Global Centre for Climate Mobility

Africa Climate Mobility Initiative
Shaping the future of mobility

# AFRICAN SHIFTS

## The Africa Climate Mobility Report: Addressing Climate-Forced Migration & Displacement

A REPORT BY THE AFRICA CLIMATE MOBILITY INITIATIVE

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# ABOUT THE ACMI

MISSION

# The ACMI supports the emergence of a new policy ecosystem on climate mobility

The Africa Climate Mobility Initiative (ACMI) is a collaboration between the African Union Commission, the United Nations Development Programme (UNDP), the UN Framework Convention on Climate Change (UNFCCC), the International Organization for Migration (IOM), and the World Bank. It aims to generate political momentum and a common policy agenda on climate mobility in Africa, and to support implementation capacity and partnerships on the continent. Over a two-year period, the ACMI developed research and modelling studies, and conducted extensive consultations with African and international experts and practitioners to arrive at a shared analysis and recommendations for action for addressing climate-forced migration and displacement, and to form a Community of Practice dedicated to advancing solutions for harnessing climate mobility in the continent.

Bringing together diverse actors and stakeholders from the realms of migration and displacement, development, and climate policy and practice, the ACMI seeks to support the emergence of a new policy ecosystem on climate mobility. It aims to foster a common understanding and integrated action across sectors to advance the implementation of relevant global and regional frameworks. These include the Agenda 2063, the Sustainable Development Goals, the UN Framework Convention on Climate Change's Paris Agreement[1], the Global Compact for Safe, Orderly and Regular Migration, and the African Union's three-year implementation plan for Africa[2].

The *African Shifts* report starts with the ground-level realities of how people experience climate vulnerability, and how it affects mobility decisions in Africa today. It then lays out plausible scenarios for how climate mobility might unfold on the continent between now and 2050, and which parts of the continent are likely to be particularly affected. It concludes by presenting an eight-point Agenda for Action for the next eight years, aligning with the Decade for Action to achieve the 2030 Sustainable Development Goals and the Paris Agreement.

The ACMI's work builds on and contributes to the growing body of research and evidence on climate mobility globally and in Africa. This includes the World Bank's *Groundswell* reports that have used a similar modelling approach to forecast future climate-driven movements on the continent. The Report also draws on recent research on African migration and displacement such as UNDP's *Scaling Fences* report that documented the profiles and motivations of African migrants in Europe, and the 2020 *Africa Migration Report* which discussed diverse migration dynamics and highlighted the need for 'a new paradigm on African migration'.


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1&1

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# ACRONYMS

| | |
|---|---|
| **ACMI** | Africa Climate Mobility Initiative |
| **AR5** | Fifth Assessment Report by the Intergovernmental Panel on Climate Change |
| **AR6** | Sixth Assessment Report by the Intergovernmental Panel on Climate Change |
| **AU** | African Union Commission |
| **CIESIN** | Center for International Earth Science Information Network of Columbia University |
| **COP** | Conference of Parties (of the UNFCCC) |
| **CRD** | Climate-resilient development |
| **EAC** | EAC |
| **ECOWAS** | Economic Commission of West African States |
| **ENSO** | El Niño Southern Oscillation |
| **FAO** | Food and Agriculture Organization |
| **GBW** | Great Blue Wall Initiative |
| **GCCM** | Global Centre for Climate Mobility |
| **GCM** | Global climate model |
| **GCR** | Global Compact on Refugees |
| **GDP** | Gross domestic product |
| **GHG** | Greenhouse gas |
| **HDI** | Human development index |
| **ITCZ** | Intertropical Convergence Zone |
| **IDPs** | Internally displaced persons |
| **IDMC** | Internal Displacement Monitoring Centre |
| **IGAD** | Intergovernmental Authority on Development |
| **IMF** | International Monetary Fund |
| **IOM** | International Organization for Migration |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **ISIMIP** | Inter-Sectoral Impact Model Intercomparison Project |
| **KNOMAD** | Global Knowledge Partnership on Migration and Development |
| **MMC** | Mixed Migration Centre |
| **NAP** | National Adaptation Plan |
| **NAPA** | National Adaptation Programme of Action |
| **NCAR-CIDR** | National Center for Atmospheric Research-CUNY Institute for Demographic Research |
| **NDC** | Nationally Determined Contribution |
| **OECD** | Organisation for Economic Co-operation and Development |
| **PIK** | Potsdam Institute for Climate Impact Research |
| **RCP** | Representative Concentration Pathway |
| **SADC** | Southern African Development Community |
| **SDG** | Sustainable Development Goal |
| **SIDS** | Small Island Developing States |
| **SSP** | Shared Socioeconomic Pathway |
| **TAG** | Technical Advisory Group |
| **UCESA** | Union of Economic and Social Councils of Africa |
| **UMA** | African Maghreb Union |
| **UN** | United Nations |
| **UNDP** | United Nations Development Programme |
| **UN DESA** | United Nations Department of Economic and Social Affairs |
| **UNFCCC** | United Nations Framework Convention on Climate Change |
| **UNHCR** | Office of the United Nations High Commissioner for Refugees |
| **UNISDR** | United Nations Office for Disaster Risk Reduction |
| **USD** | United States Dollar |
| **WMO** | World Meteorological Organization |

# EXECUTIVE SUMMARY

# The African Shifts report documents the current realities of climate-forced migration in Africa and possible scenarios for future climate displacement

1 Africa is one of the most climate-vulnerable regions in the world. The continent's share in historic greenhouse gas emissions is minimal, less than 3 percent of the global total. While Africa has much to contribute to climate action, its marginal contribution to GHG emissions means that it has little to contribute towards global efforts of decarbonize in the near-term. Yet, Africa faces an urgent climate adaptation challenge to reduce the vulnerability and strengthen the resilience of its people, communities, and institutions amidst the climate crisis.

2 Key development sectors across Africa have already experienced widespread losses and damages due to climate change, including biodiversity loss, water shortages, decreasing food production, loss of lives, and reduced economic growth. The current trajectory in global emissions leads to increasingly severe extreme heat, drought, flooding and coastal erosion, which will undermine livelihoods and make parts of the continent less habitable in the coming decades. Deteriorating living conditions will eventually force people to abandon areas where climate impacts are no longer tolerable.

3 If unplanned and poorly managed, such movements risk adding stress in already fragile places, potentially heightening tensions around land and water resources. Sudden and large population shifts affecting African cities could undermine planning efforts and social cohesion. Yet, a potentially worse outcome would see people stranded in place as a result of poverty, age, disability, or legal barriers, leaving them highly exposed and vulnerable to increasingly hazardous climatic conditions.

4 The *African Shifts* report documents the current realities of climate-forced migration in Africa and possible scenarios for future climate displacement. It makes the case for integrating advance planning for climate mobility into Africa's strategies for climate change adaptation and climate-resilient development, including countries' Nationally Determined Contributions (NDCs) and National Adaptation Plans (NAPs) in the context of the UNFCCC process. It also provides research, data, and projections to inform anticipatory actions, policy planning and political cooperation in support of locally anchored solutions for adaptation and resilience in affected communities. To that end, and guided by the three core tenets — Plan, Empower and Transform — it recommends an Agenda for Action with eight key actions for the next eight years (2023 to 2030), in line with the Decade for Action to achieve the 2030 Sustainable Development Goals and the Paris Agreement.

5 By preparing its people and institutions and investing in resilience, Africa can harness climate mobility to help communities and countries adapt and prevent loss and damage from climate change. Harnessing climate mobility could also prove a unique opportunity to consolidate regional integration, drive development under more severe climatic conditions, and further common growth on the continent.

6 The Africa Climate Mobility Initiative (ACMI) is a partnership between the African Union Commission, the World Bank, and the United Nations that aims to address climate-forced migration and displacement in Africa, and harness climate mobility for the continent's collective resilience and development. As the basis for this report, the ACMI worked with partners to undertake a desk review of the existing climate mobility literature and field research in seven communities affected by climate hazards across the continent, and to model possible future scenarios for climate mobility in Africa. In addition, the ACMI conducted nine months of consultations with African and international experts and practitioners to analyse the research and modelling findings and develop directions for action.

ADDRESSING CLIMATE MOBILITY

# Africa can harness climate mobility to help communities and countries adapt

E.1

# Research Findings: Attitudes to Climate Change and Mobility Today

# There is a widespread lack of knowledge about the connections between climate change and its impacts on livelihoods

**7** For people facing climate stressors across the continent, climate mobility is likely to be a response of last resort. Most Africans are attached to their land and homes and don't aspire to leave their communities. Half of the men and 40 percent of the women surveyed expressed hope and optimism for the future, despite experiencing severe climate disruptions.

**8** For those who have relocated or consider moving, climate stressors are usually not the primary reason. Climate impacts generally act alongside other drivers such as the search for education and job opportunities, access to livelihoods and social services, and the draw of family ties. Two out of every five African youth consulted, some 40 percent, considered mobility normal. Almost one in five had concrete plans to move.

**9** That said, there is a widespread lack of knowledge about the connections between climate change and its impacts on livelihoods. Current coping responses are therefore unlikely to prove sustainable. People are deciding to stay or move without adequate information on the risks of remaining in place or those associated with relocation.

**10** For those compelled to move due to climate impacts, relocation is often too costly. As a result, people remain in place at the risk of being forced to evacuate in worse circumstances or becoming stranded. Many people forcibly displaced by extreme and sudden climate shocks return home, as their livelihoods depend on their places of origin. Others settle in new locations where they remain vulnerable and exposed to climate risks. Hence, unplanned climate mobility can result in new risks and vulnerabilities.

E.2

# Modelling Results: A Future of Increasing Climate Mobility

# By 2050, up to 5 percent of Africa's population of some 2 billion people could be on the move due to climate impacts, up from 1.5 percent today

**11** More severe climate disruptions, combined with Africa's growing population, are forecast to propel increased movement in the coming decades. By 2050, up to 5 percent of Africa's population of some 2 billion people could be on the move due to climate impacts, up from 1.5 percent today. The overwhelming majority of this movement will happen within countries rather than across borders.

**12** The ACMI modelled four possible scenarios for future climate mobility in Africa. The first set of scenarios assumes a low emissions future in line with the Paris Agreement goals, combined with two different possible development trajectories, an inequitable versus inclusive development future. The second set of scenarios assumes a continuation of the current trajectory of high emissions based on the currently limited progress on the necessary rapid reduction of green house gas emissions in the near term. These are combined with the same two possible development futures. In light of rising emissions despite the Paris Agreement, the report prioritised the high emissions scenarios to discuss likely future climate mobility projections for the continent.

**13** Under a high emissions and inequitable development scenario (Rocky Road), internal climate mobility within countries could reach up to 113 million people by mid-century. A high emissions and inclusive development scenario (High Road) could see up to 95 million people forced to move by 2050. The most affected region will be the Intergovernmental Authority for Development (IGAD) region, where up to 10.5 percent of the population — or up to 55 million people — could be on the move by 2050 under the Rocky Road scenario.

**14** Hotspot areas of climate mobility, where a high concentration of in- and out-mobility will take place, emerge across the continent. People are predicted to move towards areas where climate conditions are forecast to be relatively better. Borderlands emerge as climate mobility hotspots, such as between Niger and Nigeria, around Lake Victoria, and in the Horn of Africa.

15 Rural areas will see famers leaving rain-fed lowlands as well as big population shifts in pastoral lands. At the high end, pastoral areas in Rwanda could see around 3 million people leave due to adverse climate impacts. Meanwhile, the population in Ethiopia's pasturelands could grow by 279,000 people by 2050 due to climate mobility.

16 Along the coasts, sea level rise and flooding will force people to move out of low-lying areas, despite the opportunities they currently provide. Coastal areas around Africa could lose up to 2.5 million people by 2050 due to steady sea level rise, flooding, and other climate stressors. Under the High Road scenario, inclusive development choices that reduce vulnerability and build climate resilience seem to offset these climate impacts, enabling people to stay in their home communities.

17 Africa's cities will be dynamic hotspots of climate mobility. Cities will continue to grow swiftly, although, on a continental scale, climate impacts could force up to 4.2 million people out of urban areas by 2050. Casablanca, Accra, and Abidjan are among the cities projected to see people leave due to climate impacts. In most small African cities and towns, climate mobility will add to population growth. Khartoum, Maputo, Goma, Tripoli, and Kigali also emerge as important climate mobility destinations on the continent.

18 Cross-border climate mobility is forecast to reach a maximum of 1.2 million people by 2050 under the High Road scenario. Climate mobility may contribute up to 10 percent of cross-border migration by 2050. Most cross-border movement will be in Southern Africa, where mobility between neighbouring countries is forecast to increase due to favourable climate impacts on crop yields that could enable people to undertake longer journeys.

19 Despite a challenging climate outlook, Africa can mitigate some of the negative effects on its populations by adopting an inclusive development pathway, including investments in social protection, climate information services and literacy, and sustainable urbanisation. The modelling results suggest that scaling this form of development will significantly reduce the number of people compelled to move due to climate disruptions.

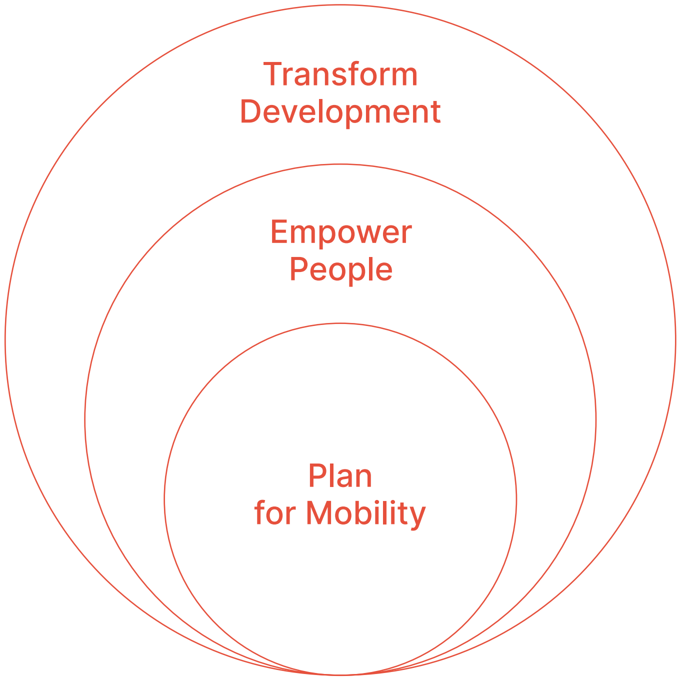
E.3

# Recommendations for Action: Plan, Empower and Transform

# Addressing climate mobility as an engine of climate adaptation and resilience-building on the continent

**20** The Africa Climate Mobility Agenda for Action is built on three key tenets that can guide African policymakers, stakeholders, and international partners in addressing climate mobility as an engine of climate adaptation and resilience-building on the continent.

**21** Addressing climate mobility begins with understanding its spatial dynamics and the affected communities. Starting with the forecasted hotspot areas allows for deeper analysis, local engagement, and anticipatory actions for adaptation and resilience.



## Plan for Mobility

22 Planning for climate mobility and anticipating adaptation needs will help African communities cope with climate shocks, reduce vulnerability, and prevent loss and damage.

23 Climate mobility on the continent will be predominantly internal, putting adaptation and development actions at the forefront of supporting affected communities and the people who move. Recognising and supporting mobility as a legitimate coping and adaptation strategy will allow communities to remain rooted in place, while pursuing new livelihood and income opportunities.

24 Many African households already have members spread out in various locations, not only to mitigate climate and other risks, but also to take advantage of opportunities in different places. By embracing this 'multilocality' and the new connections forged between people and places, Africa can fortify its climate resilience, advance its long-held ambitions for political and economic integration, and reap transformative development gains.

25 To support mobility as an adaptive strategy, adaptation actions must be locally-anchored, context-specific, and informed by community priorities. At the same time, they can create shared benefits and prevent negative side effects across communities and localities. By planning for climate mobility, governments at all levels can prevent maladaptive outcomes.

26 Laws and policies on migration, refugees, and displacement have a part to play in addressing climate mobility in the continent. They can facilitate the movement of people across borders and ensure the protection of those who are forcibly displaced due to climate shocks. Africa is well positioned to use its existing institutions and forward-leaning legal frameworks, including the Organisation of African Unity (OAU) Refugee Convention and the Kampala Convention, as well as free movement agreements, to find cooperative climate mobility solutions.

27 IGAD member states are leading the way by recently ratifying the Protocol on Free Movement in the IGAD region, which provides for the entry of persons 'in anticipation of, during or in the aftermath of disaster' (Article 16). It also calls on its members to facilitate the stay of IGAD citizens when their country of origin remains impacted by disaster and return is not possible. These provisions could inform ongoing discussions within other regional economic communities on ways to protect their citizens amidst the climate crisis.

## Empower People

28 Climate effects do not occur in a vacuum. Discrimination and marginalisation undermine people's ability to cope with climate risks, including their capacity to move. Responses to climate mobility must be embedded in existing efforts to advance rights and support disadvantaged groups.

29 When confronting climate shocks, women can be held back by social norms, traditions, and institutions that limit their autonomy and agency, including their property rights, financial access, climate literacy, and adaptation options. These constraints also limit their agency in mobility decisions. This can enhance their vulnerability to climate risks and lead to unplanned or forced movements, increasing the risk of negative outcomes. Targeted actions are needed to ease the climate adaptation burden for women. This should include equal access to rights, expanded social protection, and improved climate services, especially for women farmers.

30 By mid-century, more than half of Africa's population will be younger than 25. Young Africans have high aspirations to improve their living conditions. As climate risks increase and communities seek to cope, young people are typically the first to move in search of livelihood opportunities. Investing in green skills and jobs for youth will advance the wider societal effort for climate adaptation and for a green and just transition.

31 When addressing climate mobility, adaptation strategies must account for the specific vulnerabilities and adaptive capacities of different groups, including women, youth, and disadvantaged communities. Participatory governance and transparent decision-making will prove to be an important factor in ensuring effective and successful adaptation. This is particularly important when decisions about adaptation measures concern already disenfranchised populations, particularly those in the informal sector.

## Transform Development

32 As the world confronts the climate crisis and works towards delivering the Sustainable Development Goals, a new consensus is needed. To deliver on existing promises and ensure no one is left behind, adaptation and development efforts must merge to advance common goals and approaches, and forge a new paradigm of climate-resilient development.

33 Africa will be essential to achieve this promise. Africa needs inclusive development to cope with and adapt to increasingly severe climate impacts. Yet, with every increase in global warming, the costs of adaptation will grow, threatening to divert much-needed resources from development investments. Africa's natural resources have fuelled growth around the world and will be critical for transitioning to a new, low-carbon future. However, going forward, it is the continent's people, and their hopes and aspirations, that must be at the centre not only of policy making in Africa but also its relations with the world. Investing in the continent's human capital will yield the workforce, ideas, innovations, and solutions needed to achieve the green transition and build climate-resilient economies. To be people-centred, climate-resilient development must have an African fingerprint.

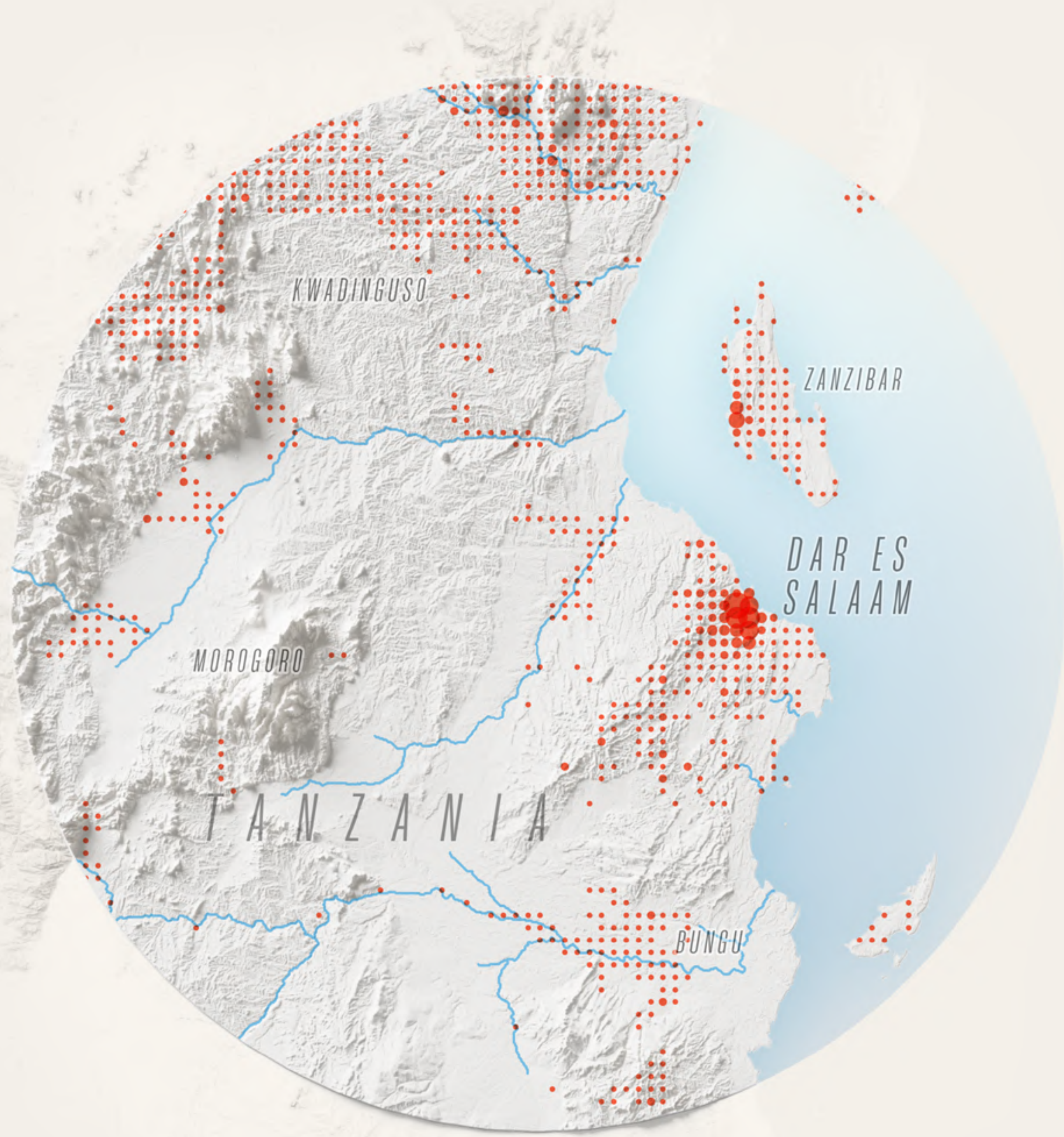
34 Climate-resilient development that is people-centred must honour people's 'right to remain' by protecting, and investing in, the places they call home. To be protective, investments must be risk informed and anticipatory, considering how actions and impacts in one place might affect another. Shared resources such as river basins open communities and countries up to transboundary climate risks, but also create the potential for common benefits. Climate mobility alters the landscape of connections between people and places, and will create increasingly strong rural-urban ties.

35 Through joint planning and stewardship of shared resources, such connections can be harnessed for greater collective resilience. While pursuing a place-based and locally anchored approach, climate-resilient development must embrace mobility and connectivity to foster resilience.

# 122k

About 8% of Dar es Salaam lies within the low-elevation coastal zone. This will make a significant part of the growing population in the city exposed to flood events and sea level rise. Improving risk predictions and understanding coastal risks will help the 122 thousand people projected to move out of Dar es Salaam by 2050 plan and adapt to climate change.

**DAR ES SALAAM, TANZANIA**




**People leaving**

Expected number of people leaving their home due to climate change by 2050 under the Rocky Road scenario (30 - 15k people)

Read more about sea level rise risks in Dar es Salaam and other coastal cities in section 3.5.

