Earth's Future

COMMENTARY

10.1029/2021EF002591

This article is a companion to Thalheimer et al. (2021), https://doi.org/10.1029/2020EF001958.

Key Points:

- Drylands in Africa are highly exposed and vulnerable to climate change impacts with important implications for human mobility
- Climate mobility is the outcome of complex interactions between individual and contextual factors shaping mobility decisions, outcomes, and risks
- Integrative approaches in science and policy are needed to address the complex nexus between climate change and human mobility

Correspondence to:

R. Hoffmann,
hoffmannr@iiasa.ac.at

Citation:

Hoffmann, R. (2022). Contextualizing climate change impacts on human mobility in African drylands. *Earth's Future*, *10*, e2021EF002591. https://doi.org/10.1029/2021EF002591

Received 7 DEC 2021
Accepted 5 MAY 2022

Contextualizing Climate Change Impacts on Human Mobility in African Drylands

Roman Hoffmann[1,2,3]

[1]International Institute for Applied Systems Analysis (IIASA), Wittgenstein Centre for Demography and Global Human Capital (IIASA, OeAW, University of Vienna), Laxenburg, Austria, [2]Vienna Institute of Demography (OeAW), Wittgenstein Centre for Demography and Global Human Capital (IIASA, OeAW, University of Vienna), Vienna, Austria, [3]Potsdam Institute for Climate Impact Research (PIK), Potsdam, Germany

Abstract Climate change is expected to have important implications for human mobility. This article discusses and contextualizes key insights from a recently published study by Thalheimer, Williams, van der Geest, and Otto in Earth's Future (2021), https://doi.org/10.1029/2020EF001958. The authors synthesize findings from the climate science and impact literature, among others from the IPCC Special Report on Global Warming of 1.5 °C, to explore the role of climatic drivers for human mobility in African drylands. Facing a number of economic, social, and political challenges, these areas are highly vulnerable to global warming and related risks. Climate mobility in this region is the outcome of complex interactions between individual and contextual factors shaping peoples' needs and incentives to move as well as their constraints. As the authors highlight, climate change can influence mobility outcomes through a number of channels, including impacts on food and water security, poverty and livelihood risks, and conflicts. These impacts are relevant for both rural areas and cities, with the latter representing a primary destination for climate-induced migration in Africa. The complexity and diversity of the climate mobility nexus call for integrative approaches in science and policy that bridge different disciplines and policy sectors. These approaches should be based on fair, equal, and inclusive processes of knowledge production, transfer, and implementation that involve a number of stakeholders. Inclusive deliberations and partnerships across fields and sectors are key elements to comprehensively studying and addressing the realities and manifold challenges faced by both mobile and immobile populations.

1. Introduction

Climate change impacts are increasingly affecting communities worldwide. More intense and frequent droughts and heat waves, extreme weather events, and rising sea levels represent a significant threat to human livelihoods, health, and well-being (Hirabayashi et al., 2013; Knutson et al., 2010; Schleussner et al., 2016). Climate impacts can result in cascading risks affecting populations through multiple, interconnected challenges, including through their effects on agricultural production, food and water security, employment, and conflict (Asseng et al., 2015; Burke et al., 2015; Dell et al., 2014; Schewe et al., 2014; Tai et al., 2014). The consequences are already felt today. About one-in-three people globally are moderately or severely food insecure (FAO, 2021) and 1.42 billion people—including 450 million children—live in areas of high or extremely high water vulnerability (UNICEF, 2021).

In order to prevent future climate impacts, 194 countries have committed in the Paris Agreement to reducing greenhouse gas emissions toward net zero emissions. The goal is to limit global warming to well below 2 °C, preferably to below 1.5 °C compared to preindustrial levels (1850–1900). Yet, with global emissions continuing to grow over the past years, Earth's warming is likely to exceed the 1.5 °C limit already in the 2030s (IPCC, 2021). Even if the commitments under the Paris Agreement are met, global temperatures are expected to likely increase by more than 2 °C until the end of the 21st century (Hausfather & Forster, 2021). Warming from anthropogenic emissions will persist for centuries to millennia causing further impacts on populations in the long-run and leading to a worsening of living conditions in many parts of the world (IPCC, 2019).

The Intergovernmental Panel on Climate Change Special Report on Global Warming of 1.5 °C (IPCC SR1.5) describes the consequences of not meeting the 1.5 °C target, highlighting that even small temperature shifts can have substantive impacts (IPCC, 2018). It stresses that limiting global warming to 1.5 °C compared to 2 °C could reduce the number of people both exposed to climate-related risks and susceptible to poverty by up to several hundred million by 2050 (see also Knutti et al., 2016; Schleussner et al., 2016). With continued warming, adaptation to the changing climatic conditions will become increasingly difficult with some regions potentially reaching habitability thresholds in the future (Warner & van der Geest, 2013; Xu et al., 2020). This may lead to large-scale migration and displacement as people will be increasingly forced to move out from those heavily affected regions if in situ adaptation is no longer possible.

In their recent article published in Earth's Future, Thalheimer, Williams, et al. (2021) combine insights from the climate science and impact literature, including findings from the IPCC SR1.5 report, with recent evidence on climate mobility to better understand the consequences of global warming for migration and displacement. In their assessment, they focus on drylands in Africa, a region that is both highly exposed and vulnerable to climate risks due to its high dependency on agricultural livelihoods and limited adaptive capacities. A particular focus is placed on the role of six impact sectors as channels through which climate change is expected to influence future mobility patterns. These include impacts on economic activities, livelihood risks and poverty, food security, health, urban areas, and cascading risks.

Here, I discuss and contextualize key insights presented in the article by Thalheimer, Williams, et al. (2021) and highlight implications for research and policy. Climate mobility is shaped by a complex interplay of influences with climatic impacts being one of many closely related reasons for households to become mobile. In this context, there is a need to better understand how local conditions shape mobility outcomes and challenges, and how these will change under a future warmer climate. As many migrants are moving toward cities, Africa has witnessed substantial urban growth in the past decades, which has created a new set of interrelated risks and challenges.

2. Climate Mobility

Whether and to what extent climate change will influence human mobility has received widespread attention in the public in the past years. Since the 1980s, UN organizations have warned of major impacts of global warming on migration and displacement (Gemenne, 2011) with countries in sub-Saharan Africa, South, East, and Southeast Asia, and parts of Latin America being severely affected (Figure 1). Drylands in Africa are particularly suffering from the consequences of climate change with major implications for human mobility (Šedová et al., 2021; Wiederkehr et al., 2018)

Climate mobility refers to any form of movement that has resulted as a direct or indirect consequence of climatic changes and related environmental hazards, such as extreme weather events. It involves a range of different forms of mobility in relation to climatic stress and hazards, including migration, forced displacement, and relocations or evacuations (Boas et al., 2019; Thalheimer, Williams, et al., 2021). Displacement refers to forced mobility, often as a result of a sudden-onset disaster event. This type of mobility is typically short-term and over short distances with many affected households returning to their origin locations once the danger is over. Climate migrants, on the other hand, are persons or groups of persons who are forced to leave their habitual home over longer periods or permanently due to a sudden or gradual change in the climatic conditions (IOM, 2021). Migration can also be the result of an initial displacement if the displaced persons do not return to their origin locations. Finally, planned relocations or evacuations refer to assisted forms of mobility that are typically supported by local or national authorities (Mach & Siders, 2021; Siders et al., 2019; Warner et al., 2013).

Mobility due to environmental influences is not a recent phenomenon. Moving away from inhabitable and dangerous regions has been a survival strategy at all times of human history (Piguet, 2013). Also for recent decades, research has shown that changes in environmental and climatic conditions were closely linked to migration dynamics and other forms of human mobility in different parts of the world (Hoffmann et al., 2020). To what extent environmental drivers influence needs, incentives, and possibilities to move depends on local socioeconomic, cultural, and political conditions as well as on the type and intensity of the experienced hazards (Niva et al., 2021; Thalheimer, Otto, & Abele, 2021).

