vulnerability can lead to a variety of migration outcomes with long-term consequences for sending and receiving areas alike.

Hurricane Mitch was a powerful storm that in one week delivered almost a year's worth of rainfall to large swathes of Central America, killing up to 20,000 people and displacing two million others [25-27]. Decades of prior civil conflict in Nicaragua, Honduras and El Salvador had created a large population of highly vulnerable people in the region, leaving many thousands of impoverished households occupying marginal and inherently hazardous lands in both the countryside and urban peripheries. These hazardous lands included steep slopes prone to failure, and easily flooded low-lying areas. The vulnerability of these households was further exacerbated by ongoing deforestation and land degradation, and governments' inability to take measures to alleviate the endemic poverty.

An exception to this regional vulnerability can be found in Belize, which had not experienced civil conflict and where environmental degradation was less pronounced. Although Belize, too, felt impacts of the storm, the nation's government was able to organize a systematic evacuation of one-third of its population from highly exposed areas before the hurricane struck, and no deaths were reported [26]. By contrast, in Honduras, where such capacity was lacking, an estimated 18,000 people were killed, hundreds of thousands of homes were damaged or destroyed, agricultural crops were wiped out and drinking water supplies and were contaminated in many areas. More than a year after the storm, tens of thousands of displaced persons continued to live in makeshift camps around urban centres [28]. Migration out of Honduras tripled after the hurricane, and increased by 40% from Nicaragua [25]. Apprehensions of illegal migrants from Central American countries other than Mexico at the US border grew by more than 60% in the months immediately following Mitch; by 2003 US Immigration and Naturalization Services had granted temporary protection status to almost 150,000 migrants of Nicaraguan or Honduran origin under a special program [29].

Hurricane Katrina in 2005 had significant effects on population patterns in New Orleans and surrounding areas. Classified as a Category 3 storm when it reached the US coast, Katrina was accompanied by a large storm surge that flooded low-lying coastal areas and overwhelmed the flood defenses protecting New Orleans. As a rough indication of the number of lives directly affected, over 1.3 million people requested disaster relief assistance from US government programs as a result of the hurricane [30]. Large parts of the exposed population evacuated before the storm hit, seeking shelter outside the region; many others left as soon as possible after the storm had passed. The city of Houston, Texas, is believed to have been one of the major recipients of Katrina displaces, receiving an estimated 150,000 people from storm-affected areas in the year immediately following the hurricane [29]. While many of those who evacuated returned to their homes, Figure 1 suggests that many others have not returned, but relocated elsewhere. Stringfield (2009) find African Americans were less likely to return, with Fussell et al (2009) observing that these return rates have been mediated by the level of flood-related housing damage [31,32]. Elliott and Pais (2006) also find that likelihood of return to New Orleans was positively correlated with home ownership and household income [30]. Consistent with this, McIntosh (2008) found that those who resettled in the Houston area tended to be young and unmarried, characteristics often negatively associated with homeownership and income [29].

Figure 1

Population of New Orleans on July 1, pre- and post-Hurricane Katrina (August 2005)

Source: US Census Bureau, City population datasets, accessed 30 March 2009

http://www.census.gov/popest/counties/files/CO-EST2008-POPCHG2000_2008-22.csv

Do not insert the image in this document; please supply as a separate file.

The overall picture that emerges from Katrina is that while the regional population suffered hardship and substantial temporary displacement, the migration outcomes that emerged were not random [31,32]. Rather, particular socio-economic and demographic groups that were economically disadvantaged were more likely to permanently relocate elsewhere. Although the causes of this marginalization do not include civil conflict, as was the case with Central America's Mitch displacees, both cases highlight the important influence of underlying socio-economic conditions on migration outcomes following extreme events. That said, it is important to remember that not all members of marginalized groups permanently migrated. One interesting outcome of Katrina reported by Airress et al (2007) concerned the ability of the New Orleans Vietnamese community to successfully reestablish its presence in the city by drawing upon the resources of a geographically extensive network of social capital within America's large population of Vietnamese origins [33]. This identification of the importance of extended social networks is consistent with a large body of scholarship that considers the role of social capital more generally in both climate adaptation and in migration decision-making [34,35].