E.4

# Deadline 2030: Eight Actions for the Next Eight Years

36 Guided by the three outlined tenets, the Agenda for Action presents eight key actions for the next eight years (2023 to 2030), in line with the Decade for Action to achieve the 2030 Sustainable Development Goals and the climate action goals under the Paris Agreement. The Agenda for Action also outlines concrete measures to advance each of the eight Actions. It calls on African leaders across sectors and levels of governance, stakeholders, and international partners to:

## Plan for Mobility

ACTION 1

### ANTICIPATE AND PLAN FOR CLIMATE MOBILITY

Anticipate and plan for climate-forced displacement and migration, including permanent relocation, to foster social cohesion in affected communities, prevent immobility, drive economic growth, sustain peace, and protect people on the move.

ACTION 2

### INTEGRATE CLIMATE MOBILITY IN CLIMATE ADAPTATION AND FINANCE COMMITMENTS

Recognise and support mobility as a legitimate strategy for climate adaptation at local, national, regional and international levels, and build cross-sector partnerships to support people and communities in staying, moving and receiving.

## Empower People

ACTION 3

### INFORM PEOPLE OF CLIMATE RISKS

Enhance public understanding of climate risks and threats — including through building climate change literacy, the co-production of actionable climate information services and access to early warnings — in order to support informed decisions on how to adapt, whether and when to move, and where to settle.

ACTION 4

### AMPLIFY WOMEN'S AGENCY

Empower women with climate information, adaptive skills, social and legal protection to bolster their agency in decisions on climate adaptation and in climate mobility.

ACTION 5

### HARNESS THE AMBITIONS OF THE YOUTH

Foster and leverage the creativity and potential of Africa's already-mobile youth to build resilience and economic prosperity, and to advance the green transition.

## Transform Development

ACTION 6

# BUILD FROM THE LOCAL

Pursue community-led solutions for climate-resilient development, disaster response and climate mobility across the continent, and invest in locally anchored climate adaptation and resilience pathways, including strong connections in border areas.

ACTION 7

# INVEST IN RESILIENT AND CONNECTED CITIES

Enable cities with actionable data, resources and agency to facilitate planned, resilient and inclusive urban growth, social inclusion and social protection, while building stronger ties across cities and with rural areas and economies.

ACTION 8

# PURSUE NATURE-POSITIVE DEVELOPMENT

Manage land, water and other shared natural resources cooperatively and sustainably to support agricultural and ecosystem-based livelihoods and boost productivity, while reducing the environmental impact and harnessing ecosystems and biodiversity protection for economic development and climate resilience.

The ACMI will work to build coalitions of champions to drive progress on each of these eight actions and the measures needed to advance them. It will continue to nurture the climate mobility policy ecosystem on the continent to drive the development and exchange of knowledge, scaling of good practices, and joint advocacy by affected communities.

By bringing different actors together and forging collective action, the Global Centre for Climate Mobility (GCCM) will galvanise a people-centred, locally led, and integrated approach to migration governance, climate action, and climate-resilient development in support of the ACMI. To this end, the GCCM will advance four Flagship Programmes focusing on:

1. Climate Literacy for Stronger Agency
2. Green Skills for Inclusive Transition
3. Water Solutions for Resilient Communities
4. Data and Knowledge for Local Impact

ADDRESSING CLIMATE MOBILITY

# The GCCM will galvanise a people-centred, locally led, and integrated approach to migration governance, climate action, and climate-resilient development

# OVERVIEW & APPROACH

The climate has changed. Climate impacts that were once remote are now a present-day reality, arriving ahead of schedule and experienced by people in every region of the world. The enormous costs of climate change, the loss and damage from its impacts, and its potential for increasing human suffering are becoming apparent.

By mid-century, population growth projections suggest a quarter of the world's inhabitants will be African[3]. Nigeria, Africa's most populous country, has a median age of 18[3]. That means that many of the Africans alive today may live to see the late decades of this century[4]. Climate scenarios that seem distant today will be their reality tomorrow. Global projections suggest that a child born in 2020 will experience significantly more extreme climate events across their lifetime than someone born in 1960[5,6]. On average, they will be exposed to twice as many wildfires, 2.8 times more crop failures, 2.6 times as many drought events, 2.8 times as many river floods, and 6.8 times more heatwaves[5,6]. Given high levels of vulnerability, Africa will be more affected by climate change than wealthier countries and regions and those in higher latitudes[7–10].

In many regions of Africa, temperatures have increased at twice the speed of the global average due to human-caused climate change[7,11,12]. Over the past two decades, 337 million people were affected by natural disasters[7]. Africa reported over 46,000 deaths from natural disasters in this period, 32 percent of which were from floods, and 46 percent from droughts. Weather-related disasters caused new displacements of over 2.6 million people in 2018, and 3.4 million people in 2019[7]. Climate change has increased heat waves and drought on land, and doubled the probability of marine heatwaves around most of the continent[7]. By some estimates, African countries' Gross Domestic Product per capita is on average 13.6 percent lower since 1991 than if human-caused global warming had not occurred[7,13]. Thus, the African continent faces one of the most challenging futures in terms of the scale and pace at which it must adapt to a changing climate[7].

Increase in global warming and the impacts from drought and flooding are projected to shrink the optimal climate niche for human habitation on the continent[7,14]. The United Nations' Intergovernmental Panel on Climate Change (IPCC) projects that between 1.5°C and 2°C global warming, negative impacts will be widespread and severe with reduced food production, reduced economic growth, increased inequality and poverty, biodiversity loss, and increased human morbidity and mortality[7]. The largest increase in exposure to extreme heat is projected to be in Africa[15].

The above evidence and trends all point toward a substantial influence of climate change on climate-forced displacement and migration in Africa. They set the context for the urgent need for Africa to adapt and make climate resilience a cornerstone of its development trajectory.

As climate change is making many lives across the continent more difficult, helping people and communities use mobility as a way to adapt may be the best strategy for supporting their resilience. Indeed, human mobility is already a distinguishing characteristic of Africa's livelihood systems, and fundamental to the continent's prosperity[16,17]. It is central to the livelihoods of communities who practice smallholder agriculture or pastoralism, or those who have a foot in both rural and urban economies[18]. Africa's regional economic blocs encourage the free movement of goods and people to varying degrees. In 2015, the African Union set out a vision for economic and political integration across the continent through free mobility[19]. In practice, barriers to cross-border migration within the continent remain. Yet, everyday mobility across borders and between rural and urban areas is common, enabled by social and family ties between communities that cross colonial and political boundaries[20,21]. Many Africans experience mobility as a recurring and normal part of their lives[20,22], rather than a once-off binary decision between migration and immobility.

This report examines how growing climate risk is affecting human mobility in Africa. The report builds on two years of modelling, field research and consultations with African and international experts, practitioners and stakeholders. It highlights the actual experience of climate vulnerability in the African continent and proposes future scenarios that project how many people might be forced to move in which locations, and where they might go. This is informed by two research projects:

1. Desk review of the existing literature, and primary data collection that focuses on people's decisions to move, or not to move, in locations already affected by climate hazards, carried out by the Mixed Migration Centre.
2. Modelling of how climate impacts affect the future population distribution in the continent as far as 2050, undertaken by Columbia University in collaboration with several expert institutions.

The modelling was built on the recent work conducted by the World Bank for its *Groundswell* reports (see Table 1). Where appropriate, the Africa Climate Mobility Report synthesises the findings from these empirical and modelling studies with the recent findings of the IPCC Sixth Assessment Report and the broader scientific, policy and practice literature on climate mobility (see Table 2).

The findings and recommendations for action presented here were informed by extensive consultations with 547 entities over a nine-month period. The ACMI convened 19 workshops with African and international experts and practitioners to analyse the findings of the research and modelling and jointly identify priorities for action. It also convened dedicated consultations with African youth and cities, as well as the Union of Economic and Social Councils of Africa (UCESA). The report's policy recommendations were further honed through a workshop on 'Prevention and Protection' organised with the IOM and further bilateral expert consultations. The Consultations process concluded with the ACMI Stakeholders Forum in July 2022, bringing together the entire Community of Practice that has emerged from and will be further built through the ACMI process, including dedicated forums for Youth, Women, Cities, Knowledge and Partnerships (see Appendix A4).

ADDRESSING CLIMATE MOBILITY

## The report builds on two years of modelling, field research and consultations with African and international experts, practitioners and stakeholders

1.1

# Climate as a driver of human mobility

Mobility is key to people's ability to cope with and adapt to increasingly severe climate impacts. Historically, millions of individuals, households, and whole tribes have used moving as a coping strategy to deal with climatic events and stressors. This is particularly true for those whose livelihoods depend heavily on natural resources that have been affected by climate factors, such as farmers and pastoralists.

For the purposes of this effort, climate mobility refers to the movement of people that is motivated by the adverse effects of sudden- or slow-onset climate impacts. It occurs both within and across national borders and involves different levels of constraints, agency, and vulnerability, encompassing both forced displacement and migration, including planned relocation. Climate mobility occurs over different distances and can be temporary, recurrent, or permanent.

In most cases, climate impacts are not the only or main reason for people's decisions to move. Usually climate drivers act together with other factors, such as the search for income and livelihoods, economic or educational opportunities, family ties, or political and personal freedoms[23·24]. Even in the context of climate stressors, some people may move because they value migration for intrinsic reasons: they may have a wanderlust, a curiosity, or an innate desire to explore new horizons[25]. For others, climate mobility is a question of survival as they move to escape immediate climate-induced harms.

# Not everyone wants to or can move when climatic conditions get worse.

Generally, sudden- versus slow-onset climate events are associated with different movement patterns. For example, people forced to evacuate because of a cyclone or flood have tended to move temporarily and then return once the event has passed. Slower but lasting changes, such as coastal erosion, may force whole villages to relocate permanently. In many cases, the climate impacts on human mobility will be more indirect. For instance, changing or extreme weather patterns may act in concert with unsustainable land use practices, which erode agricultural productivity and livelihoods and lead some people to move[26]. Mobility patterns often follow established pathways or corridors, tracking social networks that help reduce the costs and uncertainties associated with relocating. These relationships can help by providing information, such as knowledge about labour market conditions in destination areas, or by giving someone a place to land[27–30·123].

Climate mobility is a form of risk management and can be a successful response to climate change[31]. The IPCC Sixth Assessment Report recognises migration as an important adaptation response to climate risks. Successful adaptation can be enhanced by a household's improved financial security: if a family member finds a job in an area away from climate impacts and can send money home, this may increase the family's income and improve the household's overall situation[31]. But migration may not always increase resilience for everyone, particularly for those facing barriers to movement[7·32]. There is a potential for maladaptation — the unanticipated negative consequences of responses — where climate mobility does not reduce vulnerability but in fact creates new risks[33–35] for those who move and the communities at origin and destination.

Not everyone can or wants to move when climatic conditions get worse. Climate impacts do not affect everyone equally as persons' capabilities vary widely, depending on the level of income, savings, education, livelihood, health, and many other factors[25·36–39]. Similarly, access to migratory resources tends to be unequally distributed within and across communities and societies[25]. Moving can be capital-intensive. It requires financial means and social connections. Repeated climate impacts can erode people's assets and capital, and relocation may be seen as a last-resort option. There is a risk that vulnerable populations could become stranded as a result of being too poor, old, or sick to migrate[28]. This risk is particularly high for those whose livelihoods are already fragile because of climate disruption, such as farmers and herders who are dependent on predictable cycles of rainfall and grazing[28].

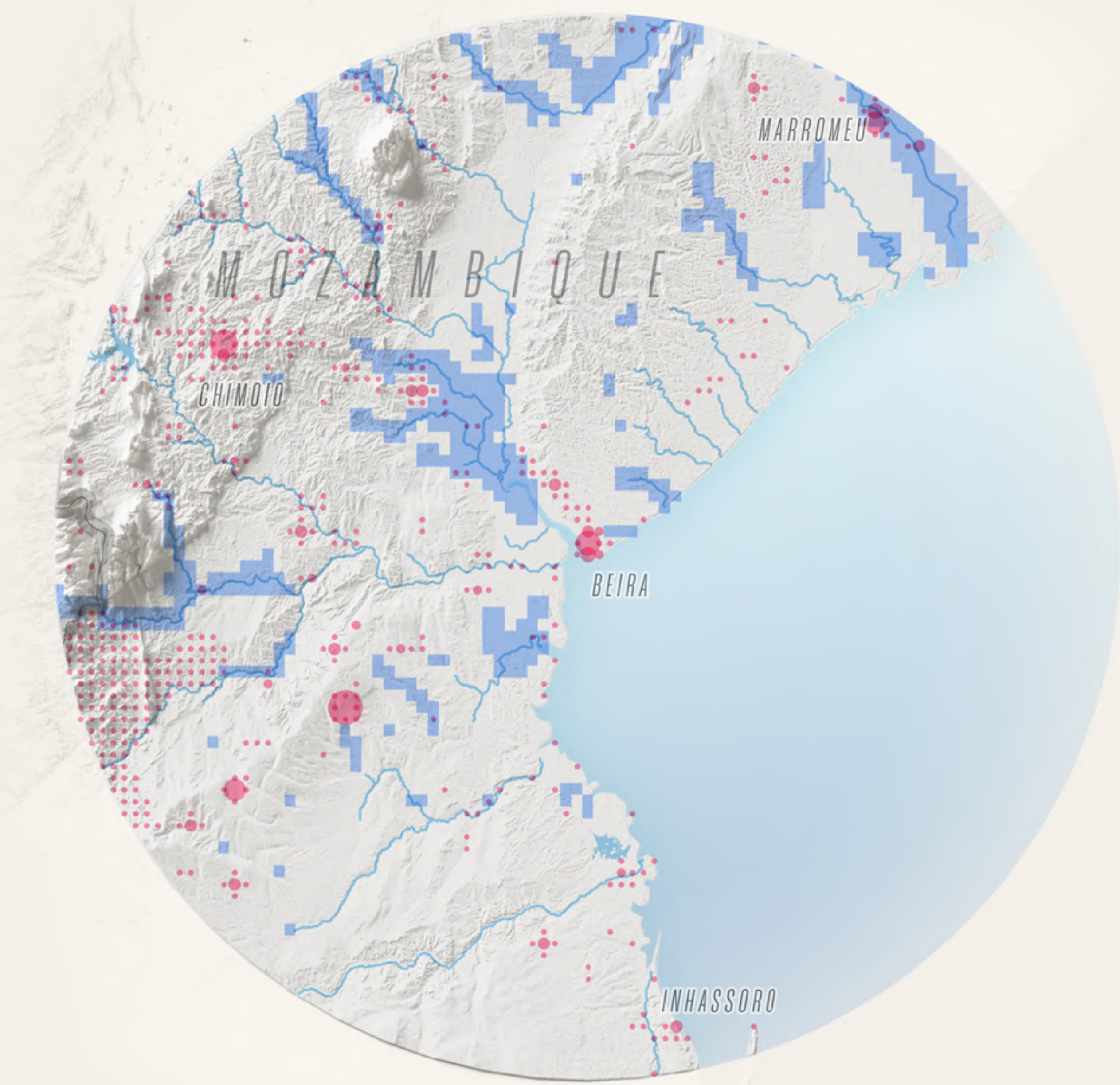
Some people choose not to move and prefer to stay in places despite high risks. This is often because they feel rooted and have a deep attachment to the land and local ecosystem[33·40]. People's perceptions of a 'good life' and their life aspirations vary across different social and cultural contexts[25·36·39]. These aspirations are also not fixed: they change as people mature in their journey through life, and as societies change around them[41–43]. People's life aspirations and perceptions of opportunities are subjective. Because of this they may or may not develop a desire to move. It is unrealistic to assume that social groups in different contexts or cultures will develop similar aspirations and migration tendencies when exposed to a similar set of external factors or stimuli, the 'push' and 'pull' factors driving migration choices[25].

When people are able to have an active choice in their mobility decisions in response to climate variability, they are said to have agency. This is true whether they stay in a home community or choose to move. Agency means having decision-making power that goes beyond the physical act of moving itself[25·44].

# 483k

At risk of cyclones and floods, climate adaptation will be crucial for the 483 thousand people who will continue to call Beira home by 2050. The generalized hope for a better future will contribute to the preparedness of those in Beira and cities across Africa.

**BEIRA, MOZAMBIQUE**




**Population**
Projected population by 2050 under the Rocky Road scenario (500 – 275k inhabitants)

**Flood risk**
Areas at risk of floods by 2050

Read more about climate risks perceptions from Beira's population in Section 2.2.

# PRESENT
# REALITIES

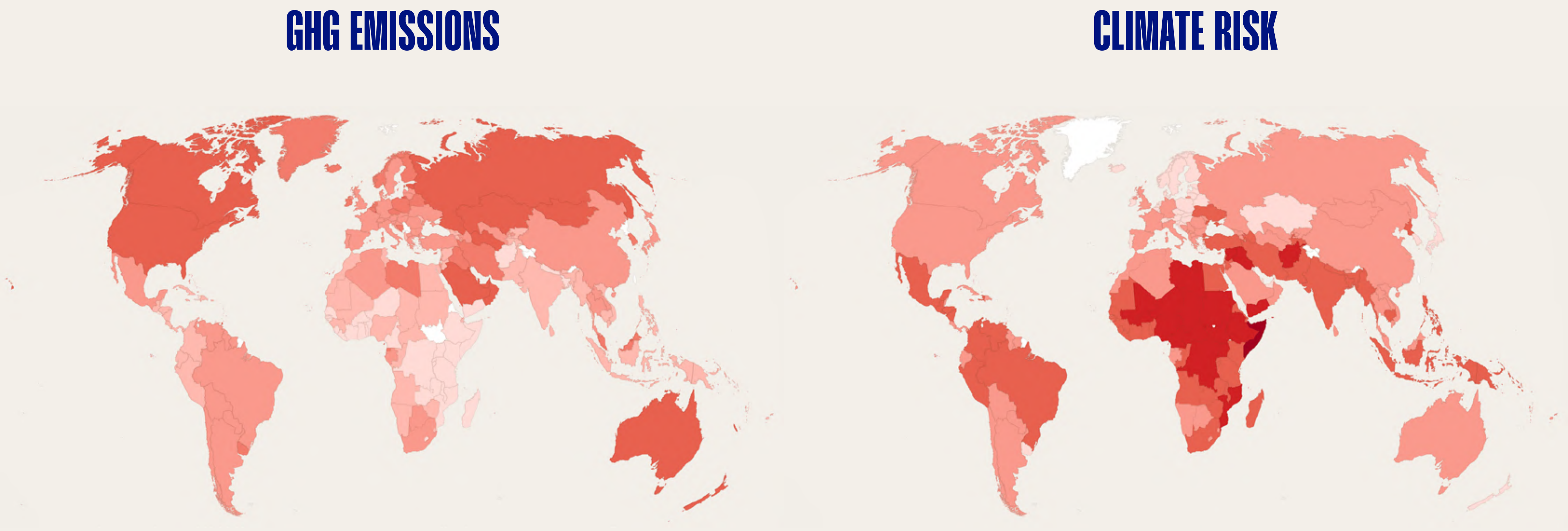
The African continent is among the most climate-vulnerable regions in the world. Over one third of all countries with high to very high exposure to climate hazards are in Africa[45]. Africa also has the highest proportion of countries with high to very high vulnerability to climate change[45], driven by underlying factors such as extreme poverty, and challenges related to access to basic infrastructure, adult literacy, health care, gender equality, governance, high dependency ratios, food insecurity and health status when compared with other regions[10·46] (Figure 1). As a result, Africa and Africans have already been heavily impacted by the climate crisis.

These dimensions of vulnerability are important to climate mobility. For example, under conditions of extreme poverty, economic losses undermine household resources needed to migrate[33·47]. Poorer households have limited access to resources such as savings, credit, irrigation technologies and insurance, which can lead to larger crop and other income losses from climate hazards, preventing investments to improve resilience to future climate shocks[7·10·48].

↓ **Figure 1**
Countries with largest current and projected risk from climate change, including non-climatic factors, are generally located in Africa. Vulnerability to climate change in Africa, a major contributor to its risk profile, is included in the INFORM Risk Index where climate risk scores are normalised between 1–10 in 2050 under SSP3 (low and inequitable development scenario), darker shades of red indicate higher vulnerability and risk. INFORM Risk Index is a global indicator-based disaster risk assessment tool that combines hazards, exposure, vulnerability and response capacity indicators with the purpose to support humanitarian crisis management decisions considering the current climate and population[45·46].

Figure 1

## Global climate change risks




**Greenhouse Gas Emissions tCO2eq/capita**

0–2 | 2–5 | 5–10 | 10–15 | >15 | Unknown

**Climate risk scores**

Very low | Very high | Unknown

Source: IPCC 6th Report, WGII, Chapter 9; INFORM Risk scores normalized between 1 to 10 in 2050 under SSP3 scenario. INFORM Risk Index combines climate hazards, exposure, vulnerability and response capacity indicators.

Against this backdrop, the ACMI sought to better understand how people presently perceive climate stressors affecting their lives, and how these shape their thoughts about moving. The ACMI and the Mixed Migration Centre (MMC) collected primary data through surveys and interviews in seven climate mobility hotspots across the continent:

1. Cahama, a peri-urban borderland in Cunene, Angola
2. Nchalo, on the peri-urban edge in Chikwawa, Malawi
3. Ajegunle, in the urban coastal delta in Lagos, Nigeria
4. Praia Nova, in the urban coastal delta in Beira, Mozambique
5. Tatki, in the rural borderland of Podor, Senegal
6. Nadunget, in Moroto, the rural borderland of Karamoja, in Uganda
7. Al Max, in the urban coastal delta in Alexandria, Egypt

Researchers chose these seven locations in order to explore a range of geographies in Africa which already experience moderate to severe climate-related events. These areas include urban and rural settings, and a variety of livelihoods and cultures. All sites are known to have experienced extreme and hazardous climate-linked events such as floods, drought, landslides, sea level rise and storm surge, and storms. At most of these sites, these events are also known to be increasing in frequency and intensity because of the influence of climate change. Across the study locations displacement or migration is already happening and is assessed to be caused, at least in part, by the effects of climate change (Figure 2).

In six of the locations, researchers gathered information from over 100 households using a survey, as well as focus group discussions and follow-up interviews. For the Senegal case study, only focus group discussions and interviews were conducted (see Appendix A.3). The survey captured primary data on:

- Participants' profile and household
- Satisfaction with living conditions
- Experience of mobility
- Aspirations around mobility, and how these might drive their decisions
- Perception and impact of climate-related events
- Use of coping and adaptation strategies
- Any links between climate impacts and movement
- Expectations for the future

These seven case studies ↗ provide a localised understanding of climate mobility and immobility in the context of rainfall variability and decline, sea level rise, drought, river and coastal flooding, and cyclones. The findings from these case studies contextualise and support the future projections of climate mobility derived from the modelling effort and complement the existing understanding of climate mobility that is found in the broader literature.

Figure 2

## ACMI case studies across seven locations in Africa affected by climate variability and extremes

2.1

# Living in Hope: Africans tend to remain optimistic, even as they experience the reality of the climate crisis

Africa has seen a steady warming trend (Figure 3). With every fraction of a degree of increased global heating, the risk of more severe and frequent climate hazards will increase[7·8·12·32]. These include more severe and widespread droughts, cyclones, heavy rains, and floods[7·8], as well as increased magnitude of extreme heat conditions up to a level that is lethal to both humans and livestock[7].

Limiting global warming to 1.5°C will protect against damage to Africa's economies, agriculture, human health, and ecosystems[7].Yet, the continent has contributed only 2 to 3 percent of the world's total historic emissions[7·51]. As a result, Africa does not have much leverage over ongoing global efforts to reduce carbon emissions. It can, however, reduce its vulnerability by committing to strengthening the resilience and adaptive capacity of its people, communities, and institutions.

Across Africa, communities express faith in a better future despite the hardships they are currently experiencing. Chikwawa in Malawi and Moroto in Uganda are two examples where communities are already being severely impacted by adverse climate conditions and have highly negative perceptions about their current situations. Yet people still expressed faith that their conditions will improve and that they can contribute to their improvement.