Climate mobility is hence the outcome of complex interactions between individual and contextual factors influencing mobility decisions, outcomes, and related risks (Black et al., 2011). The environment is rarely the only driver of changes in mobility patterns, but one of many that are often closely interrelated. While there is a consensus in the empirical literature that climatic changes and extreme events are relevant for mobility outcomes, there is no automatism at play. Not every community exposed to environmental stress sees increased mobility levels as a result and not every affected household migrates (Hunter et al., 2015).

10.1029/2021EF002591

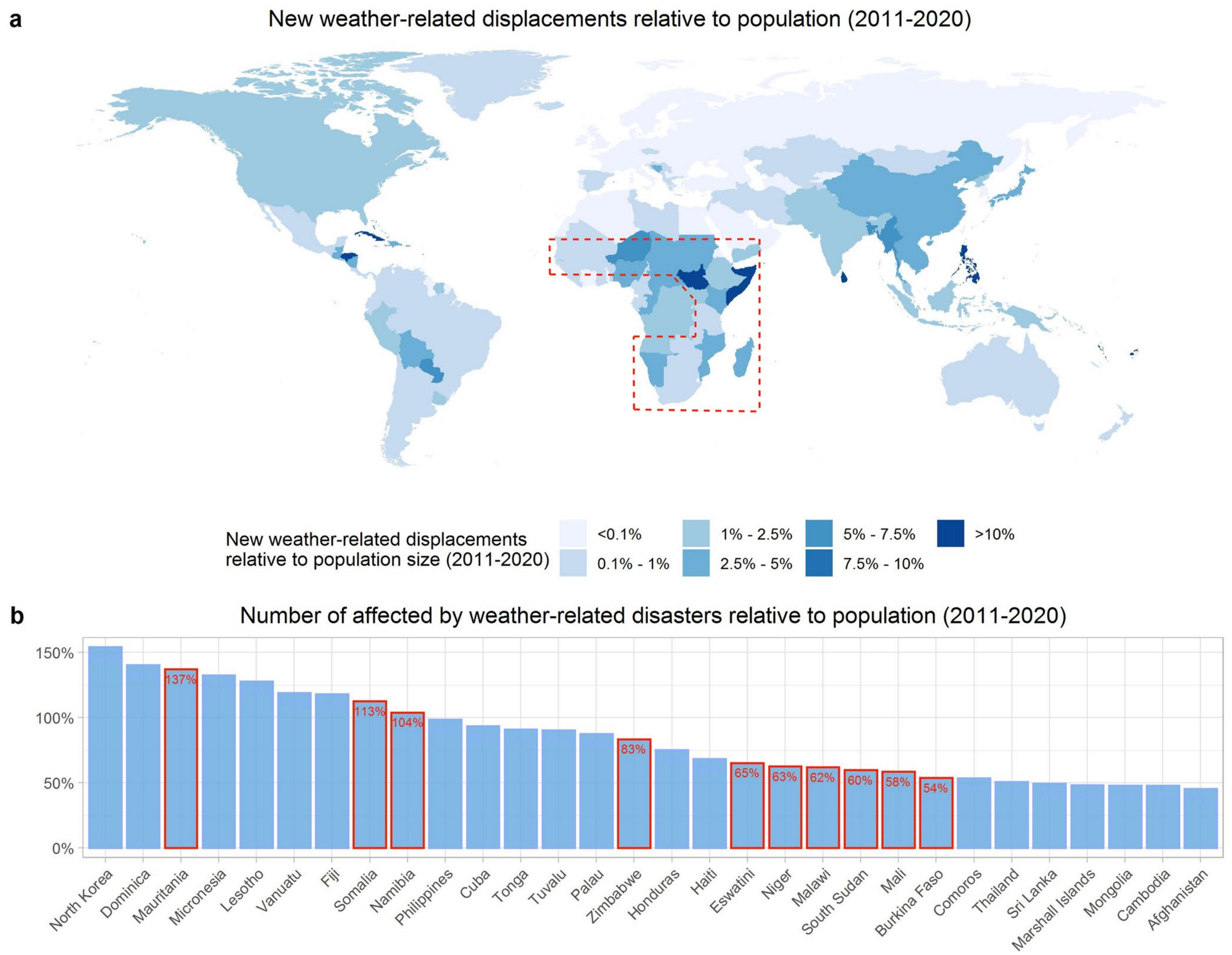

Figure 1. Displacement risks worldwide. Panel (a) shows the number of new weather-related displacements for the period 2011–2020 relative to the average population size of the countries in this period. Box with red dashes shows locations of major dryland areas in Africa. Data: Internal Displacement Monitoring Center (IDMC, 2021b). Panel (b) shows the total number of people affected by weather-related disasters for the period 2011–2020 relative to the average population size. Bars with red borders refer to African countries with major dryland areas. Data: Emergency Events Database (Centre for Research on the Epidemiology of Disasters, 2021). *Note.* Both measures serve as an indication for the affectedness of a country and do not refer to the share of displaced or affected in a population as some people may have gotten displaced or affected twice in the considered time period.

A range of other factors can influence whether a household decides or is forced to become mobile (Foresight, 2011). This depends on the household's level of exposure and vulnerability, the available possibilities to adapt to changing conditions in situ and to diversify or transfer risks (Choquette-Levy et al., 2021), how strong the incentives are to move (e.g., in form of different pull factors), how strong the motivations are to stay (e.g., for cultural or social reasons), and whether the household has sufficient resources to leave. Differences in exposure, vulnerability, and resources arise from nonclimatic factors and from multidimensional inequalities often produced by uneven development processes (Eriksen & O'Brien, 2007; King & Harrington, 2018; Roberts, 2010).

Under conditions of resource scarcity, climate events can also lead to a reduction in mobility, if they further undermine the household's ability to move. This has for example, been documented in studies from West (Findley, 1994; van der Geest, 2011) and South Africa (Nawrotzki & DeWaard, 2018). Especially poor households face a risk of getting trapped in a hazardous location as they are more constrained in their mobility (Niva et al., 2021; Zickgraf, 2019). For these vulnerable groups, climate change can lead to a vicious cycle of environmental deterioration and hazards, persistent poverty, and the inability to leave to safer areas.

3. Livelihood Contexts and Climate Vulnerability in African Drylands

Climate change is expected to have major impacts on the African continent (James & Washington, 2013; Müller et al., 2014). As documented by (Thalheimer, Williams, et al. (2021), many parts of Africa have witnessed a significant warming trend over the recent decades with an increased frequency, intensity and duration of temperature-related extreme events and heatwaves (IPCC, 2018; Rohat et al., 2019). Increased levels of aridity and drought have been observed in some regions of the continent, in particular in Southern and in parts of Eastern Africa. At the same time, there has been an increase in the intensity of heavy precipitation events in Western and Eastern Africa leading to flooding and major displacements (IDMC, 2021c). Risks arise also from more gradual environmental change processes, such as glacial retreat and sea level rise.

In their article, Thalheimer et al. place a particular focus on drylands in Africa. Depending on the level of aridity, these areas can be further distinguished in arid, semiarid, and dry-subhumid areas. They cover about 45% of the African land area and are home to around 525 billion people (CGIAR, 2021). Dryland ecosystems are characterized by challenging agroclimatic conditions, including high levels of aridity, water scarcity, and high rainfall variability. Climate change together with human activities, such as unsustainable land use, are contributing to land degradation in African drylands, leading to significant reductions in crop and livestock productivity (Shiferaw et al., 2014; Stavi et al., 2021a, 2021b). The inhabitants have adapted their livelihood strategies to these conditions with populations in drier areas being mainly involved in forms of pastoralism or agropastoralism (FAO, 2018). Pastoralists face a number of specific challenges related to dwindling access to water resources and grazing lands, poverty and marginalization, and limited access to markets (Fjelde & von Uexkull, 2012; Wiederkehr et al., 2018).