1930s drought migration on the North American Great Plains

In the mid-1930s, the combined impacts of economic recession, falling commodity prices and prolonged droughts stimulated large-scale migrations in many areas of North America's Great Plains. One of these, colloquially referred to as the "Dust Bowl Migration", saw the movement of hundreds of thousands of residents of Arkansas, Kansas, Oklahoma, north Texas and parts of Colorado and Missouri migrate to California and other Pacific coast states; hundreds of thousands more relocated within the Great Plains, often moving from rural to urban areas [36-38]. A number of lessons have been gained about environmentally-related migration behaviour during that period.

One such lesson relates to the different demographic characteristics associated with particular migrant groups and destinations. For example, those who left rural Oklahoma and neighbouring states for southern California tended to be young, married couples with children. These migrants were often joining friends or relatives who had gone before and had already established a presence in the southern California labour market [36,38]. Other rural displacees remained within the drought-affected region, a disproportionate number of whom were poor, landless agricultural labourers, often from broken households. Many thousands congregated in informal squatter settlements with few basic services [38]. These socio-demographic distinctions in migrant groups highlight the importance of access to social capital and to basic social services such as education and health care in terms of adaptive capacity-building and migration outcomes during times of pronounced climate-related stress [39].

The Dust Bowl also provides evidence of how government policies and programs, and the context in which they are formed, influence vulnerability and shape migration outcomes both intentionally and unintentionally [40]. Many key US federal government 'New Deal' policies that had important effects on rural wellbeing in drought-stricken areas were not specifically devised as drought-relief measures. Instead, they were aimed at addressing underlying causes of rural vulnerability, such as commodity price instability and endemic rural poverty. For example, the Agricultural Adjustment Act (AAA) provided farmers financial incentives to reduce production of key commodities in order to stabilize market prices, which the Act did. However, because the financial incentives to take land out of production were paid to land owners, the legislation may have also encouraged evictions and out-migration from drought-stricken areas where farm tenancy rates were high (see Lange and Taylor 1939 for one account [41]). In effect, the AAA provided livelihood stability for one segment of the rural population while increasing the insecurity of another. Another key set of New Deal programs consisted of infrastructure projects funded by the Works Progress Administration (WPA). These programs provided wage employment to many impoverished families across the drought-stricken area. Although demand for such work greatly outstripped the supply, the supplemental incomes obtained from WPA work often made the

difference between a family staying or migrating elsewhere. Over the long run, by addressing root causes of rural vulnerability, such programs likely reduced the scale of population displacements that might otherwise have occurred [41].

Some federal programs were specifically targeted at assisting drought migrants, such as the construction of migrant worker camps in southern California by the federal Farm Security Administration (FSA) to provide safe temporary housing for newcomers from the Great Plains. This initiative counteracted the efforts of state and county governments in California that were actively attempting to discourage migrants from coming to the state or accessing publicly-funded services such as schools and medical clinics [36, 42]. The FSA camps provided migrants with a springboard from which to gain entry to the California labour force. Arrivals from the Great Plains were subsequently able to establish strong local social networks in California that in turn attracted additional migrants. Despite the unwelcome reception given to them by local authorities, few Dust Bowl migrants returned to their home states, and the migrants and their children in subsequent decades became important players in the society and economy of the counties in which they settled [36,38]. This underscores an important point, in that environmental migration does not necessarily have negative long-term impacts on receiving areas, so long as newcomers are assisted in their integration – an observation Black (1994) made in studies of environmental migration in the very different social and ecological context of the Senegal valley [43].

Snowbird migration to the US Sun-Belt

A quite different example of the natural environment shaping population redistribution can be seen in the contemporary US. Here, the ‘sun-belt’ states of the southeast and southwest regions experience high rates of seasonal in-migration during the winter months. Often referred to as the ‘snowbird’ phenomenon, hundreds of thousands of older North Americans temporarily move south to avoid harsh winter conditions in their more northern home regions. For some snowbirds, the seasonal migration is a pre-cursor to a permanent move to the south, but most repeat the seasonal migration annually. These migrant groups consist predominantly of healthy, retired individuals of above-average education and income, whose primary residence is in the northeastern or midwestern states or Canada [44]. An estimated 800,000 or more snowbirds temporarily migrate to Florida for a stay of more than one month, with several hundred thousand more moving each to Texas and Arizona [44,45]. Coates et al (2002) estimated using 1999 data that 300-375,000 Canadians participated in annual winter trips to southern US destinations in excess of three weeks in length, a figure roughly equivalent to 1% of the total population of Canada [46]. Smith and House (2006) also identified an opposite migration pattern, whereby over 300,000 permanent residents of Florida over the age of 55 leave each summer for more northerly climes to escape their home state’s intense heat and humidity [44].