In Chikwawa, Malawi, livelihoods are closely tied to land and to rain-fed agriculture. This creates a strong negative correlation between the communities' wellbeing and climate-related events. Women note how difficult their lives have become and that 'farming has become useless'. Overall, respondents to the field research undertaken for this report indicated they were not satisfied with their lives, and 46 percent said they were currently worse off than they were five years ago. Over the last 10 years, this area had been repeatedly impacted by severe floods and droughts, as well as tropical cyclones, including Cyclones Idai and Kenneth in 2019. In addition, the area witnessed diseases affecting crops and livestock, land degradation, unpredictable rainfall, and extreme temperatures. Coping responses included working longer hours and reducing food consumption.

Still, most respondents were not considering moving. Of those who did consider it, almost half felt that they had no choice to move. Respondents indicated that flood damage and loss of income due to failed livelihoods were the main reasons that motivated relocations from the area. Yet, despite their dissatisfaction, and their expectation that environmental conditions would get worse, slightly more than half of those surveyed still said they expected to be better off in the next five years. The level of optimism for their own situation and household is high, with only 15 percent thinking the future would be worse for them.

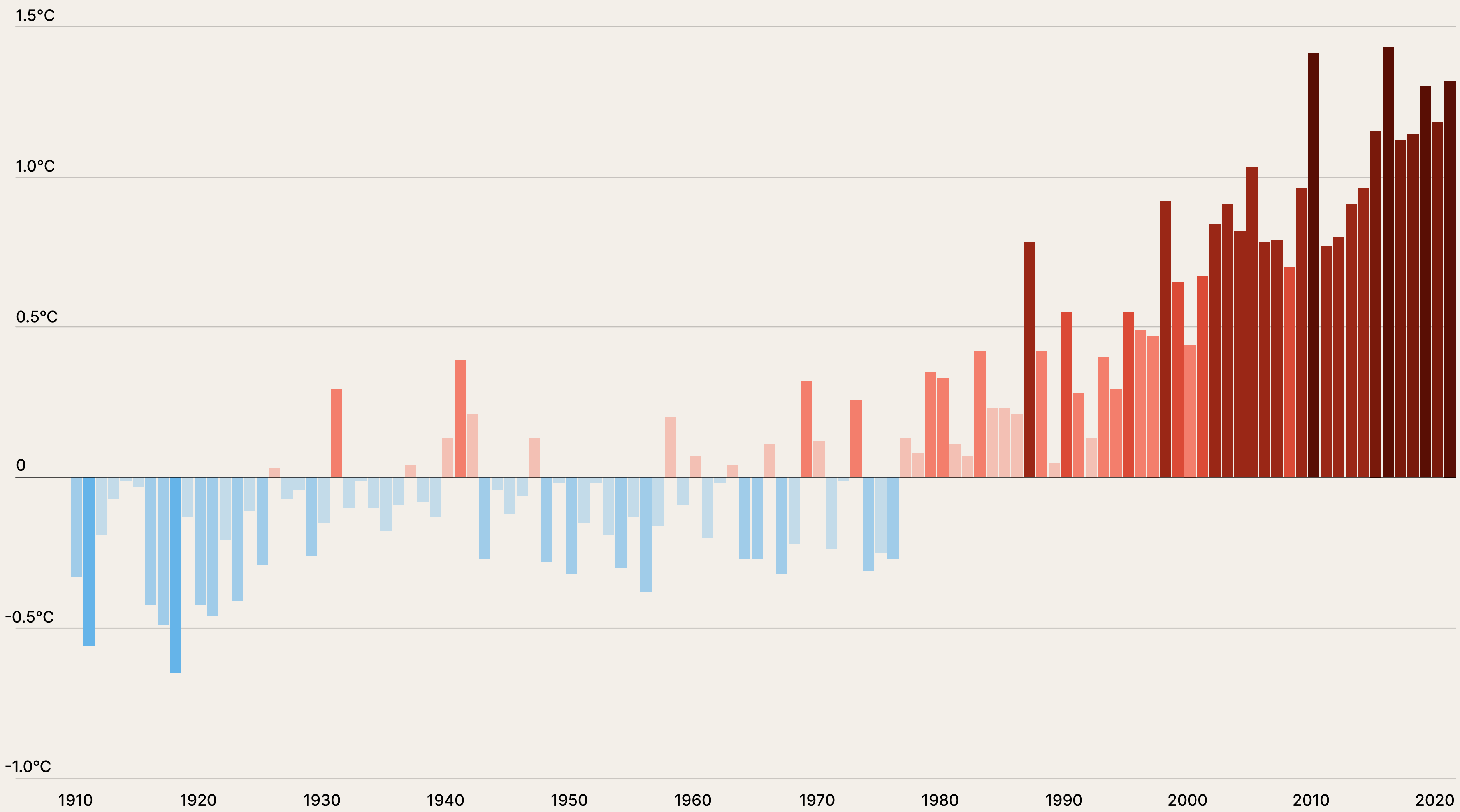
In Moroto, Karamoja, in north-eastern Uganda, traditional pastoral livelihoods are well adapted to the dry and unpredictable climate. However, the growing trend towards settled farming practices and dependence on agriculture has made these communities more vulnerable to rainfall variability, extreme temperatures, and dry spells, all of which have been increasing in frequency and intensity with climate change. Climate-related impacts also include a lack of pasture, low harvest yields, water scarcity, and increased disease and locusts. The severity of these impacts was indicated by the increased number of starvation-related deaths in the community in 2016 and 2018, with some participants expressing beliefs that the land was 'cursed'.

These findings extend those of the Afrobarometer which found that across 34 countries in Africa, about 50 percent of ordinary Africans say climate conditions for agricultural production have become worse in their region over the past decade[52]. By region, East Africans (63 percent) are almost twice as likely as North Africans (35 percent) to say climate conditions for agriculture have worsened[52].

↓ **Figure 3**
Africa has seen a steady trend of escalating warming across the continent, particularly since 1975[49]. Temperature change in Africa since 1901 indicates the recent heating trend above the average from 1971 to 2000, as seen since the mid-1970s[50], updated to the end of 2021. The average temperature from 1971 to 2000 is set as the boundary between the blue and red colours[7·11·12].

Figure 3

## Temperature increase for Africa




Source: NASA Goddard Institute for Space Studies.

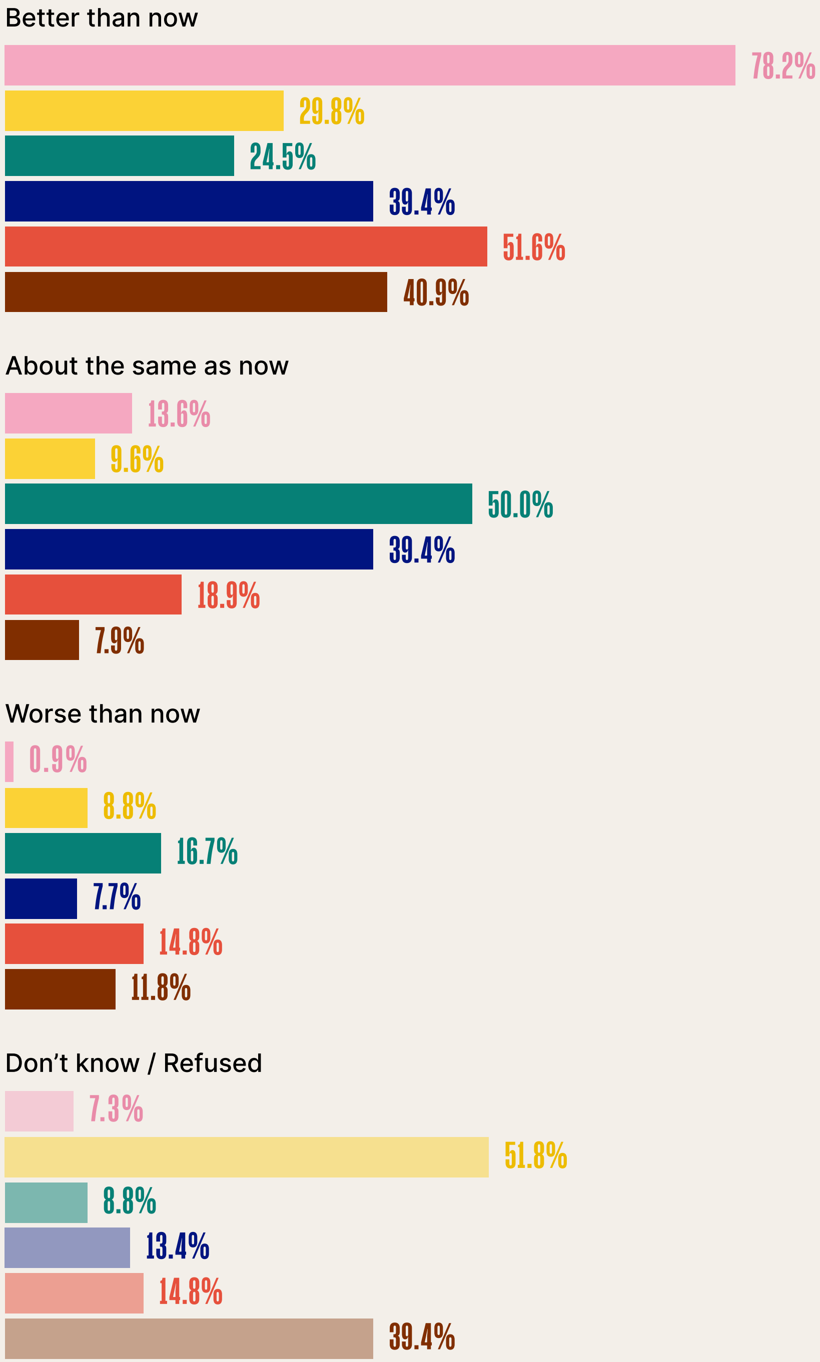
Despite a very low level of satisfaction with their situation, many people in Moroto expressed optimism that things would improve on all fronts in the future. They generally have positive expectations regarding drought and rainfall for the upcoming five years. Around 35 percent of people thought conditions would be a bit or much improved, a third felt the situation would be the same, while only 16 percent thought drought conditions would get much worse. A quarter of people said they could make small or big changes that would improve their conditions in the next five years. Almost 40 percent felt they would improve their lives in the next five years, and only 8 percent felt their situation would be worse.

This hope for a better future despite all odds is a critical resource as the continent searches for innovative ways to cope with accelerating climate risks and seeks to build community resilience in coming decades.

Figure 4A

# Confidence in improved conditions by location

Across Africa, the majority of people feel that their household will be able to provide for its members in the next 5 years.




**Question**
How do you think your household will be able to provide for its members in the next 5 years?
*We will likely be...*

**Percentage of respondents per country and category**


Source: ACMI Survey data, 2022. Over 100 households surveyed.

Figure 4B

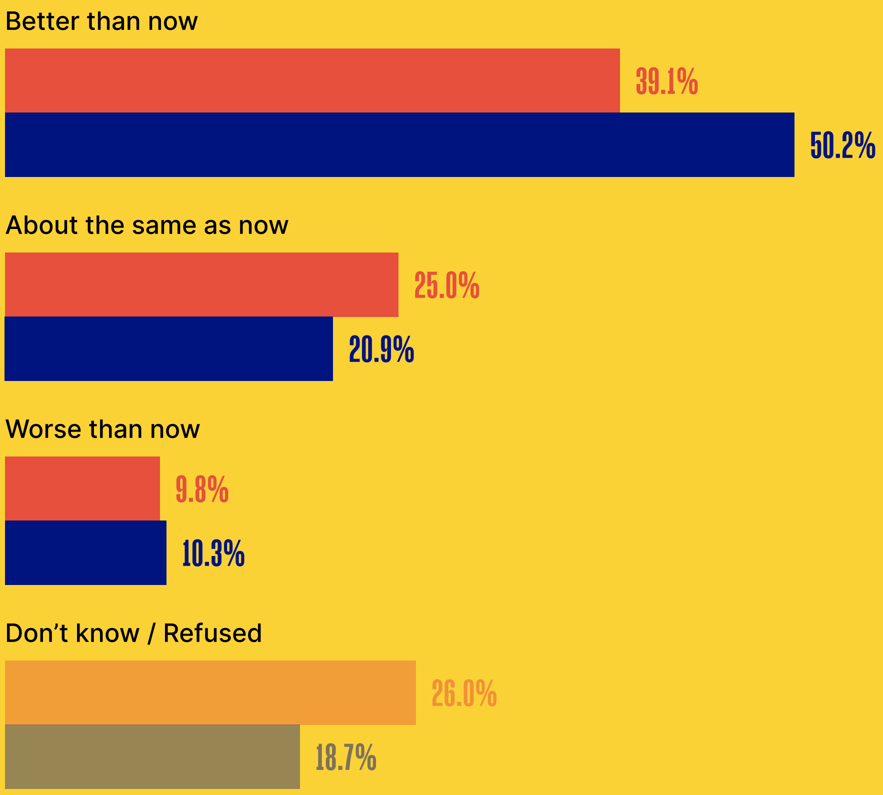
## Confidence in improved conditions by gender

Despite the negative impacts from climate disruptions, people throughout the continent feel hopeful about their future, although men indicated higher confidence in improved conditions.

**Question**
How do you think your household will be able to provide for its members in the next 5 years?
*We will likely be...*

**Percentage of respondents per gender and category**

Women
Men

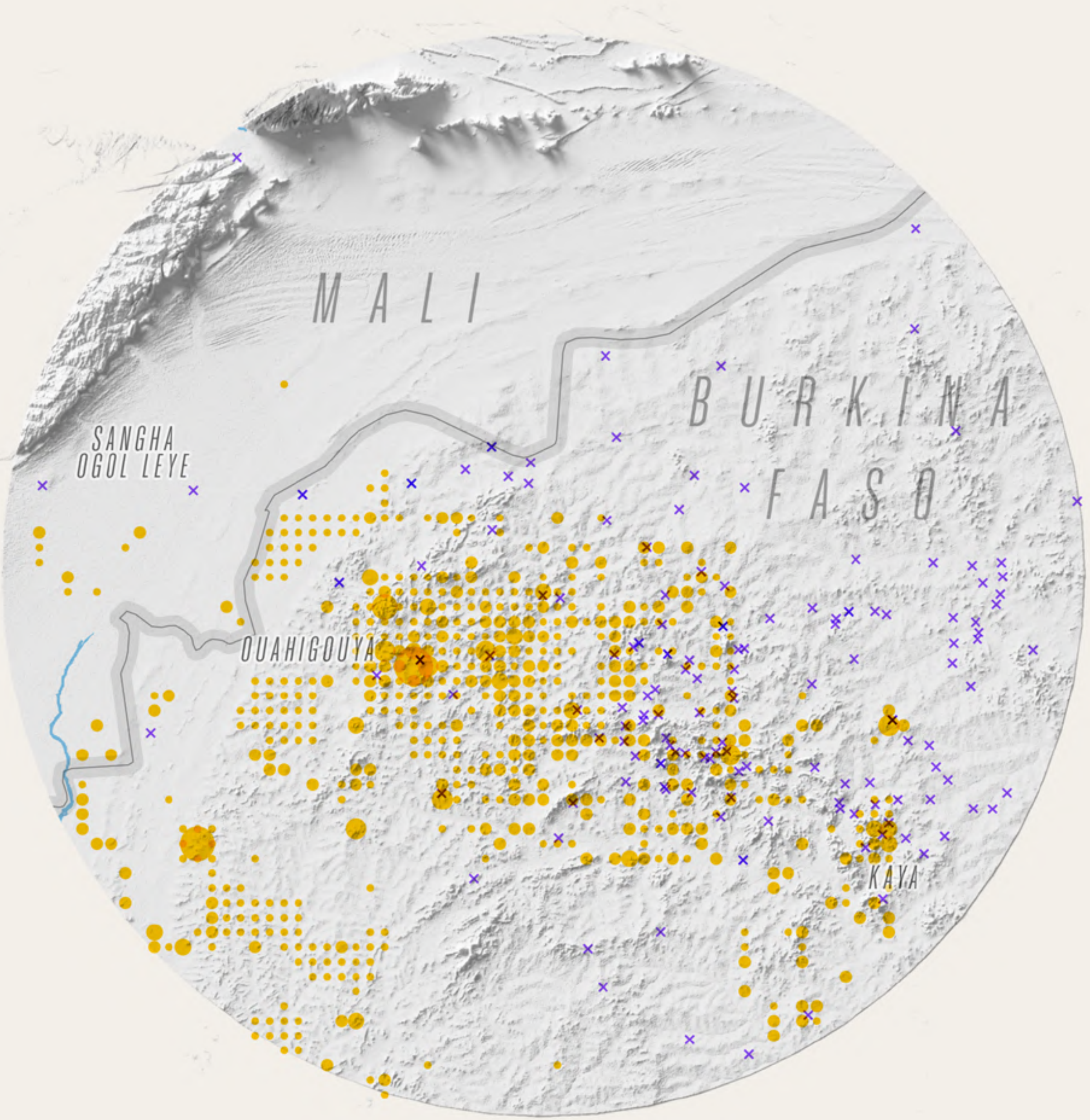



Source: ACMI Survey data, 2022. Based on survey from 6 locations in Africa. Over 100 households surveyed per location.

# 54k

Ensuring that women are not left behind after 54 thousand people may leave Ouahigouya (Burkina Faso) and other climate mobility hotspots that today host refugee camps will be a priority to reduce their vulnerability. Strategies to reduce women's vulnerability will help those who remain and those who will seek reduced climate risks elsewhere.

**OUAHIGOUYA, BURKINA FASO**




**People leaving**

Expected number of people leaving their home due to climate change by 2050 (50 – 10k people)

**Refugee camps**

Internally displaced people and refugee camps (UNHCR)

### 2.1.1
## Closing the climate information gap could help people adapt

Many Africans clearly experience the impacts of climate change in their daily lives, without always having knowledge of its human causes and its increasing effect on risk[53·54]. In Europe, where climate change literacy is high, over 80 percent of people have heard about climate change and understand that human activity is wholly or partly causing it[53]. However, Africa has a big divide in climate literacy rates, within same countries and even across communities. The national climate change literacy rate ranges from just 23 to 66 percent of the population across 33 African countries, while for the rest there is no data (Figure 5)[55].

At a minimum, climate change literacy means being aware of climate change and its human causes. A climate literate person can assess and use scientifically credible information about climate change and communicate about climate and climate change in a meaningful way. They are also able to make informed decisions about actions that may affect the climate or help better adapt to changes in the climate. Together with climate services, climate change literacy can strengthen responses to climate change through a better understanding of future risk[7·55].

Comparing sub-national administrative units across Africa, of the 394 sub-national regions surveyed, 8 percent (37 regions in 16 countries) have a climate change literacy rate lower than 20 percent, while only 2 percent (8 regions) score higher than 80 percent (Figure 5)[55]. There are striking differences when comparing sub-national units within countries. For example, rates in Nigeria range from 71 percent in Kwara, to 5 percent in Kano. In Botswana, 69 percent in Lobatse are climate literate, while only 6 percent in Kweneng West understand the issue[55].

Greater climate literacy and access to actionable climate information can increase people's sense of agency[7·17·55]. Of those who have heard of climate change, 7 in 10 people say that it needs to be stopped, and more than half believe that ordinary people can at least do a little bit to help[52]. Education and access to public or private motorised transport are strong positive predictors of climate change literacy across the continent[55]. Lack of access to transport networks is associated with lower climate change literacy. Equally, those living in poverty are less climate literate. Rural areas tend to have lower climate change literacy rates, which implies that climate mobility in these regions is less likely to be informed by an understanding of climate change risk[55]. Those who reported having gone without basic needs met during the preceding year — not having enough food, water, medical care, cooking fuel, or a cash income — were significantly less likely to be climate change literate. At a country level, climate change literacy rates are on average 12.8 percent lower for women than for men[55].

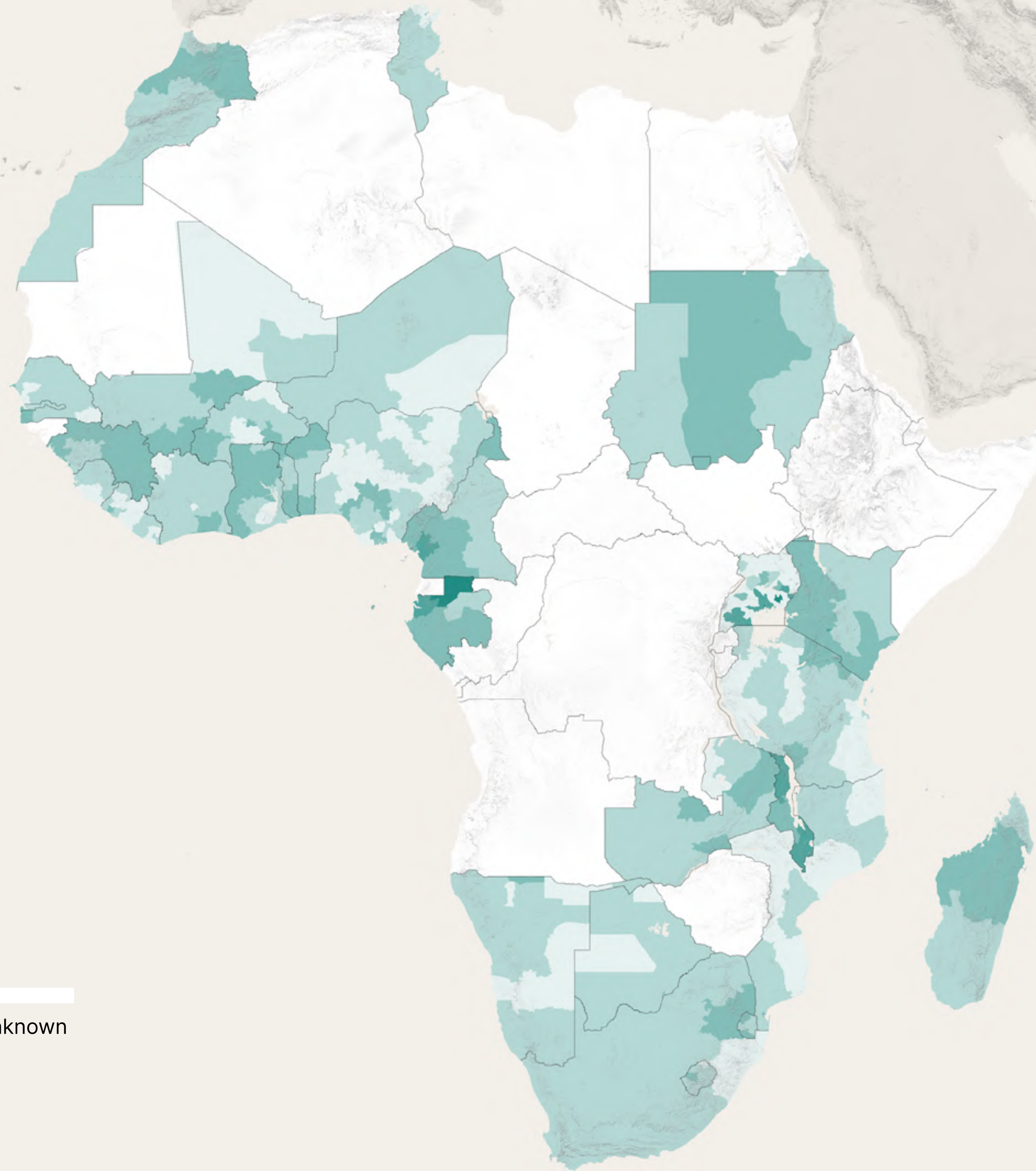
> Greater climate literacy and access to actionable climate information can increase people's sense of agency

Low levels of climate literacy across Africa are likely to affect people's decision-making in relation to mobility, and thereby their vulnerability to climate change, whether they stay or move. This connection between understanding climate risks and climate mobility is important because planned movements tend to have more positive outcomes than forced or reactive movements. Advance-planning gives people the time to prepare, collect information and gather resources. However, a lack of awareness of the progressive nature and localised impacts of climate risks can lead to inaction, or coping responses that are reactive rather than anticipatory, and which will fall short of appropriate adaptation[7·55].