Socioeconomic, agricultural, demographic, and political factors are influential in determining the impacts of climate change on populations with important implications for mobility patterns in the region. Many countries in Africa are highly vulnerable due to high levels of poverty, low adaptive capacities, structural inequalities, protracted conflicts, and political instability. Climate risks are closely related to and can be exacerbated by the occurrence of other sociopolitical and health crises (Barnett & Neil Adger, 2007; Leichenko et al., 2010). In the last 2 years, the coronavirus pandemic had a significant impact on the continent, contributing to a further increase in vulnerability in many countries (Leichenko et al., 2010; Phillips et al., 2020).

Food insecurity, fueled by changing climatic conditions, land use and management, and population dynamics, can cause major displacement and migration (Misselhorn, 2005; Stavi, Roque de Pinho et al., 2021). In 2020, an estimated 282 million people in Africa (21% of the population) were undernourished and 798.8 million were moderately or severely food insecure (59.6% of the population). Compared to 2015, these numbers increased by almost 30% (FAO, 2021). Due to their limited capacities to adapt and cope with environmental changes and hazards, the poor face particularly high climate risks. Recent estimates suggest that without immediate action, by 2030, up to 118 million extremely poor people (i.e., those living on less than US$ 1.25/day) may be exposed to drought, floods and extreme heat in sub-Saharan Africa, causing humanitarian emergencies (Shepherd et al., 2013).

Demography plays an important role in assessing the exposure and vulnerability to climate risks (Lutz & Muttarak, 2017). Whereas in most regions of the world population growth has declined, Africa has seen persistent increases in its population over the past decades. The high levels of population growth result from a combination of declining mortality and high fertility rates (Lutz & Qiang, 2002). If the African population continues to grow at the current rate, it is expected to double in size by 2050 (UN, 2019). The growing population means that more people will be exposed to hazards in the future, which is also reflected in a growing number of people affected by disasters in the region (Centre for Research on the Epidemiology of Disasters, 2021). At the same time, the demographic trends have important implications for vulnerability and mobility as public sectors and infrastructures, such as housing, transportation, and health care, cannot cope with such a rapid population increase, contributing to lower resilience and increased risks for populations (Muttarak, 2021).

Together with the rapid population growth, environmental degradation can fuel conflicts in the area. For example, increased competition for resources between farmers and pastoralists have led to disputes in the Sahel region with several outbreaks of violence in the past years (Brottem, 2016; UNEP, 2011). Institutional arrangements and social norms can play an important role in preventing violent conflict from occurring or getting out of hand. These can be arrangements regulating access to scarce resources or facilitating mediation (Adano et al., 2012).

As a result, with appropriate collective institutions in place, environmental scarcity can also foster collaboration between different social groups.

4. How Climate Change Affects Mobility in African Drylands?

For the year 2020, the Internal Displacement Monitoring Center (IDMC) recorded 11.1 million new displacements in Sub-Saharan Africa of which about 4.3 million were due to disaster events (IDMC, 2021c). For example, the Sudan and South Sudan experienced their worst floods in decades with 155 deaths and 830,000 people affected in the Sudan alone (WMO, 2021). At the same time, slow-onset processes and gradual environmental changes, which are mostly not covered in the IDMC numbers, represent a significant risk in the region, undermining local livelihoods and economic opportunities.

Climate change is expected to further amplify environmentally induced migration from these areas both within countries and across borders. Likewise, displacement risks are expected to increase due to disruptions in food supplies, threatened livelihoods, and conflicts (IDMC, 2021c; IPCC, 2018; Borderon et al., 2019). The World Bank Groundswell report estimates that until the year 2050 gradual environmental changes could force up to 86 million people to migrate within the borders of their countries in sub-Saharan Africa, if no urgent climate action is taken (Clement et al., 2021).

Based on the IPCC 1.5SR and recent findings from the literature, Thalheimer, Williams, et al. (2021) discuss six impact sectors that will be particularly affected by climate change and highlight implications for mobility. These include impacts on economies, livelihoods and poverty, food security, health, urban areas, and cascading risks. Having a comprehensive understanding of the channels through which climate change will affect populations is pivotal for policymakers to identify hotspots of highly exposed and vulnerable areas and to develop effective policy responses.

Economic impacts, livelihood disruptions, and poverty are a key mobility driver. In the last Afrobarometer wave in 2019, economic considerations, including "finding work," "economic hardship," "poverty," and "better business prospects," were cited as the most important reason for considering emigration in Africa (Afrobarometer, 2021). With the majority of the population (52.9% in 2019 in sub-Saharan Africa) employed in agriculture, the agricultural sector is critical for African economies (ILO, 2021). Climate change will have major impacts on this sector's productivity, potentially reducing crop yields by up to 50% (Dinar et al., 2008; Schlenker & Lobell, 2010; Tol, 2018). As a result, based on recent projections of the African Development Bank, the African Gross Domestic Product could suffer a significant decrease. Under a high-warming scenario, Eastern and Western Africa, could experience a reduction in GDP per capita by about 15% by 2050 (African Development Bank Group, 2019).

A second major channel through which climate change affects mobility outcomes is through its impacts on food production, water security, and health. Especially, issues related to food security have been shown to be an important determinant of both the desire and the decision to migrate (Cai et al., 2016; Sadiddin et al., 2019; Warner & Afifi, 2014). With climate change, agricultural production will become increasingly difficult in drylands, including for pastoralists, who may be forced to alter their mobility patterns in search for suitable grazing land and water (Boone et al., 2018). Food and water crises have also been the cause of major displacements in Africa in the past decades, most notably the series of drought events that have affected the Eastern African region in 2011–2012, causing a major famine and displacement. Aside of its impacts on nutrition, climate change also affects health outcomes through other channels, including through risks related to extreme weather events and disasters (Mirza, 2003; Warner et al., 2012), temperature extremes and thermal stress (Kjellstrom, 2009), alterations in the spread of diseases and pests (Epstein, 2001), and through its impacts on conflict (Abel et al., 2019).

Climate change and resulting land degradation in drylands are expected to have major socioeconomic implications and represent a major risk for achieving inclusive and sustainable development (Figure 2). Scholars have warned that climate change could threaten achievements across a number of areas. These include achievements related to the Sustainable Development Goals (SDGs) on poverty eradication (SDG1), zero hunger (2), health (3), gender equality (5), clean water and sanitation (6), decent working conditions (8), inequality (10), life below water and on land (14 and 15) and peace, justice, and strong institutions (16), among others. Across these different