The snowbird example adds some important, additional nuances to how we understand environmental migration. While the previous three cases describe the migration responses of vulnerable populations to adverse conditions or events, the snowbird migration is one driven by opportunity. It shows that migrants may be ‘pulled’ or drawn to particular destinations because of desirable environmental conditions or attributes, as much as they may be ‘pushed’ or driven by adverse environmental conditions to leave other regions. The relative desirability between environmental conditions in source areas and potential destinations, as well as the ability to access potential destinations, depend on a variety of demographic, cultural and socio-economic factors such as (in this example) having the necessary economic means and having reached a particular life cycle stage.

Dimensions of climate migration

From the preceding cases we can begin to identify some general dimensions of environmental migration that are useful when considering the impacts climate change is likely to have on future

migration patterns. The first of these is the *causal dimension*. Migration stimuli are often described in terms of 'push' and 'pull' factors, such as differentials in educational opportunities or wages between migrant sending and receiving destinations [47]. The above examples illustrate a variety of ways by which climatic conditions or events may act as push or pull stimuli. In the case of the Sahel, the inherent variability of regional climatic conditions is the stimulus pushing households to adapt through particular types of migration, most importantly the temporary seasonal migration of young adult household members to urban centres. Hurricanes in the Caribbean hold the potential to shape large scale pulses of distress migration, particularly where proactive measures to reduce harm are inadequate (as in New Orleans) or not in place (as in Honduras). The 1930s Dust Bowl migration is one where the coincidence of prolonged, adverse climatic conditions with economic recession helped tip a system into a situation of distress migration on a scale that may not have occurred had each push factor operated independently. Finally, the potential for favourable climatic conditions to pull or attract population movements is seen in the US sun-belt example.

The preceding examples also highlight several potential *temporal dimensions* of climate-related migration. They suggest a continuum, from short-term, temporary relocation to permanent migration with no intention of return, combined with any number of possibilities between these extremes. Both the snowbird and West Sahel cases describe regularized, seasonal, cyclical migration patterns; one intended to minimize short term household exposure to environmental risks, the other to optimize exposure to favourable climatic conditions. The Dust Bowl migration example describes the opposite end of the temporal spectrum. In decades prior to the 1930s, many rural households on the Great Plains had engaged in circular, seasonal labour-migration of the type witnessed more recently in sub-Saharan Africa for similar reasons [48]. The combined effects of prolonged drought and economic hardship of the 1930s so completely eroded the adaptive capacity of many households and communities that temporary relocation became pointless or impossible, and large scale out-migration from hardest-hit areas ensued. For some jurisdictions on the Great Plains it would be a generation or two before populations would return to their 1930s levels [49].

Migration responses to hurricanes in the Caribbean basin fall across the spectrum of temporal possibilities, with multiple migration outcomes arising from the same event. Hurricane-related migrations also highlight the variety of *spatial dimensions* climate-related migration may take, including:

- ◆ *localized movements* where displacees travel to the nearest safe haven and return to their homes as quickly as is feasible, which for both Hurricanes Mitch and Katrina appear to have been the largest category;
- ◆ *intra-regional migration* that may consist of both temporary migration with intention to return and permanent resettlement (such as the large influx of Katrina-migrants to Houston, Texas);
- ◆ *inter-regional or international migration* such as the tens of thousands displaced by Hurricane Mitch who followed established international migration routes, legal and otherwise, from Central America to the US.

The Sahelian and Dust Bowl case studies also fit within these spatial categories. The Sahelian example illustrates the importance of intraregional migration as an adaptive strategy where households wish to maintain a permanent place of residence in a region repeatedly exposed to climatic stresses. Where that desire to stay in the exposed region is lost or it becomes economically impossible to do so, longer-distance, interregional migration on a permanent basis can ensue, as it did in the US during Dust Bowl era. The snowbird phenomenon also involves

inter-regional movements of people, but differs from the others in that it is undertaken not out of necessity but to optimize climatic conditions to suit a household's lifestyle.