Figure 5

## Sub-national climate change literacy rates in Africa

Percentage of survey respondents at the sub-national level who are climate change literate (that is, the percentage of the population that has heard about climate change and understands that human activity is wholly or partly the cause of climate change) for 33 African countries[55]. Raising climate change literacy rates at the continent level will contribute to safer and more informed personal choices when addressing climate risks.



**Climate change literacy rates per region**

0–20% 20–40% 40–60% 60–80% 80–100% Unknown

Source: Simpson *et al.*, 2021.

2.2

# Rooted in Land & Culture: Many Africans want to stay where they live, despite growing climate risks

Most of the climate-vulnerable populations sampled for this study do not show any preference for moving, particularly to distant areas. Across the seven ACMI case studies, the vast majority of people stay in their home communities, whether voluntarily or involuntarily. For instance, in Moroto, Uganda, where living conditions are extremely precarious due to prolonged drought, 78 percent of respondents indicated they were still not considering moving, and only 12 percent mentioned that someone in their household had moved away in the past. More than a quarter of those interviewed said it was 'totally exceptional and unexpected that someone moves', indicating strong social and cultural attachments that tie people and the land together. Worsening climatic conditions do not generally prompt people to consider moving to places where conditions may or may not be better. Across locations, those with assets and transferable skills were more likely to make conscious decisions to move.

The communities surveyed understood successful adaptation as finding a way to stay where they live. Moving is a last resort measure after all other efforts to adapt have been exhausted. Most people said they expected to find place-based solutions to adapt to climate change (Figure 6). By far the most common coping response to climate impacts is to work longer hours, followed by efforts to maximise income generation. Coping with climate change in this way may not be possible in the long term, however, given the likely escalation of future risk as temperatures continue to rise. In settings where the future or current livelihood is bleak, working longer hours is unlikely to be sustainable in the medium to long term. In certain cases, this is applicable even in the short term.

Survey respondents gave various reasons for wanting to stay where they live. Some said they lacked the resources to move. Yet for many, attachment to place is a strong motivator to stay, more so than resources[56]. Some also expressed concerns regarding the risks and uncertainties of moving away, noting that they lacked opportunities elsewhere, such as access to land or jobs. Still, many are optimistic that their households will do better in the future. Their sense of urgency or need to move depends very much on their subjective assessment of living conditions, and the opportunities and risks of moving away. These insights confirm studies elsewhere on the continent that have found that people generally have a strong sense of belonging to their local community[56–58]. People stay because their livelihoods and culture are tied to the land and the local ecosystem. They also highlight the importance of connectedness of climate change and land use, biodiversity, heritage, and ecosystem-based adaptation as important factors to consider when supporting people who choose to stay.

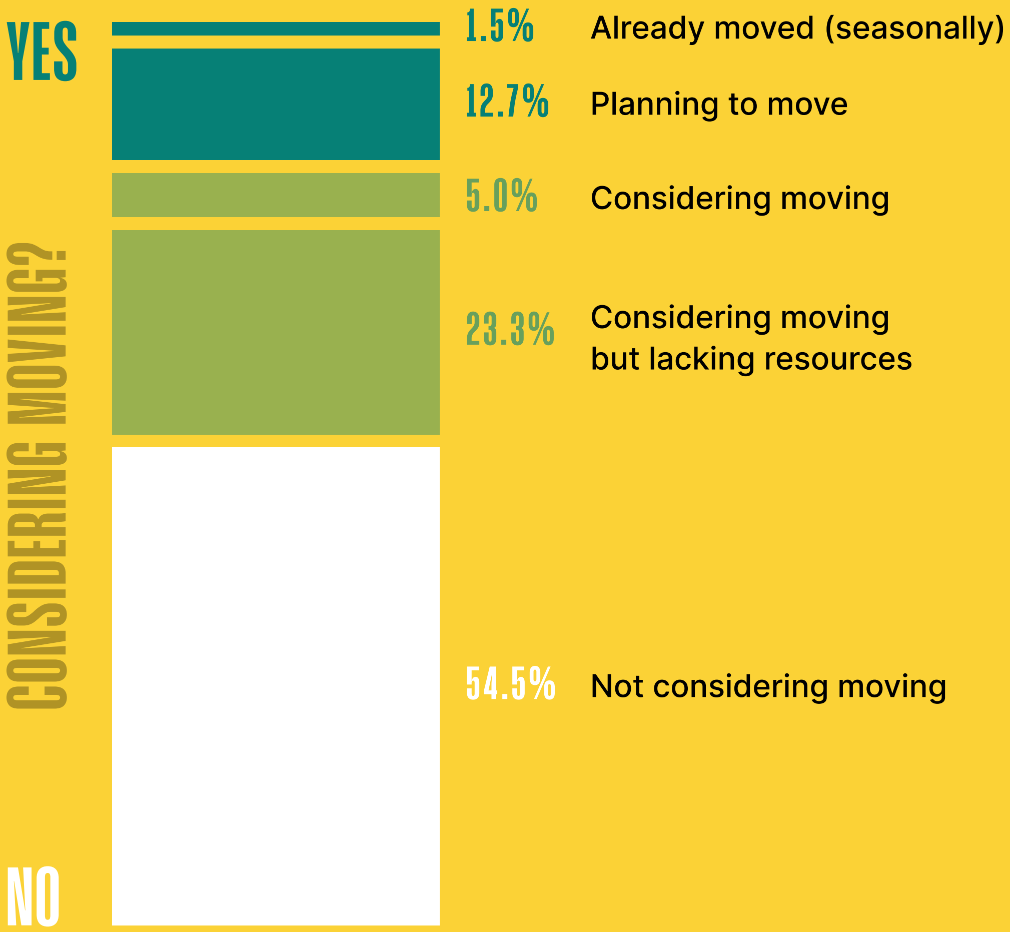
## People stay because their livelihoods and culture are tied to the land and local ecosystem.

When people's livelihoods and identities are tied to a place they call home, they tend to return there after relocating, even if these are places of known risk. In Beira, Mozambique, and Chikwawa in Malawi, where people were displaced by climate disasters, many returned home quickly. Over half of those surveyed said that those in their households who had left had returned, and most did so within a year. This suggests that displacement in response to sudden-onset climate shocks has been mostly short and cyclical in nature. These findings are consistent with the existing literature which observes that it is rare for displaced people to move away from their homelands permanently in response to climate shocks[59]. There is a risk, however, of repeated displacement as people move into destination areas, especially growing cities, that are themselves exposed to climate risks[28,60,61].

Figure 6A

## Climate mobility aspirations and capabilities

Even though they suffer from climate disruptions, most people do not consider moving; 23 percent lack the means to move even if they want to.



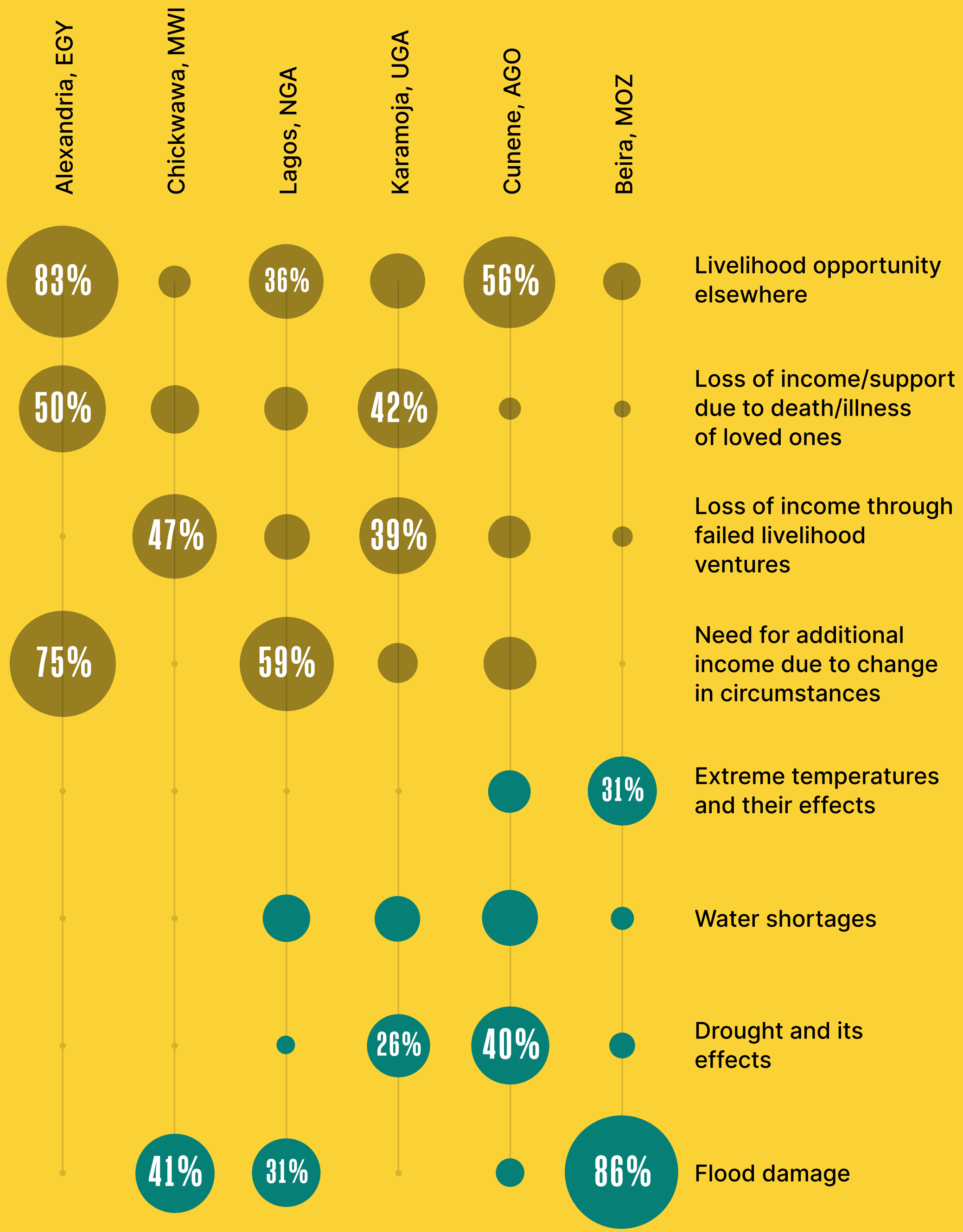

**Question**
When thinking about mobility, which of the following applies to you as an individual?

Source: ACMI Case Studies Survey data, 2022. Based on survey from 6 locations in Africa. Over 100 households surveyed, 2.9% responded with don't know or refused.

Figure 6B

## Climate mobility reasons

Seeking better economic opportunities, particularly after a sudden loss of income sources, is a major driver of mobility on the continent. In areas that have been hit by extreme events, such as cyclones impacting the coast of Mozambique, climate risks feature more prominently in people's decisions to move.




**Question**
What are the reasons for moving?

**Percentage of respondents per reason per location**

Economic factors
Climate factors

Source: ACMI Case Studies Survey data, 2022.

2.2.1

## When moving is not an option: The most vulnerable risk being stranded in high-risk places

The people most impacted by climate stressors are often struggling or marginalised in other ways. This may be due to poverty levels and a lack of alternative livelihood options. People may not have the funds to invest in adaptation solutions, such as building flood barriers or practicing irrigation. They lack the education or skills that are necessary to switch livelihoods to adapt to their changing environment. Alternatively, they lack the resources needed to migrate.
They are caught in a poverty trap, where socio-economic deprivation prevents them from adapting, responding to, or bouncing back from climate shocks.

In most of the survey locations, children and older people, and people who were sick or had disabilities, were more likely to stay. In contrast, young healthy adults were more likely to report leaving. Across the Sahel, elderly people and women were least likely to migrate[62]. This is partly due to perceptions that migration is something that men do, reflecting pre-existing gender norms that remain relatively unchanged in the face of environmental changes[62].

Most people surveyed did not consider moving away from their home communities. Given their current living conditions, for a large proportion of the respondents, this may reflect the lack of capacity or resources to move. As a result, they did not consider moving as an option, something described as 'acquiescent immobility'[40·63]. People may not consider themselves stranded, but the constraints they face within their living contexts suggest that they are, to a large degree, 'stuck'[28·40].

The water-side informal settlement of Ajegunle in Lagos, Nigeria, is home to approximately 550,000 people, most of whom are internal migrants. Here, residents reported a strong desire to move. Some 46 percent considered moving, yet they had no capacity to move. The lack of financial resources was the main driver of considering moving, and yet it was also identified as the greatest barrier to leaving. As a result, many in Ajegunle are effectively stranded, since frequent flooding adds to the poverty and deprivation that prevent them from leaving a neighbourhood that will be increasingly inundated by flood waters.

Praia Nova, Beira, is a fishing community in Mozambique, with 10,000 people. Here, many reported high aspirations to move, because they have experienced repeated extreme events, such as Cyclone Idai in 2019, which destroyed 90 percent of the city and affected over 1.85 million people[64]. As a direct result of Cyclones Idai and Kenneth — which hit the east coast in quick succession in 2019 — 46,000 people lost their lives, and damage costs were estimated at USD 2.3 billion[65]. Huge losses and damages to infrastructures in the energy, transport, water supply, communication services, housing, health and education sectors were also recorded[7]. Over 146,000 internally displaced persons (IDPs) had sought refuge in 155 temporary accommodation centres across four provinces (Sofala, Manica, Zambezia, and Tete)[64].

However, despite most people living in Praia Nova (83 percent) sharing they had moved in the past due to flooding and storms, 50 percent noted that at least one person in their household had returned home. This indicates that moving away had not sufficiently improved their circumstances. This case also shows the prevalence of short-term displacement despite aspirations for long-term migration, largely due to a lack of capacity to leave high-risk areas. Many of the people in Praia Nova survive on precarious and informal work, have little savings, and will not easily find jobs or shelter elsewhere.

These examples highlight that some communities lack the resources to move, and risk being stranded in worsening situations. Mobility as a successful adaptation strategy is simply not accessible to them. A quarter of all people surveyed across the seven case study locations said they wanted to move but did not have the resources or the capacity to do so. Climate change impacts can further erode the resources that people will need to move[28·40]. These cases confirm studies elsewhere in Africa that have exhibited immobility among low-income communities[28].

As global warming progresses, the challenge will be to identify the places and people who could be left in extreme vulnerability due to involuntary immobility[33].

## 2.2.2 Settled or stranded? Traditionally mobile pastoralism is disrupted

Africa's pastoral communities are traditionally mobile. While pastoralism can take many different forms, including different types and degrees of mobility, their challenges could be even more dramatic than for traditionally settled communities.

Pastoralism is the main livelihood of an estimated 268 million people across Africa. For those living in dryland areas, it is often one of the most viable livelihoods, if not the only suitable one. Livestock herders are able to create economic value from scarce natural resources, while also maintaining livelihood in ecologically fragile ecosystems[66].

Climate change disrupts pastoral livelihoods and adds to the existing pressures facing these communities. These include competing land uses amidst surging demographics, insecurity and hardening border regimes, poor governance of natural resources, and their marginalisation from public services and political processes. Climate change compounds these challenges by threatening animal health and survival, complicating resource access for herders, constricting livestock mobility, and bringing herders into conflict with other pastoralists or with settled farming communities.

Pastoralists cope by moving differently, settling more, and adopting new technologies. In Tatki, Senegal, pastoralists reported making changes to their movement patterns in response to changing weather and climate conditions, while young people said they also take up seasonal work in farming or urban areas. Pastoralists are increasingly adopting modern technologies such as cars and cellular phones.

When resources become harder to reach, herders use these technologies to cope. They access weather services on mobile devices. They also use vehicles to transport water and fodder, or to move animals around.

Another coping response is for herders to combine nomadic life with settled farming practices. This partially sedentary approach — agro-pastoralism — can boost their income and their resilience to climate change. However, adopting new herding routes or settling down can split up families, increase the household burden on women, and expose men to security risks while en route. Herders may not decide voluntarily to become sedentary. They may be forced settle after suffering losses in their herds due to climatic shocks or by government policies that limit their ability to move across regions. Supporting pastoralists to diversify their herds, such as by introducing camels in drying areas, and with insurance products and decentralised infrastructure could help their adaptation responses.

**Some communities lack the resources to move, and risk being stranded in worsening situations.**

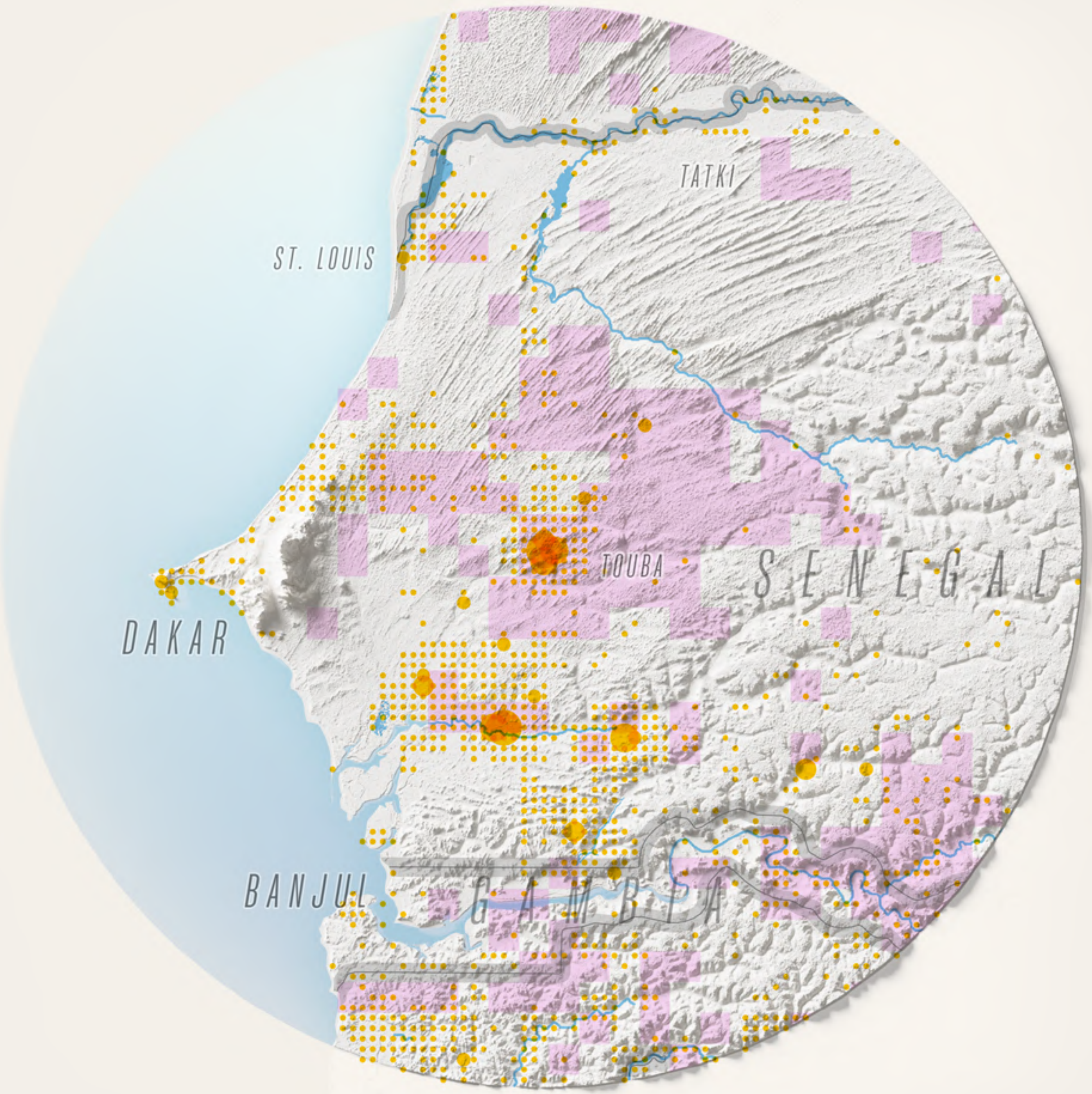
Loss of heritage and identity are harder to address. Climate change exacerbates existing risks to heritage[67,68]. This is particularly acute in Africa, where climate hazards such as sea-level rise, drought, flooding and wildfires[69–72] threaten cultural heritage. These physical risks are compounded by land-use change leading to socio-ecological tipping points, loss of food sovereignty, loss of territory, and loss of livelihoods[70,72]. In particular, local and Indigenous knowledge (a form of intangible heritage) is impacted by climate change through loss of livelihoods and migration[61,73], yet this knowledge is crucial for safeguarding other forms of heritage[74,75]. For centuries, African pastoralists have drawn on intangible heritage to build their resilience to climatic variability and to support adaptation practices[76–78]. Climate change threatens to make this traditional knowledge obsolete[7,10,77]. Historically, pastoral communities have recorded their experiences as memories that are passed on through generations and which can be translated into a range of adaptive practices. However, changes to traditional routes and distances travelled to move cattle between grazing sites are affecting the effectiveness of this handed-down indigenous knowledge[79]. These changes negatively impact local resource management institutions by weakening social bonds and diluting knowledge of rules and resource-use practices[80,81]. The fallout of these changes goes far beyond the tangible loss of ownership of pastoralists' material resources. Non-economic losses and damages to intangible heritage include the loss of oral histories, indigenous knowledge systems, identity, family structures, marriages, cultures, religions, and polities[72,82].

Men and women have different levels of vulnerability, aspirations, and agency in relation to climate mobility[62,83,84]. African women are more reliant on subsistence farming and are over-represented in poorly paid parts of the informal economy[7]. Consequently, women and women-headed households are at greater risk of poverty and food insecurity from the impacts of climate hazards on informal economies[85]. Social norms, traditions, legal frameworks and institutions limit African women's autonomy and agency, including in areas such as property rights and other legal entitlements, financial access, marital status, and economic resources[83,84,86,87]. These constraints also limit their agency in mobility decisions, which can increase their vulnerability to climate risks[87] and lead to unplanned or forced movements. Such movements tend to have more negative outcomes than planned mobility. Among other risks, women may face elevated levels of gender-based violence when on the move, in transit or in refugee camps[88,89].

# 300k

Droughts could force traditionally mobile communities – including 300 thousand pastoralists in Senegal – to seek stability and settle beyond their usual grazing lands. In the east of the continent, the number of people moving away from pastoral areas could be even 10 times greater than in the west.

**TOUBA, SENEGAL**




**People leaving**
Expected number of people leaving their home due to climate change by 2050 (50 – 40k people)

**Pasturelands**

Read more about climate mobility in pastoralist communities in section 3.2.

2.3

# Women at the Forefront: Climate impacts increase stressors for African women, but moving remains a last resort

## 2.3.1 Moving is often a last resort for women

Women perceive and experience climate stressors more acutely than men, even if they are less climate literate. Across communities, women reported experiencing greater hardship than men, largely due to their responsibilities for collecting water and fetching firewood. Women's vulnerability emerged in both the Beira (Mozambique) and Nadunget (Uganda) case studies, where women were more concerned about deteriorating security than men. In Ajegunle (Nigeria) women talked about the negative health impacts of climate stressors more frequently than men.

Despite their awareness of climate-related hazards, and the fact that more women than men had moved in the past (possibly for marriage), women were generally less likely to aspire to move than men[61·84]. They were also seen as less likely to move (Figure 7). For example, for communities in Cahama, Angola, despite a recent trend of people leaving the town because of drought, the majority (61 percent) are still not considering moving, and women are far more strongly represented within this category than men. Women were also less likely to be involved in decisions about how to prevent, mitigate and cope with climate change, including decisions on whether and when to leave home[90].

> Despite their awareness of climate related hazards, women were generally less likely to aspire to move than men.