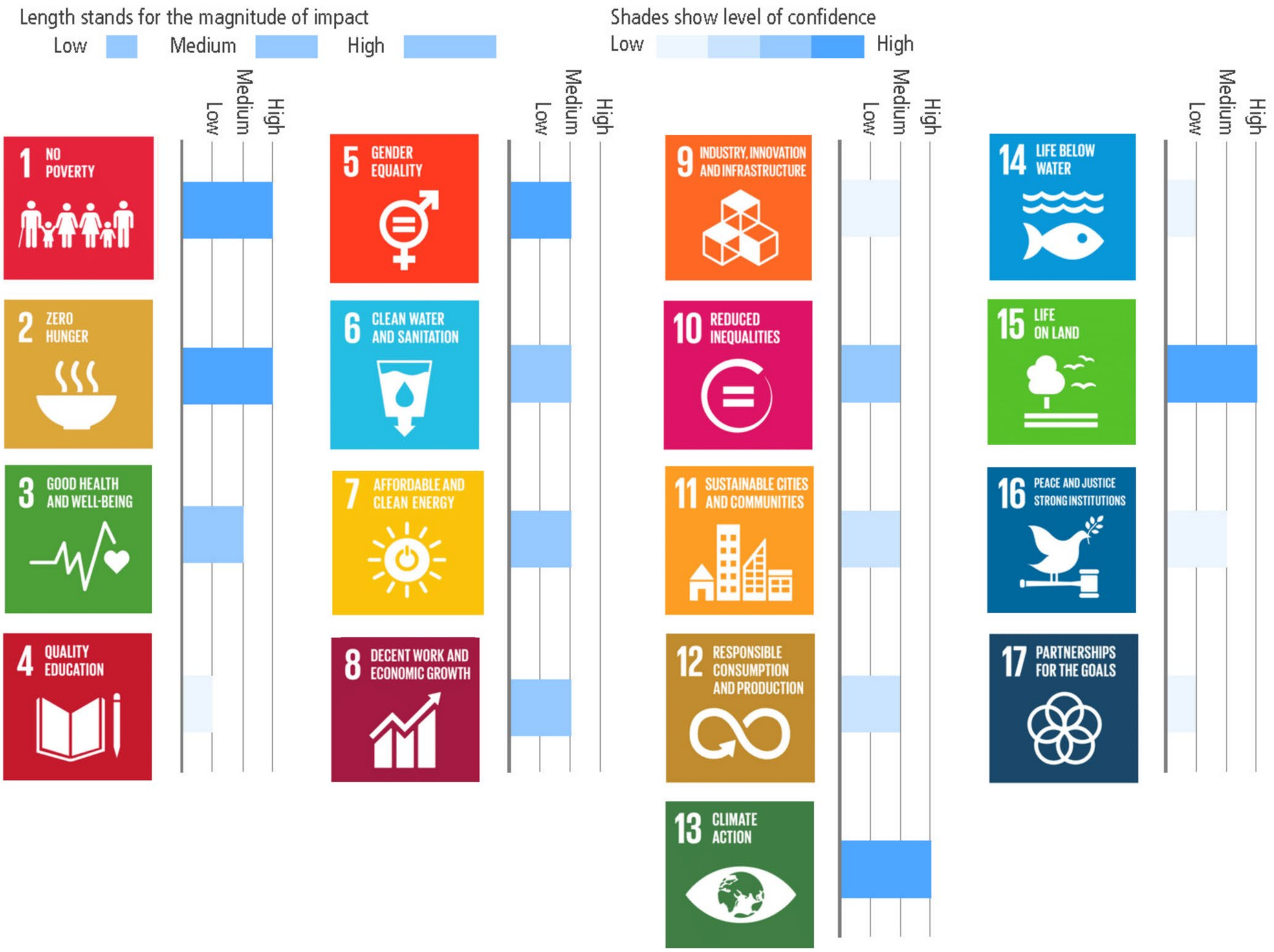

Figure 2. Socioeconomic impacts of desertification and climate change based on the Sustainable Development Goals (SDG) framework. The length of the bars shows the magnitude of the expected impacts, the shading shows the level of confidence based on the existing evidence. Darker shades indicate a higher confidence in the findings. Source: IPCC Special Report on Climate Change and Land (IPCC, 2019).

areas, capping warming to 1.5 °C can substantially minimize risks and thus considerably reduce migration pressures on affected populations (IPCC, 2018; Thalheimer, Williams, et al., 2021).

5. Mobility, Urban Growth, and Climate Resilience

While climate change undermines the livelihoods of rural communities, it also has significant implications for urban areas in Africa. Environmental degradation together with limited social and economic opportunities in rural areas have pushed large number of migrants toward cities, leading to unprecedented urban growth in the region (Storeygard et al., 2014). The 10 fasted growing urban agglomerations are all located in Africa. Cities, such as Dar es Salaam in Tanzania, Kampala in Uganda, or Ouagadougou in Burkina Faso are expected to double in size by 2035 (Figure 3). By this time, the majority of the African population (50.9%) will likely be living in cities (United Nations, 2019).

The observed urbanization trends are closely related to climate mobility patterns (Henderson et al., 2017). They highlight the need to broaden the perspective when examining the climate mobility nexus. It is important to not only ask where climate migrants are coming from, but also where they are going. Depending on the severity of future climate impacts, a further depopulation of rural areas can be expected with both significant implications for rural and urban communities. The rapid urbanization will bring new opportunities, but also a range of challenges, including new environmental risks (Hoffmann & Muttarak, 2021).

10.1029/2021EF002591

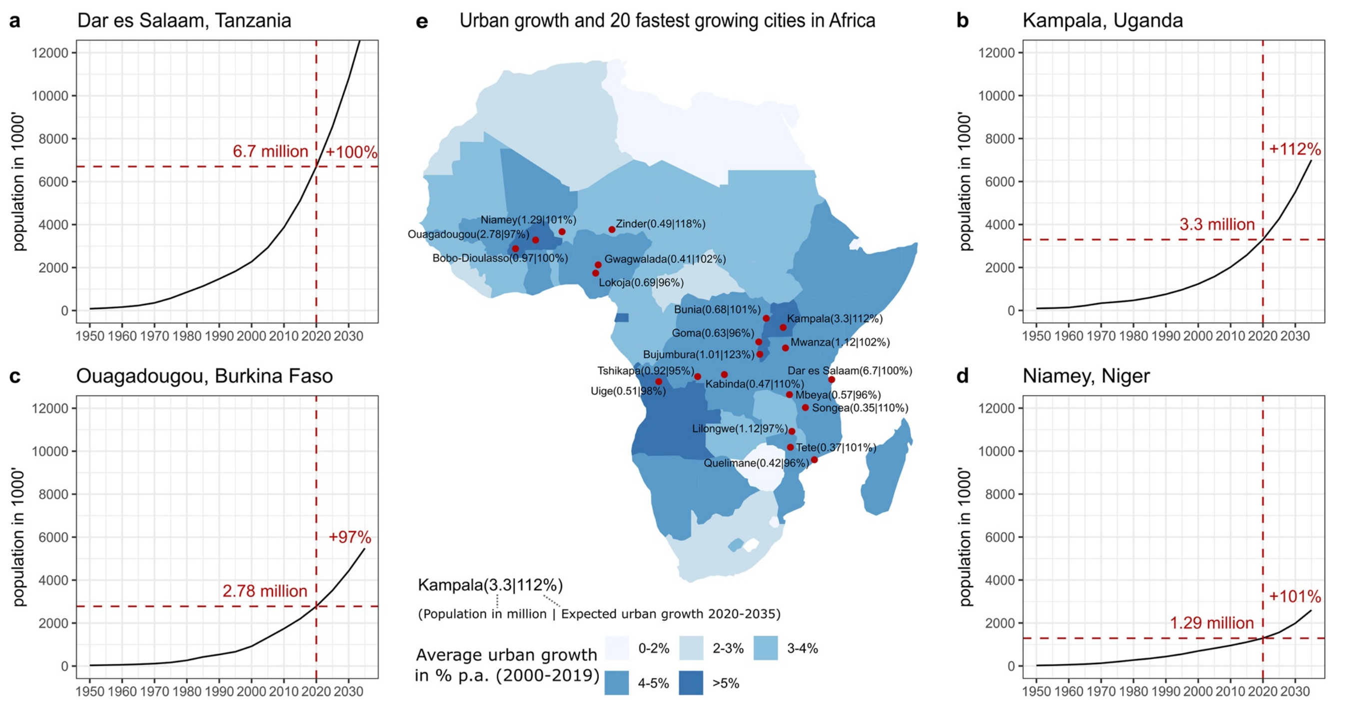

Figure 3. Urbanization trends across Africa. Panels (a–d) show the urban expansion of the four largest among the 20 fastest growing cities of the continent. The red number left of the intersection of the dashed lines shows the population size of the city in the year 2020, the reference period. The second red number to the right shows the projected growth of the city population until 2035. Panel (e) maps the urbanization trends across Africa and shows the locations of the 20 fastest growing cities. Darker shades of blue indicate higher levels of urban growth in a country. The numbers in parentheses behind the city names show the city population in million in the year 2020 and the expected growth of the city 2020–2035. Data: UN Department of Economic and Social Affairs (2019).