Another important dimension is *the use of migration relative to other possible adaptations*. In each above example, non-migrants or return migrants outnumber those individuals who permanently relocated. As an example, although approximately 150,000 people have not returned to New Orleans since Katrina, twice that number have returned. While hundreds of thousands fled drought-stricken areas on the Great Plains during the 1930s, millions did not. Virtually every household in 1930s Oklahoma and 2005 Louisiana was obliged to adapt in some way to their contemporary climate-related events, but only a minority migrated. Migration, particularly over long distances, entails significant hardships and costs (direct and indirect) and is, therefore, often not an adaptation of first resort except in the most extreme circumstances. The case studies further emphasize that those who do migrate tend to be drawn from particular socio-economic or demographic groups within an exposed population. In the Dust Bowl, Sahel and hurricane case studies, climate migrants are, for example, disproportionately young adults. Land tenure and home ownership are also key factors, with lack of home or land ownership being a characteristic of those who left the 1930s Dust Bowl as well as 2005 New Orleans. In the Sahel, circular migration patterns have emerged as part of broader rural household strategies to minimize the impacts of climatic variability and drought on food security and income. This is consistent with general scholarship that views migration as a household strategy to minimize exposure to economic risks by diversifying livelihoods [50,51]. In the case of snowbirds, the seasonal circular migration is performed at a given life cycle stage by households whose socio-economic status enables consumption of preferred climatic conditions throughout the year. In short, the motivational factors for climate migration at the household level and the migration decisions that emerge directly remain situated within the broader range of forces and factors that shape adaptive capacity and adaptation decision-making more generally, and should not be treated exclusive of these.

Understanding these dimensions of climate migration, and their connections to vulnerability, allows more informed consideration of the *potential scale* of future impacts of anthropogenic climate change on migration patterns. The most likely impacts of climate change as identified by the Intergovernmental Panel on Climate Change include increases in the frequency of both sudden-onset events and slower-onset changes in environmental conditions – both of which are known to influence migration patterns. In some areas, anticipated climatic shifts could create conditions more suitable for economic activity and thereby act as migrant “pulls”. Such may be the case in the Arctic, where warming conditions already underway may open shipping passages and create new resource-based economic activity that is accompanied by economic migration from the south. In many other regions, climate change impacts will likely be unfavourable to human economic activity and well-being, and in the absence of concerted capacity-building efforts, may be expected to stimulate population displacements, distress migration and the abandonment of some populated areas. On the basis of relationships such as those described in Table 1, researchers have suggested a range of estimates of the potential global climate-related migrations anticipated over the course of this century. Oft-cited estimates vary from hundreds of millions to up to one billion people [52-54]. Although such estimates are inherently speculative, they provide a general indication of the potential magnitude of climate change-related migration, particularly in the absence of concerted global efforts to mitigate greenhouse gas emissions and build adaptive capacity in especially vulnerable regions.

Table 1

Expected impacts of anthropogenic climate change and potential effects on global migration patterns

Expected change (from IPCC 2007 [10])	Regions to be affected (from IPCC 2007 [10])	Potential effects on global migration patterns (based on historical case studies and authors cited this article)
Decreased snow and sea ice cover	Arctic	Disruption of livelihoods in aboriginal settlements; influx of economic migrants to north. (see also Ford and Smit 2004)
Increases in annual average river runoff and water availability	High latitudes and some wet tropical areas	Risk of flood displacements in riverine settlements; may facilitate expansion of agricultural settlements
Decreases in annual average river runoff and water availability	Mid-latitudes and dry tropics	Out-migration from populated river valleys in Asia, Australia, Middle East, continental North America, South American west coast
Increased extent of areas affected by droughts	Regions already susceptible to drought	Out migration from agricultural regions in dryland Africa, south Asia, and South America; urban drought and displacement in dry regions of Asia, Australia, Europe, North America
More intense precipitation events	Will vary by region	Risk of flood displacements in riverine settlements, coastal and island communities
Reduced water availability in regions dependent on mountain snowmelt	South Asia, China, western North America, western South America	Increased rural-urban migration in exposed areas; increased potential for urban drought and consequent population displacement
Increasing number of plant and animal species at risk of extinction; increased potential for significant ecosystem disturbances	Globally	Out-migration from communities dependent on small range of resources
Decreasing crop productivity; more frequent impacts of drought and floods on crop production	Lower latitudes, dry tropics, seasonally dry regions	Increased rural-urban migration in exposed areas
Increased risk of erosion, flooding and extreme storms	Coastal regions, especially those already exposed to such risks	Abandonment of settlements in coastal plains, deltas and small islands

Implications of climate change-related migration for equity

Climate change-related migrations and population displacements have a number of broad ramifications for the global community, many of which result from inequities in a variety of domains. As an example, there are important gender implications to climate-related migration [55]. Migration is a social process, and as such, is shaped by socially-constructed gender norms and gender roles. In many regions characterized by dependence on local natural resources, such

as the Sahelian example given above, it is most often men who are engaged in circular livelihood migration, and so migration pressures may become gendered as households face declining local environmental conditions. These livelihood migrations can occasionally take dangerous turns for the migrant and his family. Terry (2009) for example, has attributed climate stress as being ultimately to blame for the many deaths of young western African men trying to reach Europe by boat [56]. The loss of that household member heightens the vulnerability of the family members who remain, experienced through such things as the loss of productive labour or the loss of remittances.