The situation is different in the context of an imminent disaster. Data from the seven ACMI case studies finds that when people flee for safety, whole households tend to move, or a family will prioritise the women and children. For instance, in Beira, women and children were the first to be evacuated when Cyclone Idai struck the Mozambican coast. Also, in Chikwawa, where mobility primarily took the form of forced displacement, it was often the whole household that left. Thus, the profile of those who move, particularly in terms of age and gender, appears to be heavily influenced by the risks of staying — in terms of a threat to safety and security — as well as by livelihood opportunities.

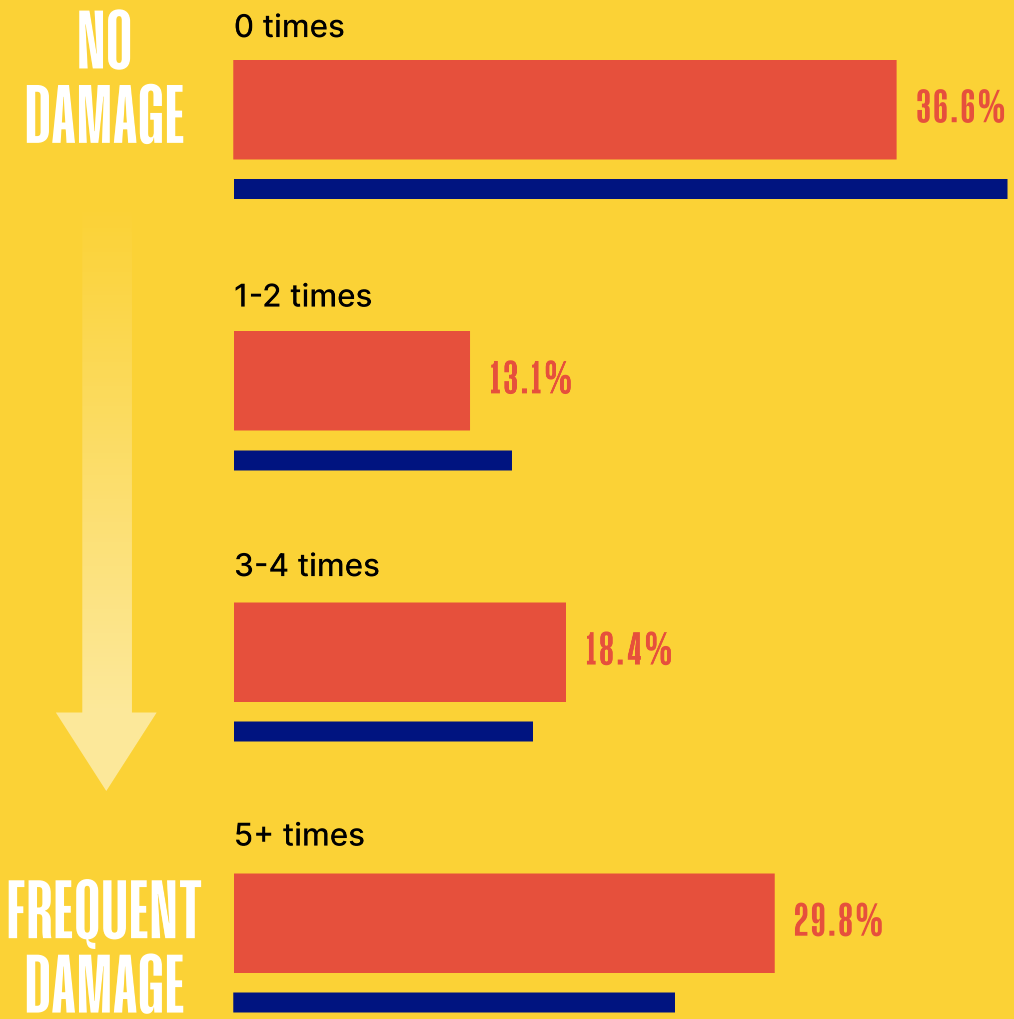
Where women and children are unable to move out of harm's way when disaster strikes, globally they are roughly 14 times more likely to die than men[91]. Women's vulnerability in that context is determined less by the strength of the climate hazard, and more by their socio-economic status in the affected country which leads to involuntary immobility[91]. Low socio-economic status puts women at significantly higher risk of dying than men[91].

When people need to move in search of livelihoods, then it is young adults who move, in some cases men more often than women. In Beira, men more often reported staying. This likely means that other household members move to safety during storms and flooding, while men stay to try to keep earning a living. But this is not always the case. In Ajegunle, Nigeria, a higher proportion of women were considering or planning to move than men, but this was attributed to a lack of economic opportunities for women where they were living. Research in Ethiopia has found a link between drought and decreased marriage-related mobility by women[92].

Figure 7A

## Gendered perceptions: frequency of negative climate impacts

Women tend to perceive more frequent impacts from extreme climate events than men living in the same location.




**Question**
How many times in the past 10 years has flooding resulted in damage to homes, buildings, crops or roads?

**Percentage of respondents per gender and category**

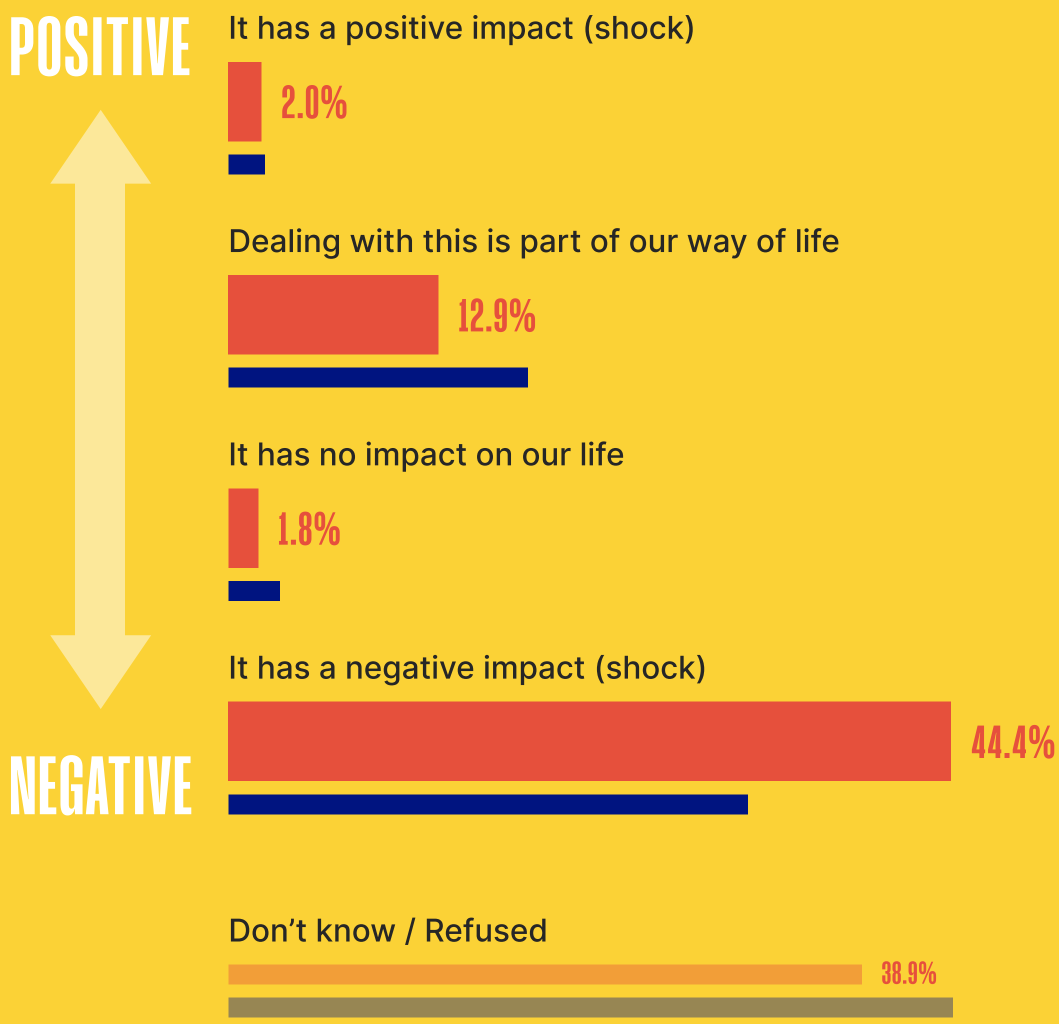
Women
Men

Source: ACMI Survey data, 2022. Based on survey from 6 locations in Africa.
Over 100 households surveyed, 2% of women and 4% or men responded with don't know or refused.

Figure 7B

# Gendered perceptions: Climate impacts on livelihoods

Women tend to perceive impacts of climate events in their households more negatively than men.




**Question**
How would you say the situation relating to flooding impacts on your household?

**Percentage of respondents per gender and category**

Women
Men

Source: ACMI Survey data, 2022. Based on survey from 6 locations in Africa. Over 100 households surveyed.

Forced displacement leaves women and girls disproportionately vulnerable[93]. Sub-Saharan Africa has the highest number of internally displaced women (8.2 million), 40 percent of the global total[94]. In Burkina Faso in 2019, 65 percent of adult IDPs were women[94]. Women and girl refugees, returnees, and IDPs face specific risks, including sexual and gender-based violence and other human rights violations. Displaced women and girls tend to be at greater risk of deprivation, insecurity, abuse, neglect, and a general deterioration of their well-being. Often, their gender and age also limit them from participating in decisions on matters that directly affect them[95]. These risks exacerbate already present health, livelihood, education, and security challenges. It also hinders their effective participation in peace-building and decision-making more broadly[93].

### 2.3.2 Women who stay behind face additional burdens and innovate to adapt

It is common for women to stay behind when men migrate, and this often comes with additional burdens that can be aggravated by climate stressors. For example, among pastoralists in Tatki, Senegal, women and older people do not travel with the herds. When men leave, women take on new responsibilities, including those traditionally carried out by men. At the same time, women also have to carry on with their usual household tasks, such as collecting water or firewood, which may become harder as the environment around their homes degrades[96].

**Women use connections and resources creatively to innovate and adapt.**

These traditional and expanding responsibilities can expose women to new security risks, including sexual and gender-based violence, or create additional barriers to education. Increasing burdens often occur within the confines of discriminatory legal frameworks that exclude or marginalise women in land tenure or property rights[96].

Women can use social connections and knowledge resources creatively to innovate and adapt. When men move away from rural areas, it can increase the women's work burden, but it can also increase their autonomy at home. Even though women and women-headed households are generally poorer and more at risk than men and men-headed households, women can be more innovative in their individual and collective responses to stressors. They may have more social capital to draw on when they stay in their home situations. For example, women-headed households in South Africa often diversify their food and income sources in times of difficulty by turning to natural resources and other local, small-scale sources of self-employment[63]. And while women on the continent have an overall lower awareness of climate change than men, they are more likely to take adaptation actions when they are made aware of climate change and given adequate climate information[55·97].

Figure 7C

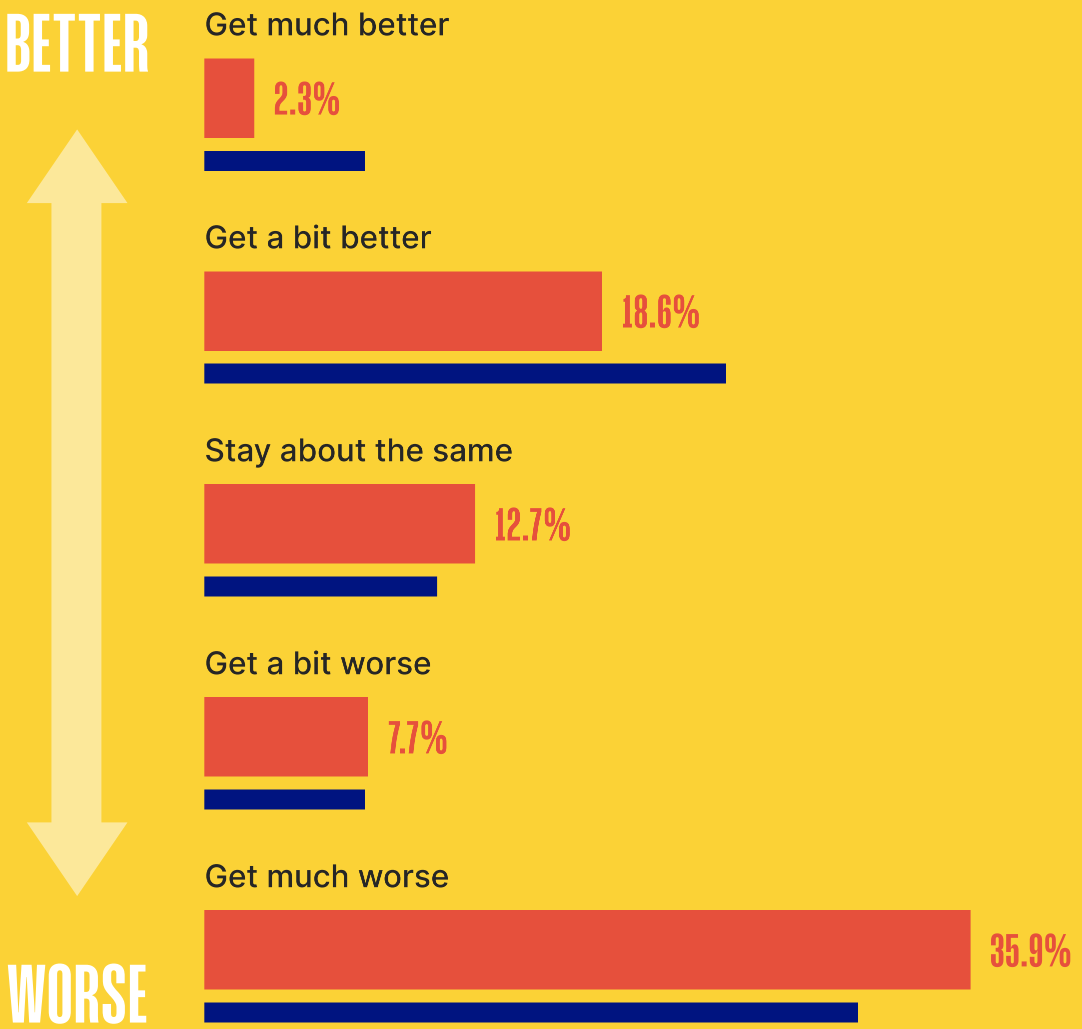
## Gendered perceptions: Future climate impacts

When considering climate risk like flooding, women's outlook for the future is more negative than men's.

**Question**
Looking to the future, how do you think flooding will affect the situation for your household in the coming 5 years, if you stay here?
*The situation will…*

**Percentage of respondents per gender and category**

Women
Men




Source: ACMI Survey data, 2022. Based on survey from 6 locations in Africa.
Over 100 households surveyed, 22.7% of women and 19% or men responded with don't know or refused.

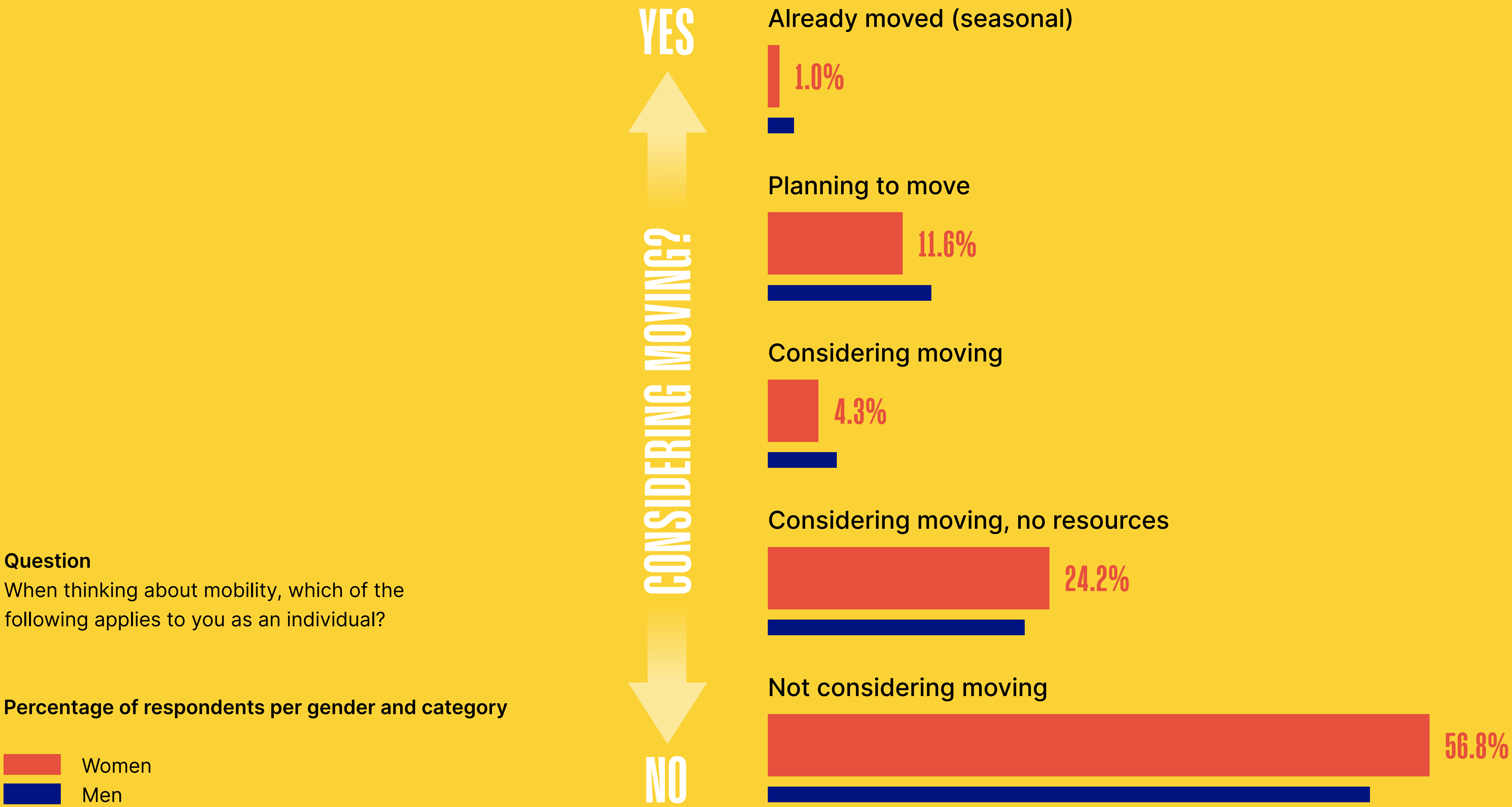
Figure 7D

## Gendered perceptions: Aspirations and willingness to move

Women may be more reluctant to move than men.

**Question**
When thinking about mobility, which of the following applies to you as an individual?

**Percentage of respondents per gender and category**




Source: ACMI Survey data, 2022. Based on survey from 6 locations in Africa.
Over 100 households surveyed, 2% of women and 4% or men responded with don't know or refused.

2.4

# The Next Generation: Young Africans are more likely to embrace moving, and can lead the way in harnessing climate mobility

Almost 60 percent of Africa's population are under the age of 25, making Africa the world's youngest continent (in 2020, the median age in Africa was 19.8 years)[98·99]. By 2100, almost half of the world's youth are expected to be from Africa (46.3 percent)[99]. Compared to previous generations, Africa's youth are more educated, less encumbered with family responsibilities, and yet are more likely to be unemployed. Young people often experience limited opportunities in their home communities. They may struggle to find avenues to pursue their aspirations and dreams, unable to advance their own and their families' prospects within their places of origin[100]. All these factors suggest that the younger generation may be more ready to migrate in response to climatic changes and stressors.

### 2.4.1

## Moving is normal for the young and educated

When communities struggle and people leave in search of livelihood opportunities, young people are typically the first to move. The ACMI and wider research find a strong link between people's interest in mobility, age, and education level. This link is even stronger than with other mobility drivers, such as poverty[101]. In the ACMI research, two out of every five youth respondents (40 percent) said that moving was something to be expected. Almost one in five had concrete plans to move (Figure 8). For example, in Karamoja, although aspirations to move are low (78 percent of respondents were not considering moving), those who did move were more likely to be youth and children. In Cahama, (Angola), younger men and women (under 25) most often move away. There also appears to be a correlation between education level and the aspiration to migrate: a majority of those with no education were not considering moving (70 percent), while those with some schooling far more frequently aspired to migrate. This may point to people with lower educational levels staying behind.

Other studies on climate mobility in Africa have found that those under the age of 34 are more inclined to migrate, particularly if they are also unmarried and educated[99]. For example, in Kenya, those with at least a primary education are twice as likely to be climate-mobile than those lacking an education. Meanwhile, in Zambia, Kenya, and Uganda, both young men and women are less mobile when they are married[102]. A 2019 Afrobarometer survey across 34 African countries found that almost half (47 percent) of 18- to 25-year-olds had considered leaving where they live. This was double or triple the proportion of people above age 45. More than half (51 percent) of Africans with post-secondary education had thought about moving, with a quarter (24 percent) saying they had considered it 'a lot'[101].

Research among young Africans who left the continent shows that they are typically more educated than the average level in their home countries[100], confirming the role of education in mobility aspirations and opportunities. Those reaching Europe commonly say that they are motivated by poor economic, governance, and service delivery conditions[100·103]. There is also a close tie with the need to self-actualise, and many have a sense that their aspirations can only be fulfilled through leaving their place of origin[100].

Young people are typically the first to move.

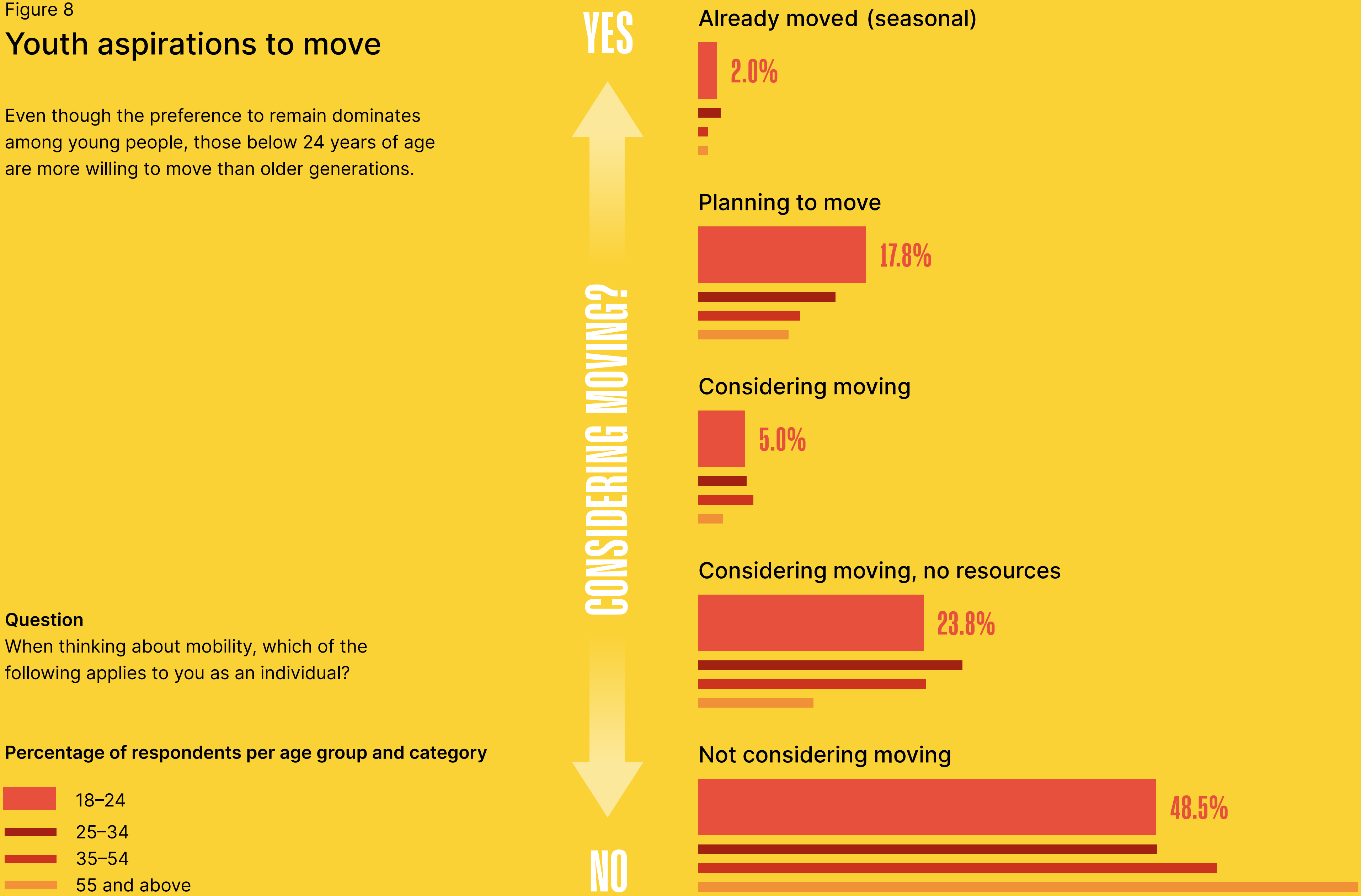
Figure 8

# Youth aspirations to move

Even though the preference to remain dominates among young people, those below 24 years of age are more willing to move than older generations.