Climate change will have major impacts on cities. Heat waves exert a particularly strong effect in urban environments due to urban heat island effects, contributing to increased heat-related morbidity and mortality in densely populated areas (Thalheimer, Williams, et al., 2021). While cities are often the destination of those forced to leave their homes due to climate change, they are at the same time hotspots for climate-induced displacements (IDMC, 2021a). Migrants and internal displaced persons (IDPs) are particularly at risk. They often live in marginalized, informal neighborhoods with insufficient infrastructures, lack of basic services, poor housing quality, and limited protection (Pantuliano et al., 2012). These areas are often located in hazard prone environments, such as in marginal lands, low-lying deltas or coastal zones (Reckien et al., 2017).

Flooding and severe storms as two common hazards have been shown to have particularly severe impacts in urban environments, where they can unfold a high destructive potential leading to major losses and damages (Donner & Rodríguez, 2008; Gu, 2019; Hoffmann & Muttarak, 2015). Vulnerable population groups, including migrants and IDPs, tend to be particularly affected, further aggravating inequalities and poverty (IDMC, 2021a). Those who have fled from harm before, may thus find themselves forced to move again. This process, which is referred to as secondary displacement (IDMC, 2018), can lead to a vicious cycle of increased environmental risks, displacement, and poverty and vulnerability.

Faced with a rapid population growth, many expanding cities in Africa are not well prepared to mitigate risks related to increasing inflows of migrants and IDPs in the future. With rising climate impacts, this entails substantive risks both for city residents and migrant populations with implications for climate adaptation. Preparing cities and building climate resilience in urban contexts is therefore crucial. This requires forward-looking urban planning, the promotion of innovative solutions to sustainable urban living, preventative disaster risk reduction efforts, inclusive infrastructure development, and strengthened efforts to integrate migrant populations into urban labor markets, particularly through inclusive education and training. Better protection and support of migrants and populations affected by climate change is needed at all stages of the migration cycle, involving both origin and destination areas (Vinke et al., 2020).

6. Toward an Integrative Approach in Science and Policy

The work by Thalheimer, Williams, et al. (2021) highlights the complexity of climate mobility processes calling for an integrative systems approach in both research and policymaking to address future warming impacts on populations (see Figure 1 in their paper). Climate change affects human livelihoods and well-being through a set of closely related and compounding channels and impact sectors. Effects on one sector may spill over to others, potentially leading to reinforcing and cascading risks.

The complexity of the issue also emerges from the very nature of human mobility, which is highly diverse. Populations respond in various ways to environmental threats either by altering their mobility or by remaining immobile and choosing other in situ adaptation and coping strategies, if possible. The question of who migrates and who stays (and under which conditions) is often closely related to issues of social inequality, poverty, and lacking opportunities. If people move, their mobility can take different forms: It can be temporary over a short period or over a longer time, over a short-distance or a long-distance, within national borders or international. It can also involve various degrees of decision power ranging from a spectrum from less to more forced forms of mobility (Hoffmann et al., 2021).

How can a systems perspective in research and policy help in understanding these processes better? System analytical approaches emphasize integrative thinking to address wicked issues and interconnected challenges (Hynes et al., 2020; van Kerkhoff, 2014). Systems are groups of related parts that influence and depend on each other. For example, (non)migration decisions are shaped by the closely connected social, economic, and political systems in a community that are influenced by environmental and nonenvironmental factors. Translocal migration networks (Greiner & Sakdapolrak, 2013) bridge origin and destination areas and constitute a social system of its own right, which closely interacts with other systems (e.g., by sending remittances, migrants contribute to building economic resilience in origin communities). Systems can respond to influences in nonlinear ways, a pattern that also applies to climate impacts on human systems (Gaupp et al., 2021). These are characterized by social tipping points (e.g., limits of habitability) beyond which the systems can no longer adapt to changes in climatic conditions, potentially leading to increased migration (Bentley et al., 2014; Warner & van der Geest, 2013).

System thinking acknowledges the close relationships and interdependencies between different types of systems and their parts, including natural (e.g., hydrologic, atmospheric, biological, geological) and human (e.g., economic, social, infrastructural) systems (Berry et al., 2018). Being inherently multidisciplinary and interdisciplinary, system analytical approaches are well-suited to understanding climate mobility in different contexts, highlighting that the climate mobility nexus is deeply rooted in broader issues of sustainable development and other population dynamics. Such a comprehensive perspective is needed to study the consequences of climate change for human mobility and its implications and related challenges for origin and destination areas.

In order to achieve a stronger integration of different perspectives, closer collaborations between diverse partners—involving actors from science and policy—are needed. These should be based on fair, equal, and inclusive processes of knowledge production, transfer, and implementation that involve a number of stakeholders, including from communities directly affected by climate change impacts. In particular, voices from the Global South are rarely heard in discourses related to climate change and human mobility (Piguet et al., 2018). Establishing more inclusive funding schemes and research partnerships and investing into science and education are key elements to successfully integrate researchers from different fields as well as geographical and economic backgrounds. Furthermore, multistakeholder partnerships and participatory approaches, involving actors from academia as well as the public and private sector, can support evidence-based decision making with a relevance for local contexts (Lemos, 2015; Wittmayer & Schäpke., 2014).

A strong solution orientation is key in addressing the challenges arising from increasingly severe climate impacts. System analytical research can support decision makers to resolve challenges they face in the short, medium, and long term (Ison, 2017). To enable forward-looking, solution-oriented approaches in the context of climate mobilities, anticipatory action and planning are needed (Thalheimer et al., 2022). These can help fostering resilience and sustainability in communities most severely affected by climate change.

Data Availability Statement

The code and data that support the findings of this study are available from the author upon reasonable request.

Acknowledgments

R. H. gratefully acknowledges funding from IIASA and the National Member Organizations that support the institute.

References

Abel, G. J., Brottrager, M., Crespo Cuaresma, J., & Muttarak, R. (2019). Climate, conflict and forced migration. *Global Environmental Change*, *52*, 239–249. https://doi.org/10.1016/j.gloenvcha.2018.12.003

Adano, W. R., Dietz, T., Witsenburg, K., & Zaal, F. (2012). Climate change, violent conflict and local institutions in Kenya's drylands. *Journal of Peace Research*, *49*(1), 65–80. https://doi.org/10.1177/0022343311427344

African Development Bank Group. (2019). *Climate change impacts on Africa's economic growth*. Retrieved from https://www.afdb.org/en/documents/climate-change-impacts-africas-economic-growth

Afrobarometer. (2021). "*A Pan-African series of national public Attitude Surveys on Democracy, Governance, and Society*." Retrieved from https://afrobarometer.org/data

Asseng, S., Ewert, F., Martre, P., Rötter, R. P., Lobell, D. B., Cammarano, D., et al. (2015). Rising temperatures reduce global wheat production. *Nature Climate Change*, *5*(2), 143–147. https://doi.org/10.1038/NCLIMATE2470

Barnett, J., & Neil Adger, W. (2007). Climate change, human security and violent conflict. *Political Geography, Climate Change and Conflict*, *26*(6), 639–655. https://doi.org/10.1016/j.polgeo.2007.03.003

Bentley, R. A., Maddison, E. J., Ranner, P. H., Bissell, J., Caiado, C. C. S., Bhatanacharoen, P., et al. (2014). Social tipping points and Earth systems dynamics. *Frontiers in Environmental Science*, *2*, 35. https://doi.org/10.3389/fenvs.2014.00035