In other developing regions, climatic variability has been found to affect resource availability important to livelihood activities typically performed by women and thereby influence women's migration [57], patterns that may be expected to be further influenced by climate change. Interesting stories also emerge from the Philippines, an archipelago nation where vulnerability to extreme storm events was dramatically illustrated by the impacts of four typhoons experienced in a single month in 2009. This is a nation where recent years have seen steady increase in circular migration by rural island women to work the Philippine's urban areas or abroad. These Filipina migrants are often employed as domestic workers, and their remittances have become critical investments in livelihood diversification in their regions of origin [58]. This is a case where gendered migration may potentially take on the characteristics of being both an outcome of climate change and a means by which households attempt to adapt to environmental shifts.

Climate change-related migration and population displacements also have implications for human security more generally. Human security represents "the condition where people and communities have the capacity to manage stresses to their needs, rights, and values" [59:640], and pertains not so much to weapons and violence but to human life and dignity. Climate change may shape future human security directly, through reductions in livelihood options due to reduced access to, and quality of, natural resources; and, indirectly, such as by undermining states' ability to respond to these livelihood threats [59]. While specific projections are necessarily uncertain, clues to future impacts on human security may be found in the case studies given above, as well as through systematic explorations of other historical examples of human impacts of environmental change, such as Davis's (2001) association of El Nino events of the 19th century with famines [60]. By considering our collective socio-ecological future in the context of past experience, we anticipate the impacts on human security to be greatest in populations or subsets of populations where there is a relatively high dependence on proximate natural resources as compared to other forms of capital and where the nature of the climatic exposure is highly pronounced. The most obvious examples would occur on atoll nations such as Tuvalu, Kiribati and the Maldives, where sea-level rise, extreme weather events, and coastal erosion endanger the long-term sustainability of island livelihoods [61-63]. In atoll nations, migration may not only be a logical form of adaptation, but could in future decades become the predominant response to sea-level rise, thereby imperiling the very future of island cultures. That said, recent studies suggest caution in attributing current migration patterns on atoll nations solely to worries about climate change, and remind that rarely is it that people undertake migration for environmental reasons alone [64]. This serves as yet one more reminder that to fully understand the ways in which climate change holds potential to shape migration patterns and thereby reshape human security, researchers must take into account the environment's interaction with prevailing economic, social, and cultural factors that shape human adaptation processes.

When and where it should occur, climate change-related migration may have indirect impacts on human security by exacerbating underlying causes of violence and conflict or by undermining states' ability to respond effectively [59,65]. Such risks are seen as being especially great in areas with existing political tensions or that are already prone to conflicts among competing groups [66]. National-level security analysts and the UN Security Council have in recent years described the potential effects of worst-case climate change scenarios as global security risks

and security threat multipliers that must be avoided, given their potential to deplete critical resources and displace large populations [67,68]. Others take a more cautious view, preferring to focus on the capacity of actors and institutions to respond to conflicts or instability [69]. Barnett (2003) further cautions that "...there is simply insufficient evidence and too much uncertainty to make anything other than highly speculative claims about the effect of climate change on violent conflict..." [70:10]. Brown and McLeman (2009) have noted that in West Africa, which since Kaplan's (1994) *The Coming Anarchy* has routinely been cited as a place where climate change is likely to create violent conflict, there still exists considerable ability for existing institutions and systems to undertake the steps necessary to avoiding such conflicts, particularly if they receive international support for capacity building [71,72].