**Question**
When thinking about mobility, which of the following applies to you as an individual?

**Percentage of respondents per age group and category**



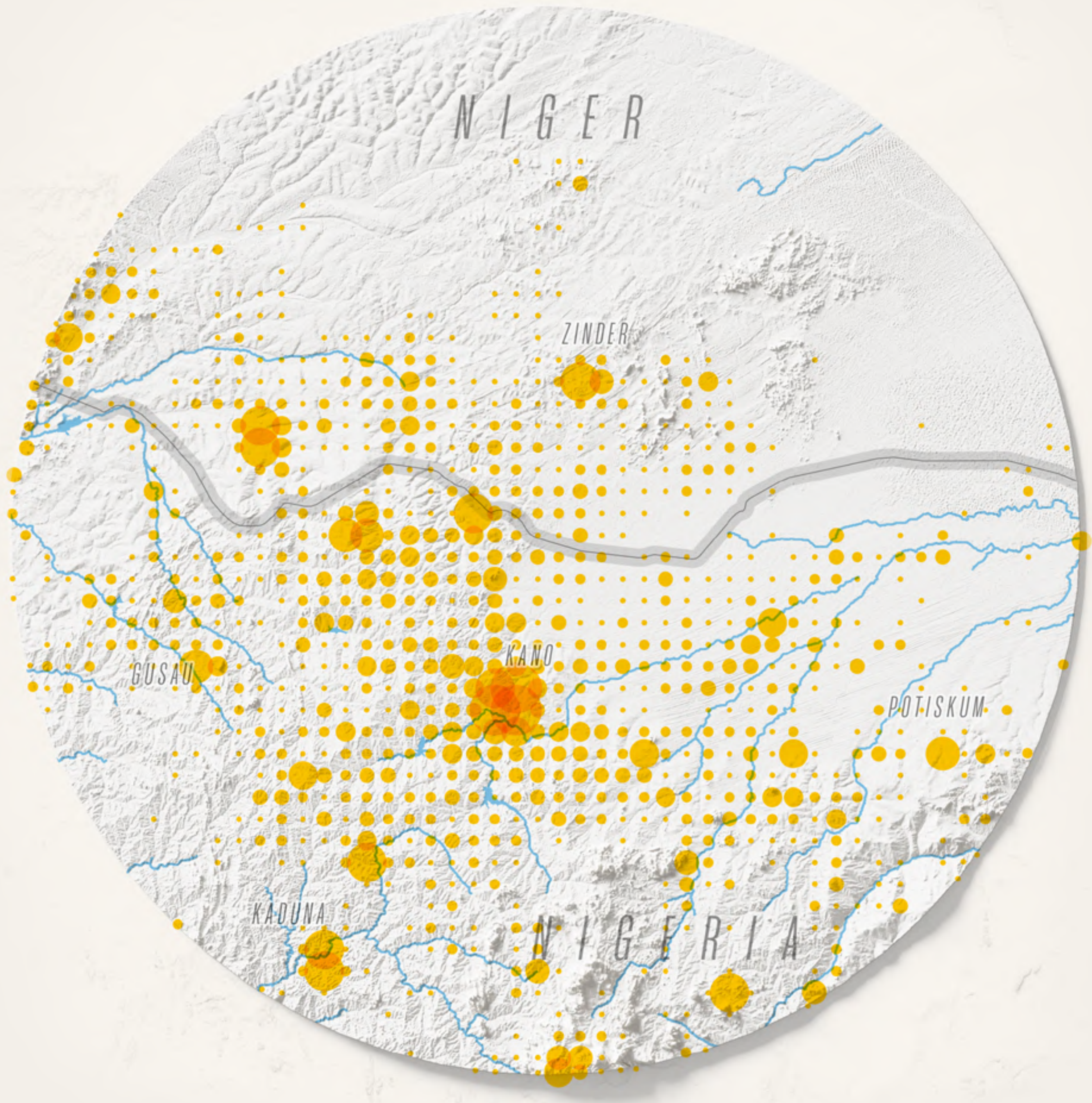

Source: ACMI Survey data, 2022. Based on survey from 6 locations in Africa.
Over 100 households interviewed, 3% of 18–24 year olds responded with don't know or refused.

# FUTURE SCENARIOS

# 10.3M

Preparing youth for future climate challenges will make the population in Kano (Nigeria's North West), expected to grow in 10.3 million people by 2050, more resilient. Adaptation will facilitate the lives of young people moving, considering moving, and staying in their current locations.

**KANO, NIGERIA**




**Population growth**

Projected population growth by 2050 (compared to 2010) under the Rocky Road scenario (35k – 900k people)

The ACMI developed the Africa Climate Mobility Model to simulate different potential futures for the continent and explore their implications for climate mobility within African countries. The model combines possible development pathways with future global greenhouse gas (GHG) emissions trajectories to develop four plausible scenarios for the future (Figure 9). The model draws on scenarios used in the IPCC Sixth Assessment Report, including the Representative Concentration Pathways (RCPs) 2.6 and 6.0, and Shared Socioeconomic Pathways (SSPs) 1 and 3[104,105].

3.0.1

## The climate scenarios

### Low emissions; warming limited to 2°C

Two scenarios assume rapid carbon reduction in the near term, and a future of lower global emissions. This is in line with the ambitions of the 2015 Paris Agreement on climate change, which aims to hold the global mean temperature increase to 'well below 2°C [...] and to pursue efforts to limit [warming] to 1.5°C'[1]. It is important to note that even at the current level of average global warming (1.3°C), key development sectors across Africa have already experienced widespread losses and damages attributable to human-induced climate change, including biodiversity loss, water shortages, reduced food production, loss of lives, and reduced economic growth[7]. While useful to explore and illustrate the effect of different climate change scenarios on human mobility, the report considers a low emissions future as unlikely, given the current lack of progress towards limiting greenhouse gas emissions at the rate necessary to keep warming well below 2°C. Consequently, much of the following analysis will prioritise the high emissions scenarios to discuss likely and near-term future developments in the continent.

### High emissions; warming exceeds 2°C

Two scenarios project a future of continuously high greenhouse gas emissions, where global heating passes 2°C of warming between the early 2040s and the early 2050s[104–106]. In these scenarios, rising temperatures present serious challenges for both climate change mitigation and adaptation, for instance putting up to 80 million people globally at risk of hunger by mid-century[7,107]. Because this future is more likely, the high emissions scenarios are used as reference scenarios for much of the discussion of the modelling outcomes that follows.

3.0.2

## The development scenarios

The development scenarios used for the ACMI model include variables such as population size, GDP growth, education levels, and urbanisation. Thus, they emphasise not only the importance of inclusive economic growth but also factors that influence human wellbeing. Framing development scenarios in this way highlights the role of investments in Africa's people, their education and health, reducing their vulnerability to climate change, and managing population dynamics.

### Low population growth; inclusive development

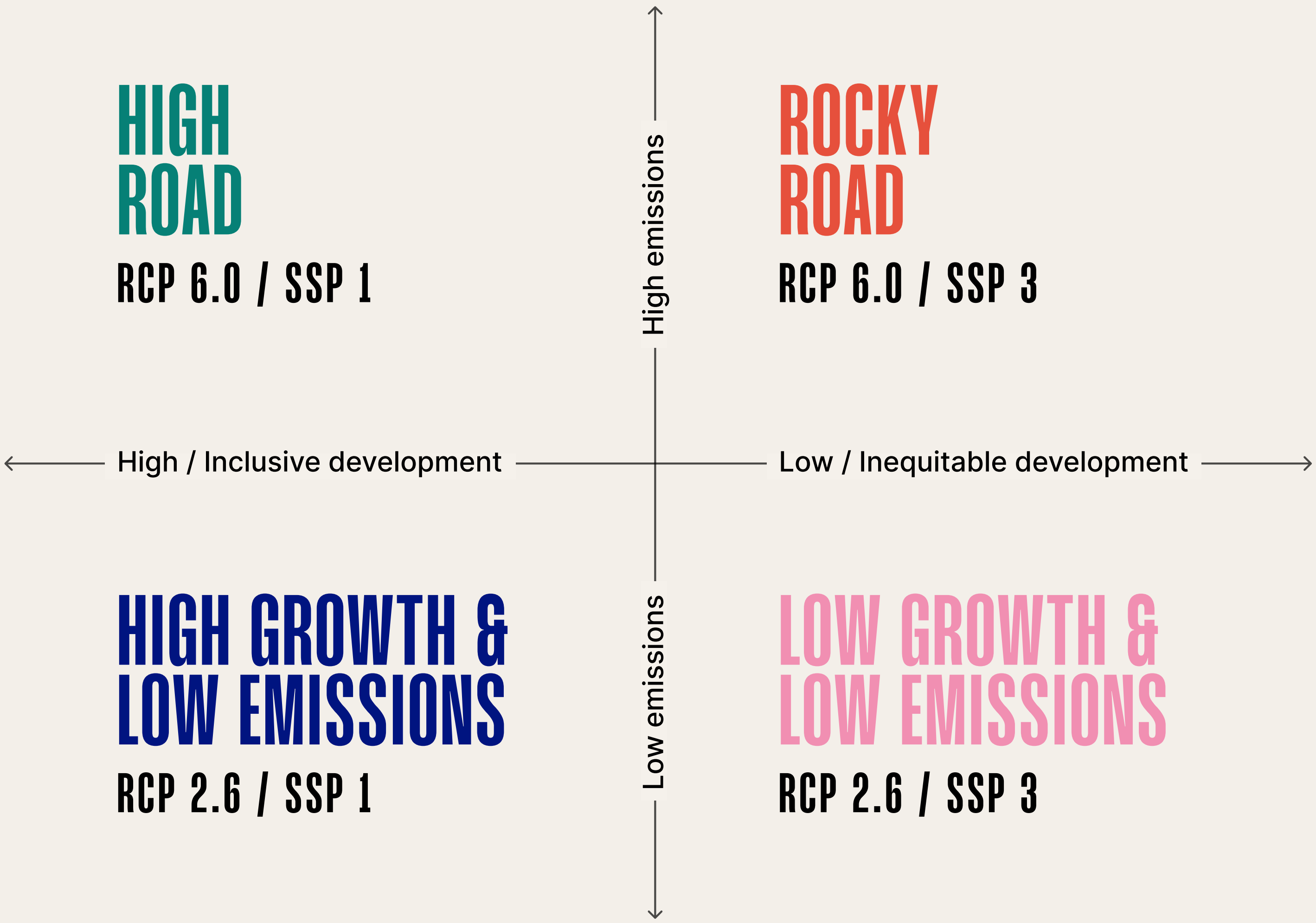
This development scenario assumes lower population growth, reaching 1.76 billion by 2050, along with high urbanisation, medium GDP, and high education across the continent. This development pathway is driven by an increasing commitment to achieving development goals and assumes reduced inequality across and within countries. It shifts consumption patterns toward low material growth, and lower resource and energy intensity[104,105].

### High population growth; low development

This scenario is characterised by low levels of cooperation globally, combined with high population growth in Africa, where the number of people reaches 2.3 billion people by 2050. It assumes a lower rate of urbanisation, low GDP growth, and low educational outcomes across much of the continent[105]. The lower urbanisation rate in this scenario leads to a much larger rural population[105].

Figure 9

## The four scenarios used to model climate mobility in Africa 2020–2050



### 3.0.3
## Two possible futures

Based on the above climate and development scenarios, this report discusses the results with a focus on the two possible high emissions futures that arise. It considers how these will shape the future of mobility on the continent between 2020 and 2050:

**The 'Rocky Road' scenario**
Emissions remain high, and the planet heats by at least 2°C by mid-century; Africa sees low development progress, with low levels of cooperation, high population growth, lower rate of urbanisation, low GDP, and low education (Figure 9 top right).

**The 'High Road' scenario**
Emissions remain high, and the planet heats by at least 2°C by mid-century; Africa adopts inclusive development, has low population growth, high urbanisation (double the rate of the Rocky Road scenario), medium GDP, and high education (Figure 9 top left).

### 3.0.4
## Modelling population responses

To project future climate mobility within countries, the ACMI model forecasts future population distribution in the African continent based on an assessment of the relative attractiveness of places to each other (for instance, urban areas tend to draw population as they offer more opportunities). It projects how future development scenarios affect population distribution. It then projects a future in which climate impacts alter the continent's development trajectory and make some places more and others less attractive. For example, low soil moisture during drought tends to negatively affect crop yields and rural livelihoods and can drive people away from increasingly arid areas[108,109]. People also tend to leave urban areas after repeated urban flooding or leave agricultural areas when crop yields have been damaged by flooding[109].

A comparison of the projected population distribution for the 'development only' and the 'climate impacts' scenarios points to geographic areas where discrepancies in population arise. These population gains or losses are attributed to climate impacts affecting people's location choices and driving them to move.

The method employed for this work is a modified version of the spatial population gravity model underlying the 2018 *Groundswell* report on climate change-related internal migration produced by the World Bank[18] and their related follow-up work in Africa[110–112]. Although the ACMI model includes a number of innovations (see Table 1), the results echo those of the *Groundswell* project and lead to similar and complementary findings and recommendations in this report.

The ACMI modelling includes climate impacts on water availability, crop production, net primary productivity (an indicator used to gauge conditions in rangelands), flood risk, sea level rise, and heavy rainfall associated with tropical cyclones. In doing so, the model draws in the actual impacts on critical primary sectors, such as water, agriculture, and ecosystem services, all of which are central to a range of livelihoods. Beyond climate impacts, other factors, such as armed conflict, are also considered when projecting population shifts out of the affected areas and towards more favourable environments. This marks a significant technical advance compared to previous methods used to model climate mobility.

To complement the modelling of internal climate mobility, the ACMI also modelled future climate driven cross-border migration on the African continent out to 2050. These projections are intended to shed light on how climate change will affect international migration trends within a South-South context. The cross-border climate mobility model projects future bilateral migration between two countries, combining development and emissions scenarios, and considering the same climate impacts that were used for modelling internal climate mobility. Rather than comparing a 'development only' to a 'climate impacts' scenario, the cross-border modelling compares the latter to a *counterfactual* scenario, which holds water availability and crop yields constant at their historical average (1990 to 2010) (see Appendices).

Table 1

## Advances of the ACMI modelling approach building on the *Groundswell* report: Approach at a glance

| ***Groundswell*** | **Advances in the Africa Climate Mobility Initiative model** |
| --- | --- |
| *Groundswell* used a unique population gravity modelling technique to project future population distributions to the year 2050. | ACMI added to this model maximum rural and urban population densities. |
| *Groundswell* focused on slow onsets: The modelling was the first time actual climate impact models for agriculture and water resources were used to understand how these would affect future population distributions, as well as sea level rise compounded by storm surge. | ACMI added to this model slow onset ecosystem impacts.<br>ACMI added to this model two types of rapid onset impacts: flood risk projections and conflict areas. |
| There were three scenarios based on combinations of socioeconomic development scenarios (SSPs) and representative concentration pathways (RCPs) in the *Groundswell* approach. | ACMI added to this model a fourth scenario — the high growth & low emissions scenario — to capture the full range of possible climate mobility projections. |
| *Groundswell* scenarios were run in decadal increments from 2010 to 2050; parametrised and validated from 1990 to 2010. | ACMI model was run at finer temporal scale at five-year increments to capture the combined effects of repeated extreme events better than the ten-year time step used in *Groundswell*. |
| Modelling work was done by *Groundswell* using a coarse resolution population grid as a baseline, with estimates of climate migration for 14 km grid cells. | The ACMI population grid uses a higher resolution baseline that uses remote sensing to model distribution, and the modelling resolution is performed at 4 km grid cell affording greater local-level accuracy. |
| *Groundswell* modelling approach was supplemented with a peer-reviewed literature review and contextualisation for illustrative case studies; with in-country consultations. | ACMI modelling approach was supplemented by case studies exploring the lived experience of climate mobility and immobility for a range of climate impacted communities and findings synthesised with the literature and with the IPCC Sixth Assessment Report. |

3.1

# A Future on the Move: Climate impacts will force more Africans to move, mostly within their countries

As Africa's population grows and climate impacts intensify, human mobility is expected to increase[113]. The Africa Climate Mobility Model findings suggest that climate change will drive human mobility on the continent directly and indirectly. This will contribute to existing mobility trends, especially for internal and rural-to-urban migration[7] that are driven by factors such as family ties, educational and economic opportunities, and conflict[114,115].

3.1.1

## Climate mobility within countries will increase noticeably by 2050

Through 2050, climate mobility levels will increase both for internal and cross-border mobility. However, cross-border mobility will be a fraction of the numbers for internal mobility. This trend is consistent with the IPCC assessment that climate mobility has been mainly within African countries. The IPCC also projects an increase in internal and rural-to-urban climate mobility[7].

By mid-century, under the Rocky Road scenario, internal climate mobility is predicted to reach 88 million people in the continent. Taking account of existing uncertainties, it could reach as high as 113 million people. The High Road scenario sees less movement, with 70 million people forecast to move due to climate stressors by 2050, while uncertainty bands reach up to 95 million people (Figure 10A).

It is worth noting that, while slipping out of reach, both low emissions future scenarios (based on RCP 2.6) produce higher climate mobility forecasts for the continent than the more likely high emissions scenarios (RCP 6.0). This suggests that adverse climate conditions generally depress rather than spur movement.

When comparing how the different development scenarios affect the projections, it appears that low development futures will see more climate mobility than the high development futures. One factor driving this difference is population growth. Under the low development scenarios, Africa is forecast to have a population of 2.3 billion people by 2050 versus 1.8 billion people under the high development scenarios.

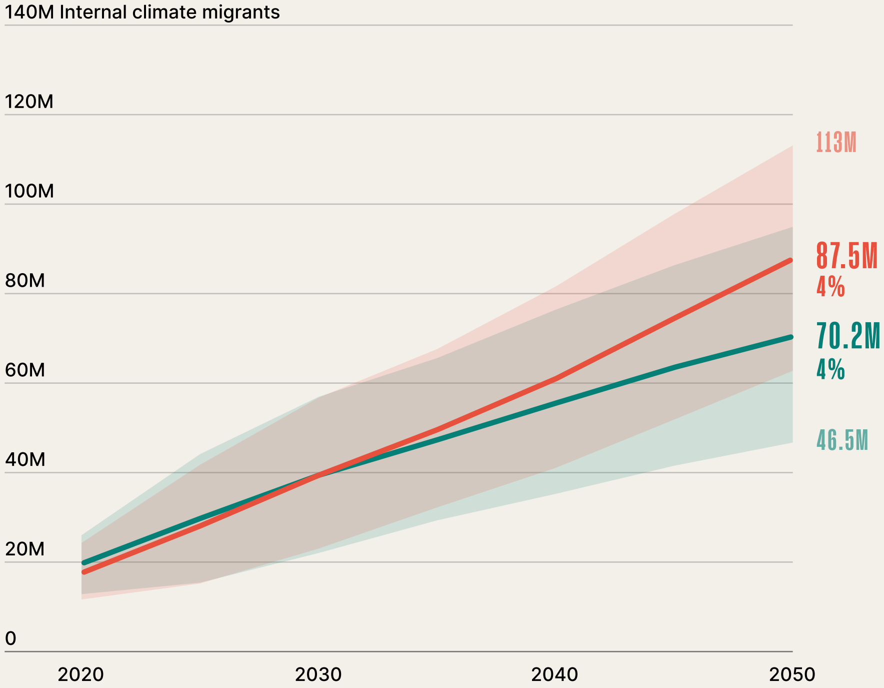
In all future scenarios, climate mobility is projected to account for up to 5 percent of the African population by 2050, a significant increase from its share of around 1.5 percent today.

↓ **Figures 10A and 10B**

Mobility projections suggest that the number of internal climate migrants in Africa will multiply by four within the next two decades. Total numbers represent movement of population based on climate impacts across the continent. The climate mobility totals indicated in the figure represent the difference between a future world where climate impacts drive mobility, and projected population growth for Africa with no climate impacts projections. The lighter shaded bands around each line represent the confidence interval based on four model runs per scenario, each using different combinations of global climate models (GCMs) and impact models. Wider bands reflect higher levels of uncertainty.

Figures 10A and 10B

## Climate mobility within African countries from 2020 to 2050



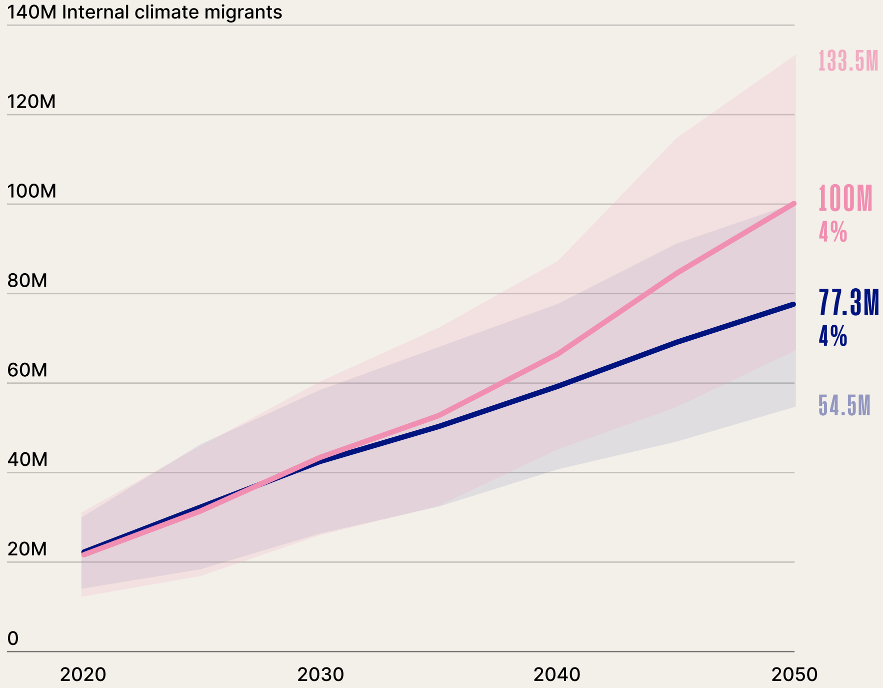




Figure 10A

**Internal climate mobility in Africa under high GHG emission scenarios (and % over total population)**

High Road scenario
Uncertainty (95% CI)
Rocky Road scenario
Uncertainty (95% CI)

Source: ACMI Africa Climate Mobility Model, 2022.

Figure 10B

**Internal climate mobility in Africa under low GHG emission scenarios (and % over total population)**

High Growth & Low Emissions scenario
Uncertainty (95% CI)
Low Growth & Low Emissions scenario
Uncertainty (95% CI)

Source: ACMI Africa Climate Mobility Model, 2022.