Berry, H. L., Waite, T. D., Dear, K. B. G., Capon, A. G., & Murray, V. (2018). The case for systems thinking about climate change and mental health. *Nature Climate Change*, *48*(4), 282–290. https://doi.org/10.1038/s41558-018-0102-4

Black, R., Adger, W. N., Arnell, N. W., Dercon, S., Geddes, A., & Thomas, D. (2011). The effect of environmental change on human migration. *Global Environmental Change*, *21*(Suppl. 1), 3–11. https://doi.org/10.1016/j.gloenvcha.2011.10.001

Boas, I., Farbotko, C., Adams, H., Sterly, H., Bush, S., van der Geest, S., et al. (2019). Climate migration myths. *Nature Climate Change*, *9*(12), 901–903. https://doi.org/10.1038/s41558-019-0633-3

Boone, R. B., Conant, R. T., Sircely, J., Thornton, P. K., & Herrero, M. (2018). Climate change impacts on selected global rangeland ecosystem services. *Global Change Biology*, *24*(3), 1382–1393. https://doi.org/10.1111/gcb.13995

Borderon, M., Sakdapolrak, P., Muttarak, R., Kebede, E., Pagogna, R., & Sporer, E. (2019). Migration influenced by environmental change in Africa: A systematic review of empirical evidence. *Demographic Research*, *41*, 491–544. https://doi.org/10.4054/DemRes.2019.41.18

Brottem, L. V. (2016). Environmental change and Farmer-Herder conflict in agro-Pastoral west Africa. *Human Ecology*, *44*(5), 547–563. https://doi.org/10.1007/s10745-016-9846-5

Burke, M., Hsiang, S. M., & Miguel, E. (2015). Climate and conflict. *Annual Review of Economics*, *7*, 577–617. https://doi.org/10.1146/annurev-economics-080614-115430

Cai, R., Feng, S., Oppenheimer, M., & Pytlikova, M. (2016). Climate variability and International migration: The importance of the agricultural linkage. *Journal of Environmental Economics and Management*, *79*, 135–151. https://doi.org/10.1016/j.jeem.2016.06.005

Centre for Research on the Epidemiology of Disasters. (2021). *EM-DAT: The emergency events Database*. Retrieved from www.emdat.be

CGIAR. (2021). *Global landscapes forum Africa: Restoring Africa's drylands needs a localized, integrated approach, say experts at the conference*. Retrieved from https://www.cgiar.org/news-events/news/global-landscapes-forum-africa-restoring-africas-drylands-needs-a-localized-integrated-approach-say-experts-at-the-conference/

Choquette-Levy, N., Wildemeersch, M., Oppenheimer, M., & Levin, S. (2021). Risk transfer policies and climate-induced immobility among smallholder farmers. *Nature Climate Change*, *11*(12), 1046–1054. https://doi.org/10.1038/s41558-021-01205-4

Clement, V., Rigaud, K. K., de Sherbinin, A., Jones, B., Adamo, S., Schewe, J., et al. (2021). *Groundswell Part 2: Acting on internal climate migration*. World Bank.

Dell, M., Jones, B. F., & Olken, B. A. (2014). What do we learn from the weather? The new climate-economy literature. *Journal of Economic Literature*, *52*(3), 740–798. https://doi.org/10.1257/jel.52.3.740

Dinar, A., Hassan, R., Mendelsohn, R., & James, B. (2008). *Climate change and agriculture in Africa: Impact assessment and adaptation strategies*. Routledge. https://doi.org/10.4324/9781849770767

Donner, W., & Rodríguez, H. (2008). Population composition, migration and inequality: The influence of demographic changes on disaster risk and vulnerability. *Social Forces*, *87*(2), 1089–1114. https://doi.org/10.1353/sof.0.0141

Epstein, P. R. (2001). Climate change and emerging infectious diseases. *Microbes and Infection*, *3*(9), 747. https://doi.org/10.1016/S1286-4579(01)01429-0

Eriksen, S. H., & Karen, O. (2007). Vulnerability, poverty and the need for sustainable adaptation measures. *Climate Policy*, *7*(4), 337–352. https://doi.org/10.1080/14693062.2007.9685660

FAO. (2018). *Pastoralism in Africa's drylands*. FAO. Retrieved from https://www.fao.org/resilience/resources/resources-detail/en/c/1160694/

FAO. (2021). *The state of food security and nutrition in the world*. FAO. Retrieved from https://www.fao.org/publications/sofi/2021/en/

Findley, S. E. (1994). Does drought increase migration? A study of migration from rural Mali during the 1983–1985 drought. *International Migration Review*, *28*(3), 539. https://doi.org/10.2307/2546820

Fjelde, H., & von Uexkull, N. (2012). Climate triggers: Rainfall anomalies, vulnerability and communal conflict in sub-Saharan Africa. *Political Geography*, *31*(7), 444–453. https://doi.org/10.1016/j.polgeo.2012.08.004

Foresight. (2011). *Migration and Global Environmental Change: Future Challenges and Opportunities*. Final Project Report, The Government Office for Science, London.

Gaupp, F., Ruggeri Laderchi, C., Lotze-Campen, H., DeClerck, F., Bodirsky, B. L., Lowder, S., et al. (2021). Food system development pathways for healthy, nature-positive and inclusive food systems. *Nature Food*, *2*(12), 928–934. https://doi.org/10.1038/s43016-021-00421-7

Gemenne, F. (2011). Why the numbers Don't Add up: A review of estimates and predictions of people displaced by environmental changes. *Global Environmental Change*, *21*(Suppl. 1), 41–49. https://doi.org/10.1016/j.gloenvcha.2011.09.005

Greiner, C., & Sakdapolrak, P. (2013). Rural-urban migration, Agrarian change, and the environment in Kenya: A critical review of the literature. *Population and Environment*, *34*(4), 524–553. https://doi.org/10.1007/s11111-012-0178-0

Gu, D. (2019). *Exposure and vulnerability to natural disasters for World's cities* (Tech. Pap. No. 2019/4). Population Division, United Nations Department of Economic and Social Affairs.

Hausfather, Z., & Forster, P. (2021). *Analysis: Do COP26 promises keep global warming below 2C? Carbon brief analysis*. Retrieved from https://www.carbonbrief.org/analysis-do-cop26-promises-keep-global-warming-below-2c

Henderson, J. V., Adam, S., & Uwe, D. (2017). Has climate change driven urbanization in Africa? *Journal of Development Economics*, *124*, 60–82. https://doi.org/10.1016/j.jdeveco.2016.09.001

Hirabayashi, Y., Mahendran, R., Koirala, S., Konoshima, L., Yamazaki, D., Watanabe, S., et al. (2013). Global flood risk under climate change. *Nature Climate Change*, *3*(9), 816–821. https://doi.org/10.1038/NCLIMATE1911

Hoffmann, R., Anna, D., Muttarak, R., Cuaresma, J. C., & Jonas, P. (2020). *A meta-analysis of country level studies on environmental change and migration | replication data and code*. Harvard Dataverse, V1. https://doi.org/10.7910/DVN/HYRXVV

Hoffmann, R., & Muttarak, R. (2015). *A tale of disaster experience in two countries: Does education promote disaster preparedness in the Philippines and Thailand*. Vienna Institute of Demography Working Papers No. 9/2015. Retrieved from https://www.econstor.eu/handle/10419/126222

Hoffmann, R., & Muttarak, R. (2021). *Environment, migration and urbanisation: Challenges and solutions for low- and middle-income countries*. T20 task force on migration policy brief. Retrieved from https://www.g20-insights.org/policy_area/youth-aging-population-migration/

Hoffmann, R., Šedová, B., & Vinke, K. (2021). Improving the evidence base on climate migration: Methodological insights from two meta-analyses. *Global Environmental Change*, *71*, 102367. https://doi.org/10.1016/j.gloenvcha.2021.102367

Hunter, L. M., Luna, J. K., & Norton, R. M. (2015). Environmental dimensions of migration. *Annual Review of Sociology*, *41*(1), 377–397. https://doi.org/10.1146/annurev-soc-073014-112223

Hynes, W., Lees, M., & Marco Müller, J. (2020). *Systemic thinking for policy making: The potential of systems analysis for addressing global policy challenges in the 21st century*. OECD Publishing.