Although both environmental factors and changes in migration patterns may play a role in conflict generation or persistence, other factors such as poverty, entrenched social inequalities, ethnic tensions, and the level of state legitimacy often play much greater roles [59]. Some have suggested that the potential for conflict is ultimately shaped by the capacity of political and institutional systems to respond to new pressure points [73]. New pressure points associated with climate change will emerge as the viability of rural livelihoods in many developing regions declines, increasing migration to urban areas and placing greater demand on urban services. Political pressure will in turn be placed on the state to address these demands through provision of access to education, health care, and the maintenance of law and order [59]. Causal paths such as this, where climate-related resource pressures in the countryside lead to new pressures associated with rapid urban growth, are long, multi-step ones that involve many actors at many levels, and as a result offer many opportunities for interventions to avoid violent outcomes [23]. Barnett and Adger (2007) warn there are inherent perils in framing climate change as a conflict and security issue, for if wealthy nations come to see vulnerability to climate change in developing countries as a risk to their own national security through migration or violent conflict, "their responses may be more weighted towards increased border protection and defence spending, rather than towards the reduction of emissions and efforts to foster adaptation " [59:650].

These stories describing security and gender dimensions merely hint at the implications climate change holds for equity at a broader, global scale. While all nations will in various ways be obliged to adapt to the impacts of climate change, the politically and economically powerful nations responsible for most global greenhouse gas emissions will likely not be those that experience the greatest levels of climate-induced migration. Moreover, the bulk of climate-shaped migration will not consist of masses of impoverished people arriving in wealthy nations from vulnerable developing ones; most population movements will take place internally within vulnerable countries [65]. Nation-states that are most vulnerable to climate impacts and least well-equipped to adapt will suffer the greatest erosion of livelihoods and adaptive capacity from the effects of climate-driven population redistributions. While we have in this article taken pains to frame migration as one of a range of potential adaptations to climate change, it is essential to remember that it is an adaptation whose outcomes, particularly when undertaken by large number of people, have considerable feedback effects on the overall well-being of the populations from which they emerge.

Conclusion

As the impacts of anthropogenic climate change become increasingly experienced across a range of human populations and environments, greater attention will be paid to climate-related population redistribution. Existing research on both historical and contemporary migration-environment connections yields important insight as to the causal, temporal and spatial dimensions of this association. On causal connections, scholarship suggests environmental change represents but one 'push' or 'pull' factor acting upon migration. Ultimately, environmental

factors interact with socio-economic, cultural and political dimensions to shape migration decision-making. Temporally, a wide variety of migration patterns are revealed, ranging from short-term, temporary environmentally-related migration to permanent relocation resultant of, for example, natural disasters. On the spatial aspects, existing research suggests the majority of climate-related movements will likely be internal as opposed to crossing international boundaries.

In addition, existing research strongly suggests that human migration within the context of environmental change is closely tied to adaptive capacity. As such, the nature and scale of future climate migration will depend considerably on the extent to which the global community engages in proactive capacity building within vulnerable populations and regions. Past research suggests possible migratory outcomes in the absence of capacity-building efforts. In particular, rural-to-urban and peri-urban migration rates may increase, particularly within developing regions where existing exposure to climate-related risks is high. High levels of dependence on local natural resources represents one such dimension of exposure. In addition, depending on the nature of climate changes and rate of onset, populations inhabiting low-lying coastal regions, small island states and floodplains will also be at risk of displacement although the eventual nature of such impacts will be shaped by capacity building.

Patterns of “non-migration” are also of particular importance in considering future climate-related population movements. In the four case studies presented here, permanent migration is the livelihood option chosen by only a fraction of households affected by environmental change. Because socio-demographic characteristics shape the probability of permanent migration so strongly, targeting efforts to enhance adaptive capacity at particularly vulnerable households may well have the effect of reducing climate-induced migration in many settings.

Although our knowledge of the interactions between climate change and migration patterns is growing, considerable work still needs to be done. There is a high degree of variability and inconsistency in many of the projections currently being made of future climate-related migration, reflecting challenges in scaling from local examples to global estimates and measures. Future research is also needed to refine our understanding of the specific ways in which households and their members assess and evaluate migration options in comparison with other adaptation alternatives, and the critical thresholds at which distress migration becomes the predominant adaptation option. A much wider range of empirical studies of climate-migration interactions across regions and communities is needed, and additional attention should also be paid to gender dimensions of environmentally-related migration as well as other equity and human security considerations. Research initiatives such as these would greatly enhance the development of adaptation policies and programs in coming years by eliminating much of the still-remaining guess work about how climate change-related migration will unfold.

Notes

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Further Reading

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Cross-References

CC-0366: Vulnerability and adaptation to climate change

CC-0347: Adaptation and international climate policy

CC-0341: Are cultures endangered by climate change?

Supplementary Information

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Reviewer suggestions

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