3.1.2

## The impacts will be unequally distributed

Climate impacts are expected to affect the population distribution of all countries on the continent, making some areas more attractive while forcing people to leave others. Under the pessimistic Rocky Road scenario, hotspots for in- and out-movement emerge as early as 2030 (Figure 11). In most countries, the places that people will move to and from remain the same, but the number of people moving due to climate impacts will increase by 2050.

Some countries and regions will be more affected than others. For example, East African countries in the Intergovernmental Authority on Development (IGAD) economic bloc could see up to 10.5 percent of their population on the move by 2050, in response to climate drivers. Under the Rocky Road scenario, about 41 million people, and potentially up to about 55 million, could be displaced by climate impacts within countries in the IGAD region by 2050 (Figure 12).

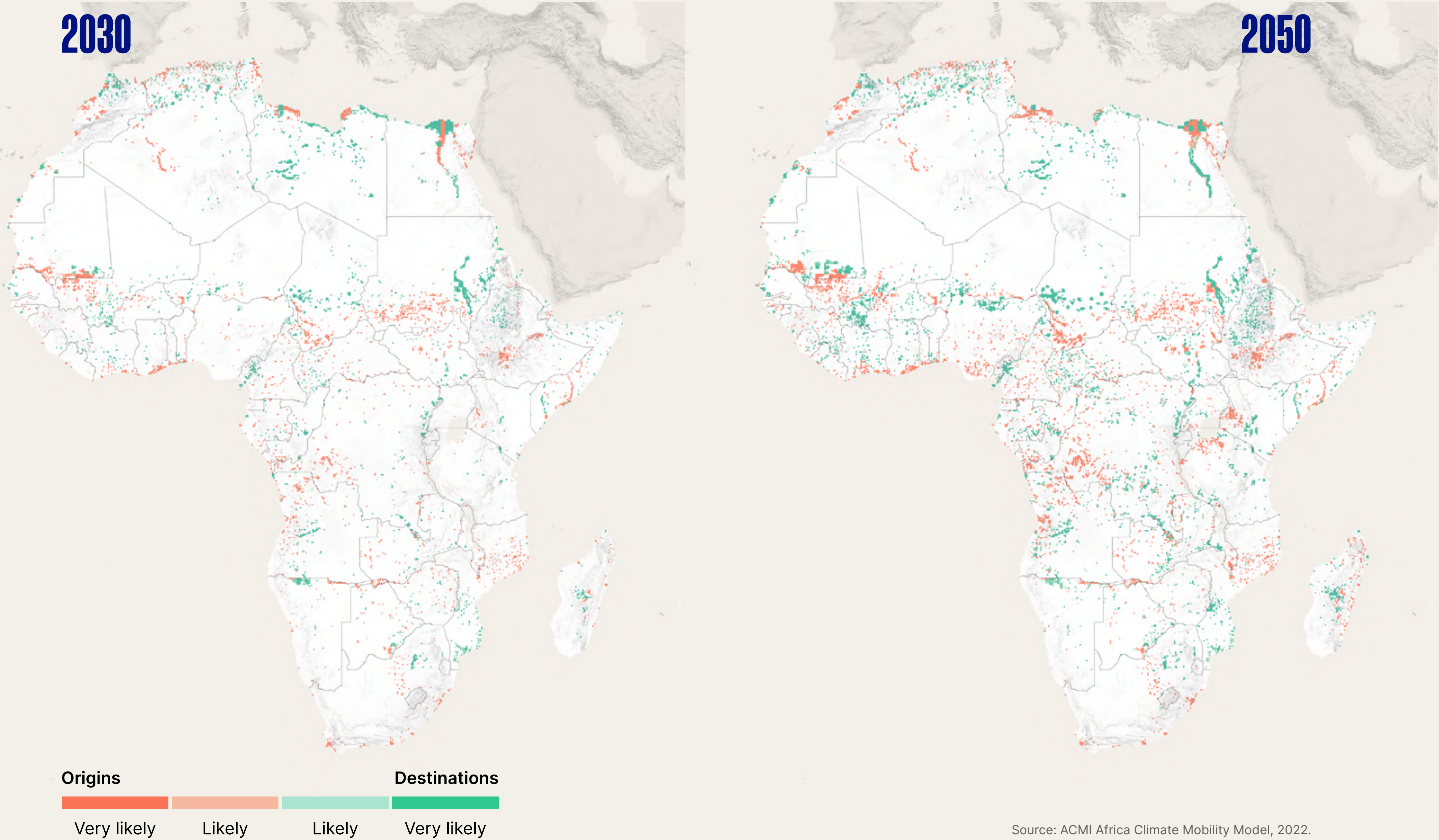
↓ **Figure 11**
For some areas the results of multiple scenarios agree on the direction of population change (increase vs. decrease or arrivals vs. departures). Those areas where the results of the Africa Climate Mobility Model are consistent across three or more future scenarios are represented by levels of confidence of likely and very likely internal (within country) climate mobility. The projected magnitude and direction of internal climate mobility will vary across space and time, and across future scenarios.

↓ **Figure 12A**
Projections of total internal climate migrants for IGAD where climate mobility could increase from around 2.5 percent, to as much as 10.5 percent of the region’s population by 2050.

↓ **Figure 12B**
Regionally defined hotspots in the IGAD region depicting the number of people moving out from (orange) and to (green) specific areas owing to climate impacts under the Rocky Road scenario in 2050. Climate mobility projections assume people will move based on push and pull factors associated with climate impacts. Where impacts will be negative, projections show movement out of those regions. Where impacts are projected to result in comparatively better conditions (such as suitability for certain crops), projections indicate movement to, and a growth of population in, such areas. Total numbers represent deviations between the climate impacts and no climate impacts projections, which represents, in turn, differences in population distributions in the respective years, and therefore a cumulative shift in population distribution. The bands around each line represent the confidence interval based on four model runs per scenario, each using different combinations of global climate models (GCMs) and impact models. Wider bands reflect higher levels of uncertainty.

Figure 11

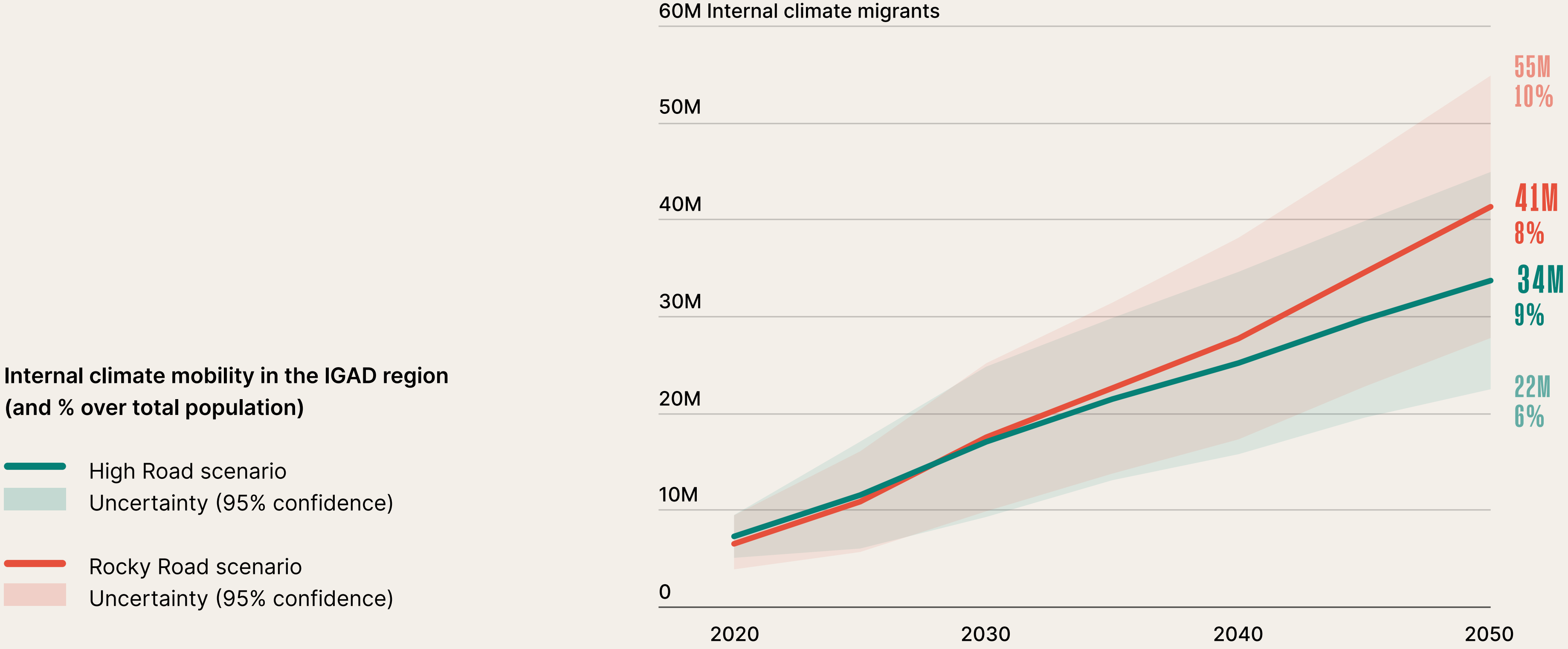
## Internal climate mobility hotspots (movements within countries)




Source: ACMI Africa Climate Mobility Model, 2022.

Figure 12A

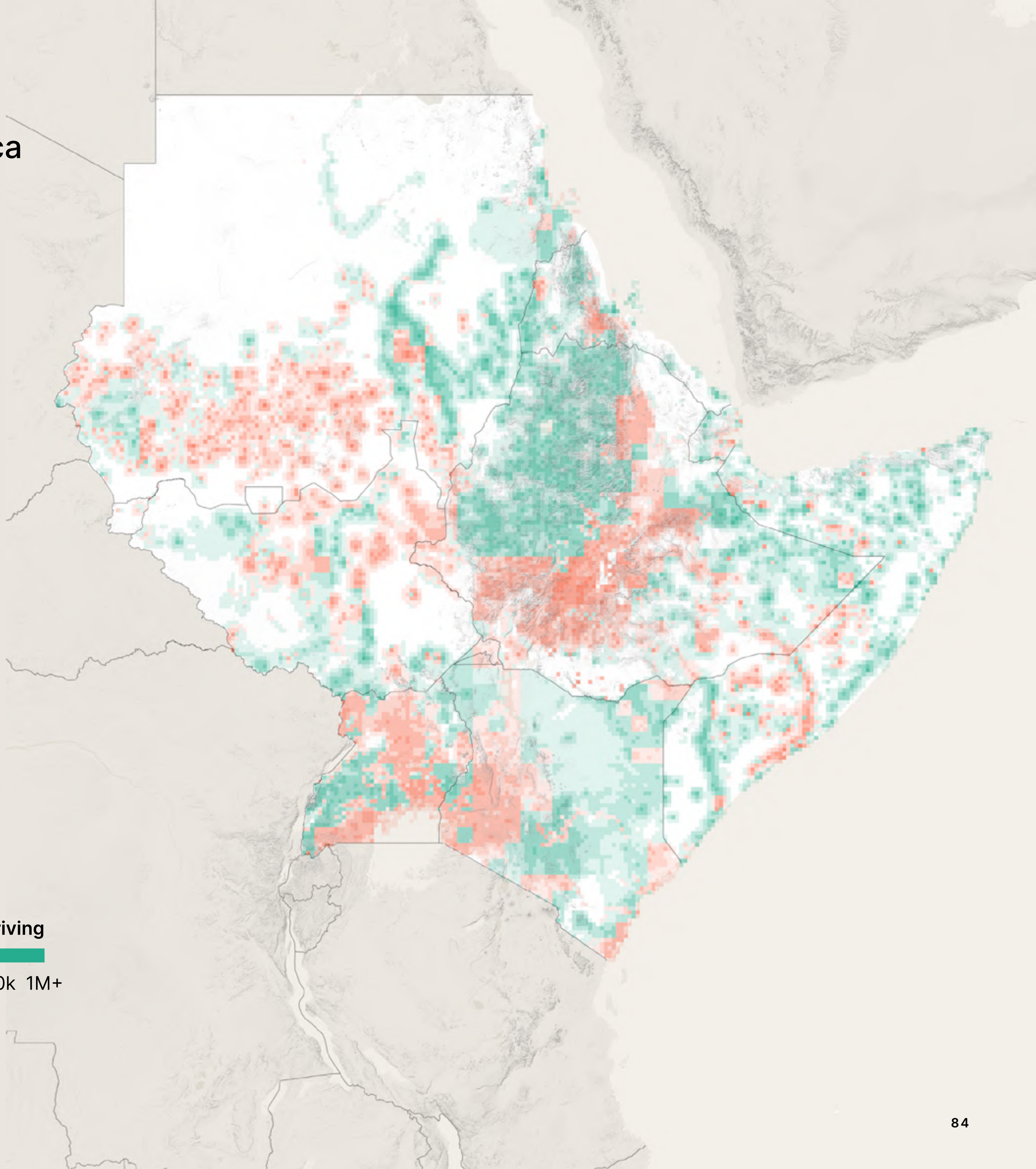
# Climate mobility by 2050 in the IGAD region in the Horn of Africa




Source: ACMI Africa Climate Mobility Model, 2022.

Figure 12B

## Climate mobility by 2050 in the IGAD region in the Horn of Africa



**Internal climate mobility by 2050 in the IGAD region (Rocky Road scenario)**

| Leaving | | | | | Total migrants | | | | | Ariving |
|---|---|---|---|---|---|---|---|---|---|---|
| 1M+ | 100k | 10k | 1k | 100 | 0 | 100 | 1k | 10k | 100k | 1M+ |

Source: ACMI Africa Climate Mobility Model, 2022.

3.1.3

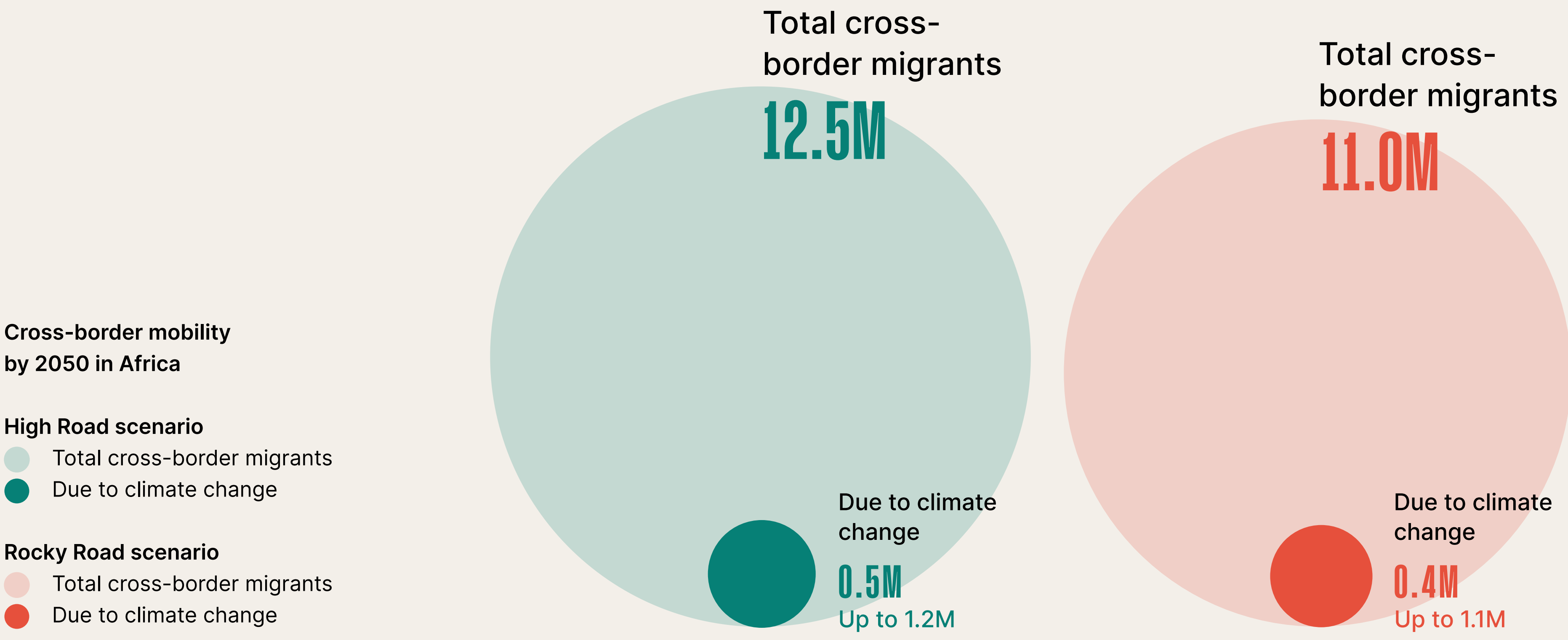
## Climate mobility may contribute up to 10 percent of cross-border migration by 2050

Between 2020 and 2050, the movement of people across borders in response to climate change is expected to be relatively small. Across Africa, 500,000 people — and potentially up to 1.2 million — are projected to migrate to a neighbouring country due to climate factors under the High Road scenario. This will be a small fraction of the continent's overall population and will contribute about 10 percent of total likely cross-border migration of 11 to 12 million people by 2050 (Figure 13).

**Figure 13**
Total projected cross-border migration in Africa compared with cross-border climate mobility by 2050. Across scenarios, climate-driven cross-border mobility could make up a significant share of overall projected migration between countries.

Figure 13

## Total cross-border migration compared with cross-border climate mobility by 2050




Source: ACMI Africa Climate Mobility Model, 2022.

These findings dovetail with those of previous research in Africa, which suggest that most climate-related mobility takes place within countries[18]. Only when extreme social or environmental conditions force a second migration, do people cross over into another country[59]. The UN World Migration Report found that over half of all migrants who moved within the African continent were relocating to countries within the same region as their country of origin[98, 116]. More than 70 percent of sub-Saharan migrants move within the continent[98, 116].

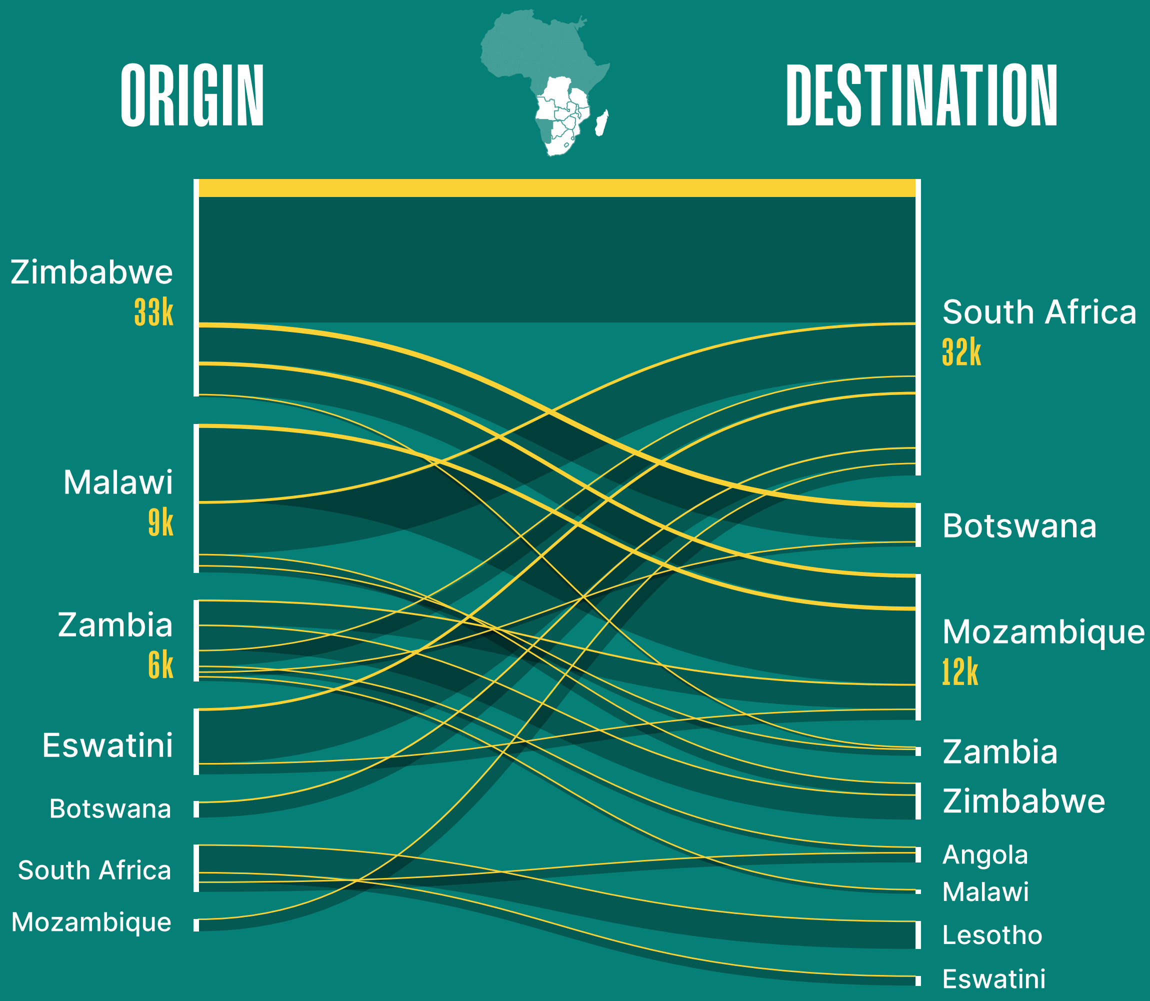
Cross-border climate mobility will be particularly pronounced in the Southern African Development Community (SADC). Between 200,000 and 800,000 people could be moving between neighbouring countries in the region by 2050 under the High Road scenario. Meanwhile, in the Economic Community of West African States (ECOWAS), climate impacts could lead to up to 200,000 fewer migrants crossing borders within the region by 2050 under the High Road scenario (Figure 14).

At the country level, Zimbabwe, Malawi, Uganda and Zambia could see the largest increases in emigration due to climate impacts, while South Africa, Zimbabwe, Mozambique, Botswana, and Kenya are forecast to see the largest increases in climate-driven immigration.

↓ **Figure 14**
Climate impacts will intensify cross-border mobility between neighbouring countries in the SADC region. Zimbabwe, where climatic conditions are forecast to improve, could become a major country of origin. Across the region, improved conditions for crop production are associated with higher outward mobility from the countries concerned. Improved crop yields may allow people to accumulate the resources needed for longer distance, cross-border migration.

Figure 14

## Contribution of climate mobility to total cross-border movements in the SADC region by 2050




**Cross-border mobility by 2050 under the Rocky Road scenario in the SADC region**

Migrants due to climate change

Other migrants

Source: ACMI Africa Climate Mobility Model, 2022.
Figure excludes mobility routes to and from Namibia.

### 3.1.4

## Inclusive development reduces climate mobility

Future projections of internal climate mobility for the Rocky Road scenario compared with the High Road scenario show that, by pursuing a more inclusive development path in line with its ambitions, the continent can mitigate some of the harmful effects of a high emissions future and significantly lower climate-forced migration and displacement in the coming decades. In the inclusive development scenario, the number of people likely to be forced to move due to climate impacts is reduced from 88 to 70 million, a 20 percent difference.

The importance of inclusive and sustainable development for mitigating harmful climate impacts is shown elsewhere: Without development progress, climate change is projected to push 40 million Africans into extreme poverty by 2030, with the brunt of the impact being felt in rising food prices[117–119]. The IPCC found this number is cut roughly by half under an inclusive economic growth scenario[7,117]. This suggests that Africa's best chance to cope with the challenges it faces in any of its likely climate futures is to work towards inclusive climate-resilient development. Africa has little influence over global carbon emission rates, but it can protect its people and lead by example by taking a greener, more inclusive development path.