IDMC. (2018). *City of flight—New and secondary displacements in Mogadishu, Somalia*. Internal Displacement Monitoring Centre. Retrieved from https://www.internal-displacement.org/publications/city-of-flight-new-and-secondary-displacements-in-mogadishu-somalia

IDMC. (2021a). *Assessing urban disaster displacement risk*. Internal Displacement Monitoring Centre. Retrieved from https://www.internal-displacement.org/publications/assessing-urban-disaster-displacement-risk

IDMC. (2021b). *Global internal displacement Database*. Internal Displacement Monitoring Centre. Retrieved from https://www.internal-displacement.org/database

IDMC. (2021c). *Global report on internal displacement 2021*. Internal Displacement Monitoring Centre.

ILO. (2021). *ILOSTAT Database*. International Labour Organization Statistical Database. Retrieved from https://ilostat.ilo.org/

IOM. (2021). *Migration, environment and climate change*. The International Organization for Migration. Retrieved from https://www.iom.int/migration-environment-and-climate-change-climate

IPCC. (2018). *Special report on global warming of 1.5°C. An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat*. Cambridge University Press.

IPCC. (2019). *Special report on climate change and land*. IPCC. https://doi.org/10.4337/9781784710644

IPCC. (2021). Climate change 2021: The physical science basis. In V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, et al. (Eds.), *Contribution of working group I to the sixth assessment report of the intergovernmental panel on climate change*. Cambridge University Press.

Ison, R. (2017). Systems practice: How to act. In *Situations of Uncertainty and complexity in a climate-change world*. Springer. https://doi.org/10.1007/978-1-4471-7351-9

James, R., & Washington, R. (2013). Changes in African temperature and precipitation associated with degrees of global warming. *Climatic Change*, *117*(4), 859–872. https://doi.org/10.1007/S10584-012-0581-7

Kerkhoffvan, L. (2014). Developing integrative research for sustainability science through a complexity principles-based approach. *Sustainability Science*, *9*(2), 143–155. https://doi.org/10.1007/S11625-013-0203-Y/FIGURES/3

King, A. D., & Harrington, L. J. (2018). The inequality of climate change from 1.5 to 2°C of global warming. *Geophysical Research Letters*, *45*, 5030–5033. https://doi.org/10.1029/2018GL078430

Kjellstrom, T. (2009). Climate change, direct heat exposure, health and well-being in low and Middle-Income countries. *Global Health Action*, *2*(1), 1958. https://doi.org/10.3402/gha.v2i0.1958

Knutson, T. R., McBride, J. L., Chan, J., Emanuel, J., Holland, G., & Landsea, C. (2010). Tropical cyclones and climate change. *Nature Geoscience*, *3*(3), 157–163. https://doi.org/10.1038/NGEO779

Knutti, R., Rogelj, J., Jan, S., & Fischer, E. M. (2016). A scientific critique of the two-degree climate change target. *Nature Geoscience*, *9*(1), 13–18. https://doi.org/10.1038/NGEO2595

Leichenko, R. M., O'Brien, K. L., & Soleck, W. D. (2010). Climate change and the global financial crisis: A case of double exposure. *Annals of the Association of American Geographers*, *100*(4), 963–972. https://doi.org/10.1080/00045608.2010.497340

Lemos, M. C. (2015). Usable climate knowledge for adaptive and co-managed water governance. *Current Opinion in Environmental Sustainability*, *12*, 48–52. https://doi.org/10.1016/J.COSUST.2014.09.005

Lutz, W., & Muttarak, R. (2017). Forecasting societies' adaptive capacities through a demographic metabolism model. *Nature Climate Change*, *7*(3), 177–184. https://doi.org/10.1038/nclimate3222

Lutz, W., & Qiang, R. (2002). Determinants of human population growth. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, *357*(1425), 1197–1210. https://doi.org/10.1098/RSTB.2002.1121

Mach, K. J., & Siders, A. R. (2021). Reframing strategic, managed retreat for transformative climate adaptation. *Science*, *372*(6548), 1294–1299. https://doi.org/10.1126/science.abh1894

Mirza, M. M. Q. (2003). Climate change and extreme weather events: Can developing countries adapt? *Climate Policy*, *3*(3), 233–248. https://doi.org/10.3763/cpol.2003.0330

Misselhorn, A. A. (2005). What drives food insecurity in Southern Africa? A meta-analysis of household economy studies. *Global Environmental Change*, *15*(1), 33–43. https://doi.org/10.1016/j.gloenvcha.2004.11.003

Müller, C., Waha, K., Bondeau, A., & Heinke, J. (2014). Hotspots of climate change impacts in sub-Saharan Africa and implications for adaptation and development. *Global Change Biology*, *20*, 2505–2517. https://doi.org/10.1111/gcb.12586

Muttarak, R. (2021). Demographic perspectives in research on global environmental change. *Population Studies*, *75*(S1), 77–104. https://doi.org/10.1080/00324728.2021.1988684

Nawrotzki, R. J., & DeWaard, J. (2018). Putting trapped populations into place: Climate change and inter-district migration flows in Zambia. *Regional Environmental Change*, *18*(2), 533–546. https://doi.org/10.1007/s10113-017-1224-3

Niva, V., Kallio, M., Muttarak, R., Taka, M., Varis, O., & Kummu, M. (2021). Global migration is driven by the complex interplay between environmental and social factors. *Environmental Research Letters*, *16*(11), 114019. https://doi.org/10.1088/1748-9326/ac2e86

Pantuliano, S., Metcalfe, V., Haysom, S., & Davey, E. (2012). Urban vulnerability and displacement: A review of current issues. *Disasters*, *36*(Supp. 1), S1–S22. https://doi.org/10.1111/j.1467-7717.2012.01282.x

Phillips, C. A., Caldas, A., Cleetus, R., Dahl, K. A., Declet-Barreto, J., Rachel Licker, L., et al. (2020). Compound climate risks in the COVID-19 pandemic. *Nature Climate Change*, *10*, 586–588. https://doi.org/10.1038/s41558-020-0804-2

Piguet, E. (2013). From 'Primitive migration' to 'climate Refugees': The curious fate of the natural environment in migration studies. *Annals of the Association of American Geographers*, *103*(1), 148–162. https://doi.org/10.1080/00045608.2012.696233

Piguet, E., Kaenzig, R., & Guélat, J. (2018). The uneven Geography of research on 'environmental migration. *Population and Environment*, *39*(4), 357–383. https://doi.org/10.1007/s11111-018-0296-4

Reckien, D., Creutzig, F., Fernandez, B., Lwasa, S., Tovar-Restrepo, M., Mcevoy, D., & Satterthwaite, D. (2017). Climate change, equity and the sustainable development goals: An urban perspective. *Environment and Urbanization*, *29*(1), 159–182. https://doi.org/10.1177/0956247816677778

Roberts, J. T. (2010). Global inequality and climate change. *Society and Natural Resources*, *14*(6), 501–509. https://doi.org/10.1080/08941920118490

Rohat, G., Flacke, J., Dosio, A., Dao, H., & Maarseveen, M. (2019). Projections of human exposure to dangerous heat in African cities under multiple socioeconomic and climate scenarios. *Earth's Future*, *7*(5), 528–546. https://doi.org/10.1029/2018EF001020

Sadiddin, A., Cattaneo, A., Cirillo, M., & Miller, M. (2019). Food insecurity as a determinant of International migration: Evidence from sub-Saharan Africa. *Food Security*, *11*(3), 515–530. https://doi.org/10.1007/s12571-019-00927-w

Schewe, J., Heinke, J., Gerten, D., Haddeland, I., Arnell, N. W., Clark, D. B., et al. (2014). Multimodel assessment of water scarcity under climate change. *Proceedings of the National Academy of Sciences of the United States of America*, *111*(9), 3245–3250. https://doi.org/10.1073/PNAS.1222460110

Schlenker, W., & Lobell, D. B. (2010). Robust negative impacts of climate change on African agriculture. *Environmental Research Letters*, *5*(1), 014010. https://doi.org/10.1088/1748-9326/5/1/014010

Schleussner, C. F., Lissner, T. K., Fischer, E. M., Jan, W., Perrette, M., Golly, A., et al. (2016). Differential climate impacts for policy-relevant limits to global warming: The case of 1.5°C and 2°C. *Earth System Dynamics*, *7*(2), 327–351. https://doi.org/10.5194/esd-7-327-2016

Šedová, B., Čizmaziová, L., & Cook, A. (2021). A meta-analysis of climate migration literature (CEPA Discussion Pap., 29). Center for Economic Policy Analysis.

Shepherd, A., Mitchell, T., Lewis, K., Lenhardt, A., Jones, L., Scott, L., & Muir-Wood, R. (2013). *The geography of poverty, disasters and climate extremes in 2030*. Retrieved from https://odi.org/en/publications/the-geography-of-poverty-disasters-and-climate-extremes-in-2030/

Shiferaw, B., Tesfaye, K., Kassie, M., Abate, T., Prasanna, B. M., & Menkir, A. (2014). Managing vulnerability to drought and enhancing livelihood resilience in sub-Saharan Africa: Technological, institutional and policy options. *Weather and Climate Extremes*, *3*, 67–79. https://doi.org/10.1016/j.wace.2014.04.004

Siders, A. R., Hino, M., & Mach, A. R. (2019). The case for strategic and managed climate retreat. *Science*, *365*(6455), 761–763. https://doi.org/10.1126/science.aax8346

Stavi, I., Paschalidou, A., Kyriazopoulos, A. P., Halbac-Cotoara-Zamfir, R., Siad, S. M., Suska-Malawska, M., et al. (2021). Multidimensional food security nexus in drylands under the slow onset effects of climate change. *Land*, *10*(12), 1350. https://doi.org/10.3390/land10121350

Stavi, I., Roque de Pinho, J., Paschalidou, A. K., Adamo, S. B., Galvin, K., de Sherbinin, A., et al. (2021). *Food security among dryland pastoralists and agropastoralists: The climate, land-use change, and population dynamics nexus*. The Anthropocene Review. https://doi.org/10.1177/20530196211007512

Storeygard, A., & Henderson, J. V., & Deichmann, U. (2014). *50 Years of urbanization in Africa: Examining the role of climate change. WPS 6925. Policy research working Paper*. World Bank Group. Retrieved from http://documents.worldbank.org/curated/en/2014/06/19679968/50-years-urbanization-africa-examining-role-climate-change

Tai, A. P. K., Martin, M. V., & Heald, C. L. (2014). Threat to future global food security from climate change and Ozone Air Pollution. *Nature Climate Change*, *4*(9), 817–821. https://doi.org/10.1038/NCLIMATE2317

Thalheimer, L., Otto, F., & Abele, S. (2021). Deciphering impacts and human responses to a changing climate in East Africa. *Frontiers in Climate*, *3*, 84. Doi https://doi.org/10.3389/FCLIM.2021.692114/BIBTEX

Thalheimer, L., & Simperingham, E., & Jjemba, W. E. (2022). The role of anticipatory humanitarian action to reduce disaster displacement. *Environmental Research Letters*, *17*(1), 014043. https://doi.org/10.1088/1748-9326/ac4292

Thalheimer, L., Williams, D. S., Geest, K., & Otto, F. E. L. (2021). Advancing the evidence base of future warming impacts on human mobility in African drylands. *Earth's Future*, *9*, e2020EF001958. https://doi.org/10.1029/2020EF001958

Tol, R. S. J. (2018). The economic impacts of climate change. *Review of Environmental Economics and Policy*, *12*(1), 4–25. https://doi.org/10.1093/reep/rex027

UN. (2019). *World population prospects 2019*. Department of Economic and Social Affairs.

UN Department of Economic and Social Affairs. (2019). *World urbanization prospects: The 2018 Revision*. Department of Economic and Social Affairs. https://doi.org/10.18356/b9e995fe-en

UNEP. (2011). *Livelihood security: Climate change, migration and conflict in the Sahel*. UNEP.

UNICEF. (2021). *Water security for all*. UNICEF. Retrieved from https://www.unicef.org/reports/reimagining-wash-water-security-for-all

United Nations. (2019). *World urbanization prospects: The 2018 Revision*. United Nations Department of Economic and Social Affairs, Population Division. Retrieved from https://population.un.org/wup/

van der Geest, K. (2011). North-south migration in Ghana: What role for the environment? *International Migration*, *49*(Suppl.1), e69–e94. https://doi.org/10.1111/j.1468-2435.2010.00645.x

Vinke, K., Bergmann, J., Blocher, J., Upadhyay, H., & Hoffmann, R. (2020). Migration as adaptation? *Migration Studies*, *8*(4), 626–634. https://doi.org/10.1093/migration/mnaa029

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 and Development*, *6*, 1–17. https://doi.org/10.1080/17565529.2013.835707

Warner, K., Afifi, T., Walter, K., Scott, L., Ferris, B., Martin, S. F., & Wrathall, D. J. (2013). *Changing climate, moving people: Framing migration, displacement and planned relocation*. Retrieved from https://migration.unu.edu/publications/policy-briefs/changing-climate-moving-people-framing-migration-displacement-and-planned-relocation.html

Warner, K., & van der Geest, K. (2013). Loss and damage from climate change: Local-level evidence from nine vulnerable countries. *International Journal of Global Warming*, *5*(4), 367–386. https://doi.org/10.1504/IJGW.2013.057289

Warner, K., van der Geest, K., Kreft, S., Huq, S., Harmeling, S., Kusters, K., & De Sherbinin, A. (2012). *Evidence from the Frontlines of climate change: Loss and damage to communities despite coping and adaptation* (Policy report, Rep. No. 9). Retrieved from http://lib.riskreductionafrica.org/bitstream/handle/123456789/716/

Wiederkehr, C., Beckmann, M., & Hermans, K. (2018). Environmental change, adaptation strategies and the relevance of migration in sub-Saharan drylands. *Environmental Research Letters*, *13*(11), 113003. https://doi.org/10.1088/1748-9326/aae6de

Wittmayer, J. M., & Schäpke, N. (2014). Action, research and participation: Roles of researchers in sustainability Transitions. *Sustainability Science*, *9*(4), 483–496. https://doi.org/10.1007/S11625-014-0258-4/FIGURES/1

WMO. (2021). *State of the climate in Africa 2020*. WMO. Retrieved from https://library.wmo.int/index.php?lvl=notice_display&id=21973#.Ya43Yboo82w

Xu, C., Kohler, T. A., Lenton, T. M., Svenning, J. C., & Scheffer, M. (2020). Future of the human climate niche. *Proceedings of the National Academy of Sciences of the United States of America*, *117*(21), 1–6. https://doi.org/10.1073/pnas.1910114117

Zickgraf, C. (2019). Keeping people in place: Political factors of (im)mobility and climate change. *Social Sciences*, *8*(8), 1–17. https://doi.org/10.3390/socsci8080228