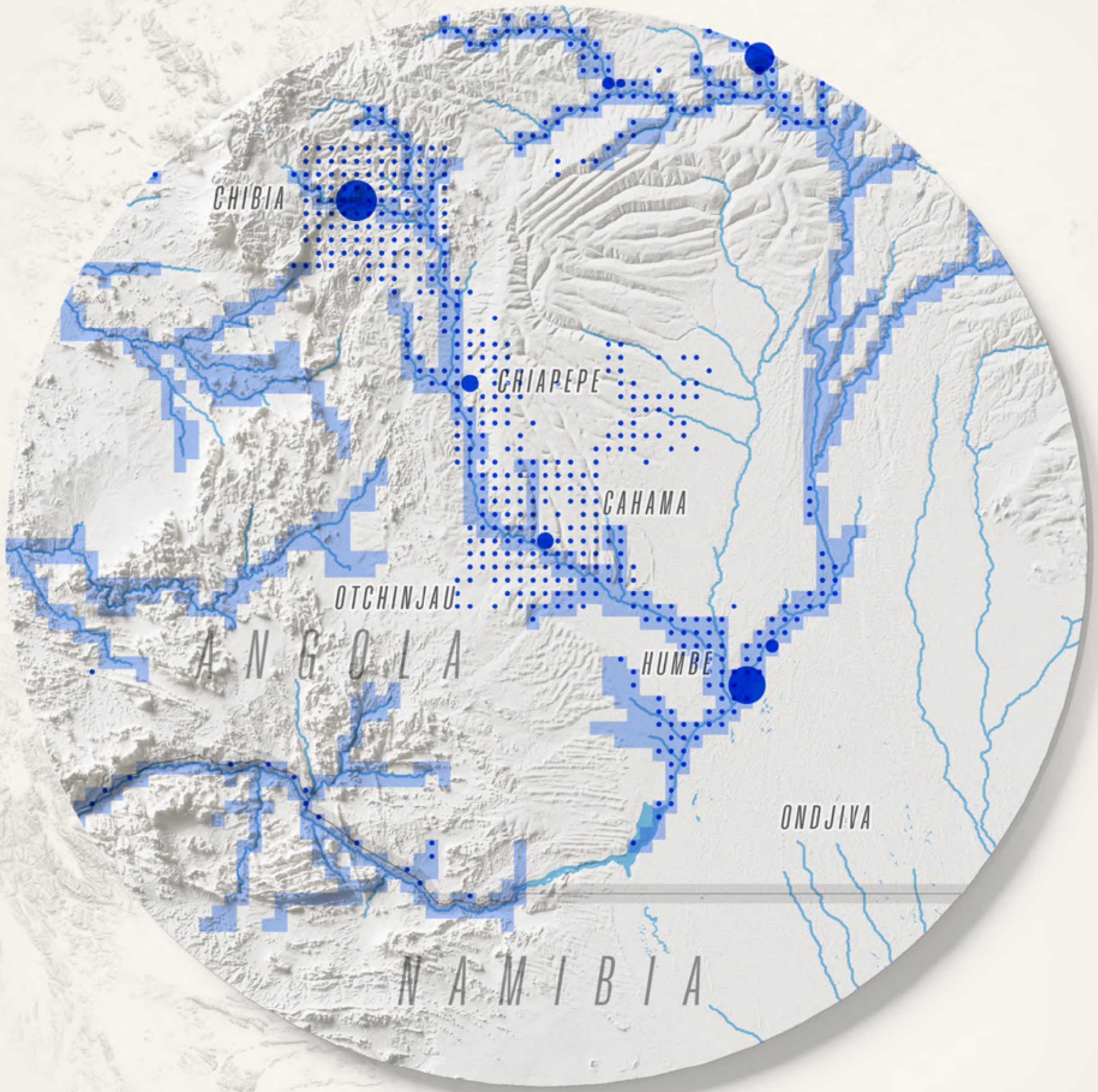
3.2

# Rural Shifts: Climate impacts are driving people from rain-fed farming areas, leading to major population shifts in pastoral lands

# 153k

While currently affected by severe droughts, river floods upstream from Humbe (Angola) are expected to drive 153 thousand people to move away by 2050. This movement will continue a generalized pattern of people moving towards irrigated lands within African countries.

**CAHAMA, ANGOLA**




**People leaving**

Expected number of people leaving their home due to climate change by 2050 (1k – 2M people)

**Flood risk**

Areas at risk of floods by 2050

Africa is particularly vulnerable to climate impacts because of its reliance on rain-fed agriculture and pastoralism for livelihoods. Africa's climate-exposed sectors are also its biggest employers: 55 to 62 percent of the sub-Saharan workforce is employed in agriculture, and 95 percent of cropland is rain-fed[7]. Africa has lost a considerable percentage of its anticipated growth in agricultural productivity due to climate change in the past few decades. Growth in the sector is 34 percent lower than it should have been since 1961 due to climate impacts, more than any other region of the world[17]. Arid and semi-arid countries in the Sahelian belt and the greater Horn of Africa are amongst the most vulnerable regions on the continent[120,121]. Pastoralists[122,123], fishing communities[124–126] and small-scale farmers[127,128] are among the most vulnerable livelihoods.

In rural Africa, poor and female-headed households face greater livelihood risks from climate hazards. Men tend to have larger farms than women, and women's smaller plots of land are largely used for subsistence purposes[129]. In many cases, women rely on their own or immediate family labour to work their fields, while men are able to hire labour more often than women[129]. Water scarcity can expose women to increased risk of gender-based violence[90,96]. Among pastoralists, women generally have lower coping and adaptive capacities to climate variability and change compared to men[130]. Drought can shift pastoralist migration patterns, causing families to split, which increases the household burden for women who typically remain behind[96]. Women generally have less secure land tenure and access to resources and savings, as well as having less technological capacity, all of which limits their ability to cope with crises and adapt[129,131].

### 3.2.1 The big drivers: Changes in water availability and crop yields

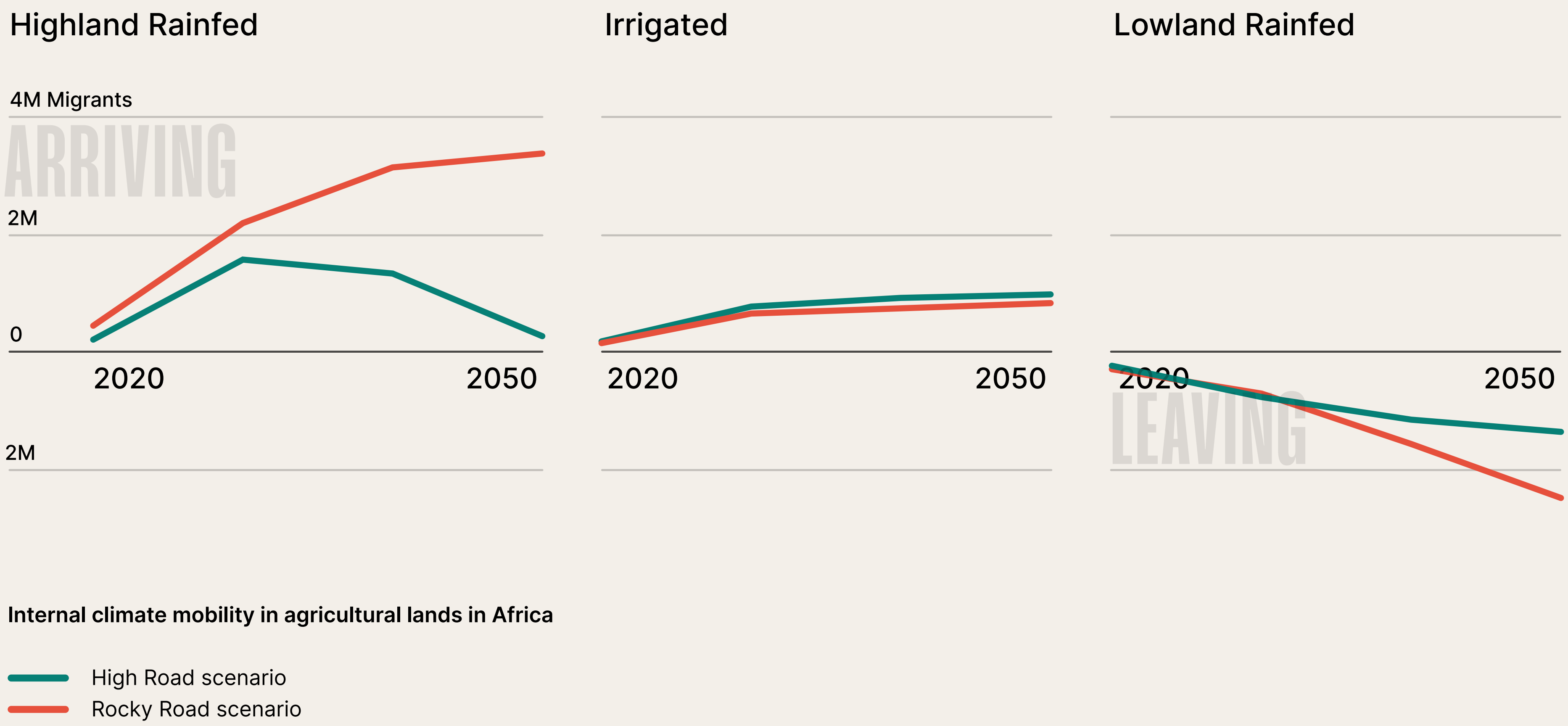
Changes in water availability and crop yields will be main drivers of climate mobility. When people move between rural areas, it will mostly be when climate impacts have disrupted water availability, inducing people to search for new livelihood opportunities. Water availability drives internal movement, and people are expected to mostly leave rain-fed lowlands when water availability declines. The farming systems in lowland rain-fed areas are likely to be out-mobility areas across all model scenarios, suggesting that higher temperatures lead to greater water scarcity and negative impacts on crops in these lowland tropical environments (Figure 15).

People are expected to leave highland rain-fed areas under the high emissions scenarios, but these areas are likely to attract populations under the low emissions scenarios. This suggests that some highland areas may become relatively more attractive if emissions are low, but this comparative advantage will likely be short-lived and disappear under higher emissions (both High Road and Rocky Road scenarios). Irrigated areas are projected to attract people, although they represent a comparatively small share of Africa's landmass.

Figure 15

## Climate mobility in and out of highland and lowland rainfed areas, and areas under irrigation by 2050

The future is particularly uncertain in highland rain-fed agricultural areas, where increases in internal migration trends may slow for both scenarios, and even reverse by 2030 under High Road scenario.




Source: ACMI Africa Climate Mobility Model, 2022.

Climate impacts on crop yields are a driving force behind projected cross-border movements. Climate impacts on crop production in countries such as Zimbabwe drive the projected increase in cross-border migration in the SADC region. Here, Namibia, Zimbabwe and Malawi are all likely to see climate-driven out-migration, while South Africa and Mozambique are expected to attract people. Climate impacts on the water and agricultural sectors are expected to reduce movement between countries in the Economic Commission of West African States (ECOWAS) region. Several Sahel countries — Mali, Burkina Faso, and Niger — are projected to experience declines in crop productivity that will likely slow the number of people crossing borders.

In the East African Community (EAC), Uganda is projected to see the greatest increases in cross-border movements going towards Kenya, due in part to better crop conditions in Uganda in the period 2020 to 2040. Confidence in the projections of climate-driven cross-border mobility is less conclusive after 2045. These findings are consistent with empirical evidence suggesting that cross-border migration levels generally slow in response to reduced crop yields in the country of origin, while internal mobility from affected areas may increase in some cases[26,47,132]. They also align with projections by the IPCC warning that crop yield losses, even after adaptation, are projected to rise rapidly above 2°C global warming[7].

As populations leave rain-fed lowlands, and some highland areas may become relatively more attractive in the near term, it will be increasingly important to consider how a wider range of climate impacts will affect these areas, with consequences for climate mobility and human well-being. Climate impacts on health are one example. Tens of millions more people are projected to be exposed to malaria in east and southern Africa as the Anopheles mosquito is projected to expand into higher altitudes which may overlap with rain-fed agriculture areas[133,134]. Further, the consequences of adaptation interventions for those moving or staying need to be carefully thought through. For example, small-scale irrigation infrastructure, if not managed properly, may serve as breeding grounds for malaria-causing mosquitoes[7].

### 3.2.2
## Climate mobility could reshape the population in pasturelands

From a continental view, agro-pastoral and pastoral areas will decrease across Africa, which is forecast to see a reduction of between 27 and 81 percent of the agro-pastoral zone[135]. Pastoralists in West Africa will need to contend with a projected decline of 42 percent of net primary productivity (that is the fertility of rangelands) by 2050 at 2°C global warming[7]. This would leave a significantly smaller area that is climatically suited for productive agro-pastoral practices and could threaten food security and livelihoods in those areas. Further, vector-borne livestock diseases and the duration of severe heat stress are both projected to become more prevalent under warming with increased livestock mortality and price shocks[7].

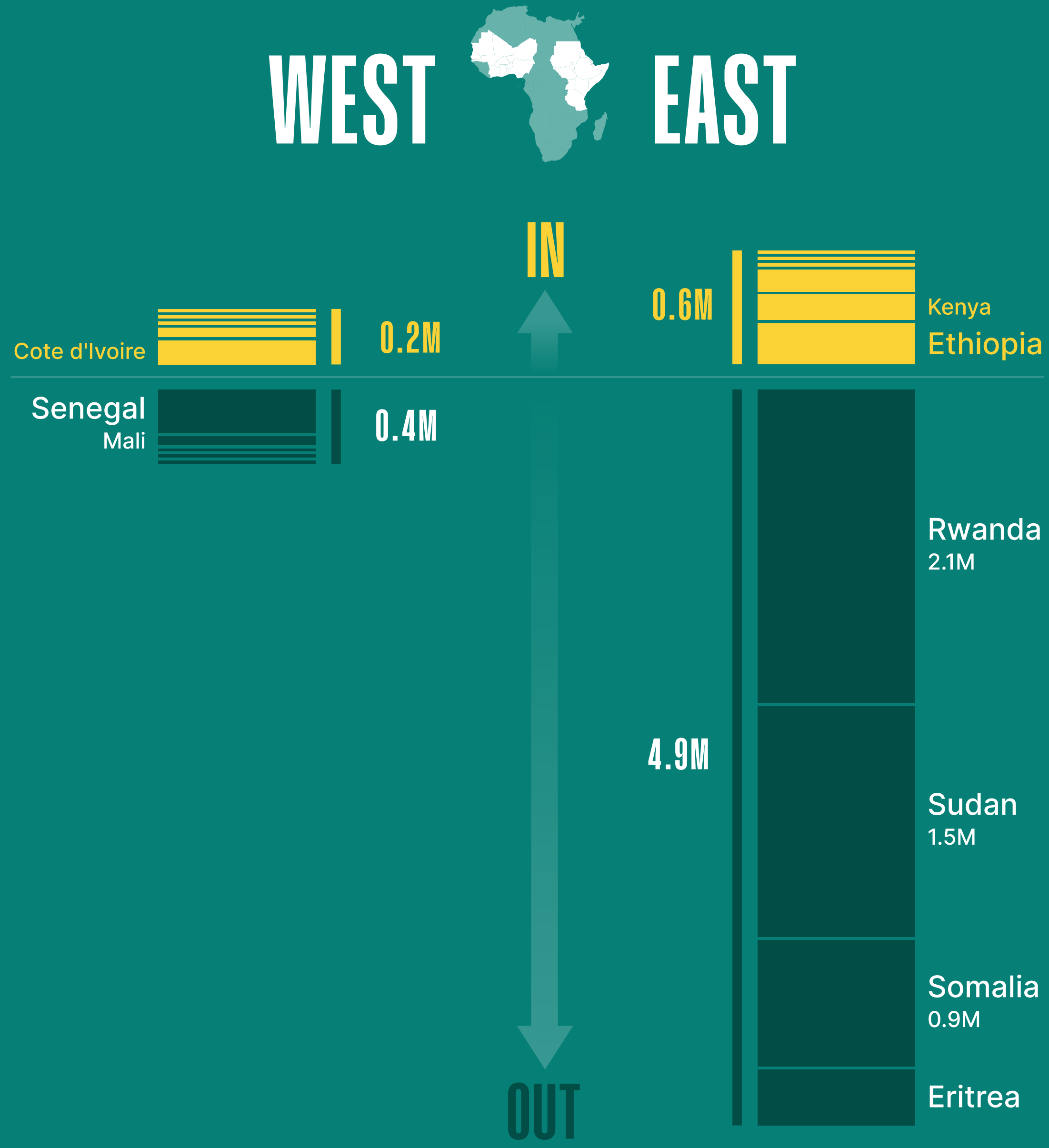
At a continental level, and across the different high emissions scenarios, Africa’s pastoral areas are forecast to see a net outward movement of people of around 4 million by 2050. However, the uncertainty around these projections is rather high. Outward movements could range as high as 8.7 million people or even reverse into a potential net population gain in pastoral areas of 0.7 million people under the Rocky Road scenario.

The analysis of climate mobility dynamics in pasturelands in West and East Africa shows both population gains and losses. Under low emissions scenarios, climate mobility into pasturelands is relatively high. However, in the High Road scenario, up to 3 million people are projected to leave pastoral areas by 2030, and 7.3 million by 2050. The Rocky Road scenario projects slightly lower out-mobility of 6.4 million people by 2050 (Figure 16).

Figure 16

# Climate mobility into and out of pastoral areas of East and West Africa by 2050

Internal climate mobility into and out of pastoral lands will be significantly greater and less balanced in East Africa compared to the west of the continent.




**Internal climate mobility by 2050 in pastoral areas under the Rocky Road scenario**

Incoming migration
Outgoing migration

Source: ACMI Africa Climate Mobility Model, 2022.

For West Africa, climate mobility could add between 250,000 and almost 2 million people to the population living in pasturelands. Senegal could see between 211,000 and 380,000 people migrating away from pastoral areas by 2050 under the Rocky Road scenario. Meanwhile, pasturelands in Côte d'Ivoire and Ghana are forecast to see an increase in population of 163,000 and 64,000 people respectively under the Rocky Road scenario.

In East Africa, pastoral areas could see a net population loss of as many as 1 million people by 2050 due to climate stressors. Rwanda and Sudan will see the highest population decreases, with around 3 million people moving out of pasturelands in Rwanda under the High Road scenario, and 1.5 million people forecast to leave Sudan's pastoral areas under both the Rocky Road and High Road scenarios. This is likely due to drying trends. Pastoral areas in Eritrea and Somalia could see smaller population declines.

However, in Ethiopia, Kenya and South Sudan, pastoral lands are projected to see more people moving in due to more favourable climatic conditions. Ethiopia is forecast to see the largest increase in population under the Rocky Road scenario, with around 280,000 people expected to move into its pastoral areas by mid-century.

Pastoral systems in Africa are already being affected by increased precipitation variability leading to decreasing water and fodder availability[7]. The future looks to hold increased stresses for these communities.

↓ **Figure 17**
Projections of climate mobility out of pasturelands show a trend of decreasing viability of these regions to support pastoral livelihoods. Suitability of pasture is projected to affect movement into or out of pastureland areas. Both High Road and Rocky Road scenarios indicate a similar median values of approximately 4 million people leaving Africa's pasturelands by 2015. However, there is also wide uncertainty to this projection with a potential high of 8.7 million leaving pasturelands (Rocky Road) as well as a potential that there could be a marginal increase in population in pasturelands by 2050 (Rocky Road).

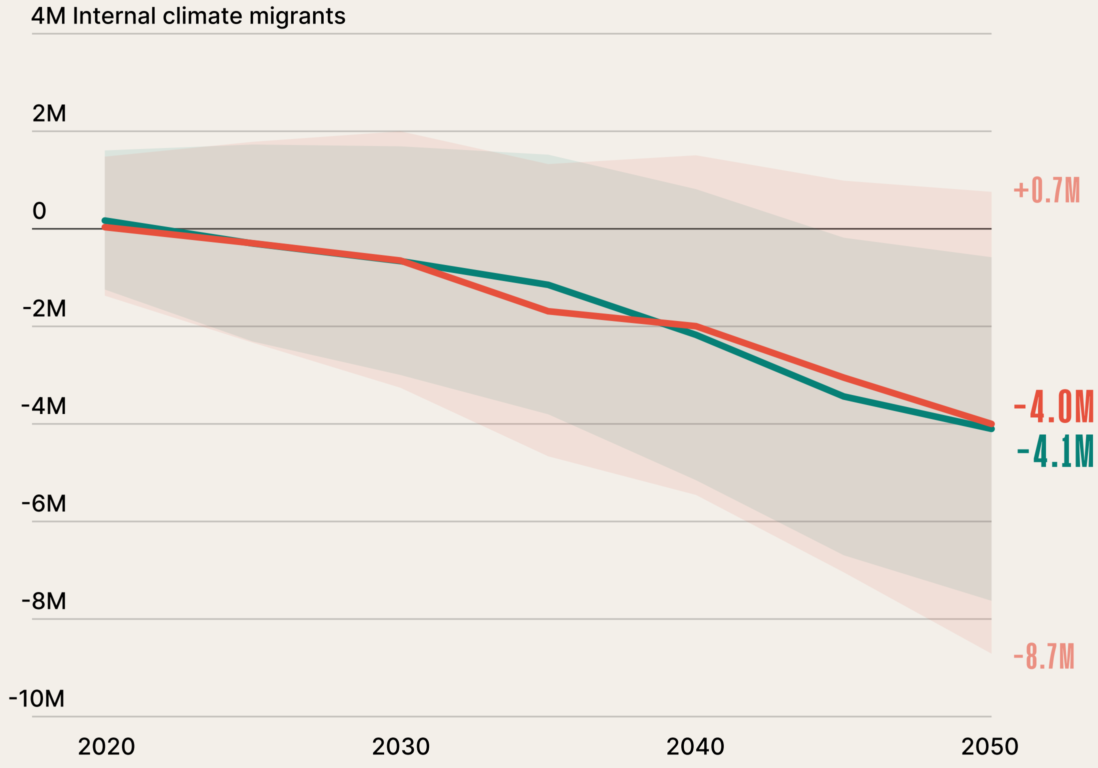
Figure 17

# Climate mobility out of pastureland areas until 2050

**Internal climate mobility in African pasturelands**

High Road scenario
Uncertainty (95% confidence)

Rocky Road scenario
Uncertainty (95% confidence)




Source: ACMI Africa Climate Mobility Model, 2022.

3.3

# Cross-border Bonds: Climate impacts drive movements into and out of border areas, increasing contact and potential for cooperation

Borderlands can be dynamic areas for cross-border and internal mobility, as they often have strong trade links, and high concentrations of population and economic activity[136,137]. Yet, many African borderlands exist on the periphery of the social contract, with limited government presence, rule of law, and service delivery.

### 3.3.1

## On the margins: Borderland climate mobility hotspots

At a continental level, the areas surrounding national borders will largely see an outflow of people in response to climate disruption. Nevertheless, some border areas are expected to draw a large number of arrivals (Figure 18). Dense clusters of climate mobility emerge by 2050, including along the Nigeria-Niger border; in northern Ethiopia, Eritrea and Sudan; along the border between the Democratic Republic of Congo, Rwanda, and Uganda; and on the border between Malawi and Mozambique.

Climate mobility into and out of borderland areas is very high in the IGAD region. This is consistent with the high rate of projected internal climate mobility relative to the expected population in the region. Notable climate destinations emerge in the border area between Eritrea and Sudan, the Ethiopian side of its borders with Eritrea and Sudan, and Somalia's border with Kenya. The Ethiopian side of the Ethiopia-Somalia border will likely see the highest number of climate-related arrivals of any borderland in the continent[a], with about 1.4 million people likely to make this move.

The Lake Victoria region is another critical border area for climate mobility. In the Democratic Republic of Congo, climate impacts are likely to drive substantial movements away from low-lying and flood prone areas in the west, with people moving towards the borders with Rwanda and Uganda in the eastern highlands (the Rift Valley), and Lubumbashi in the south.

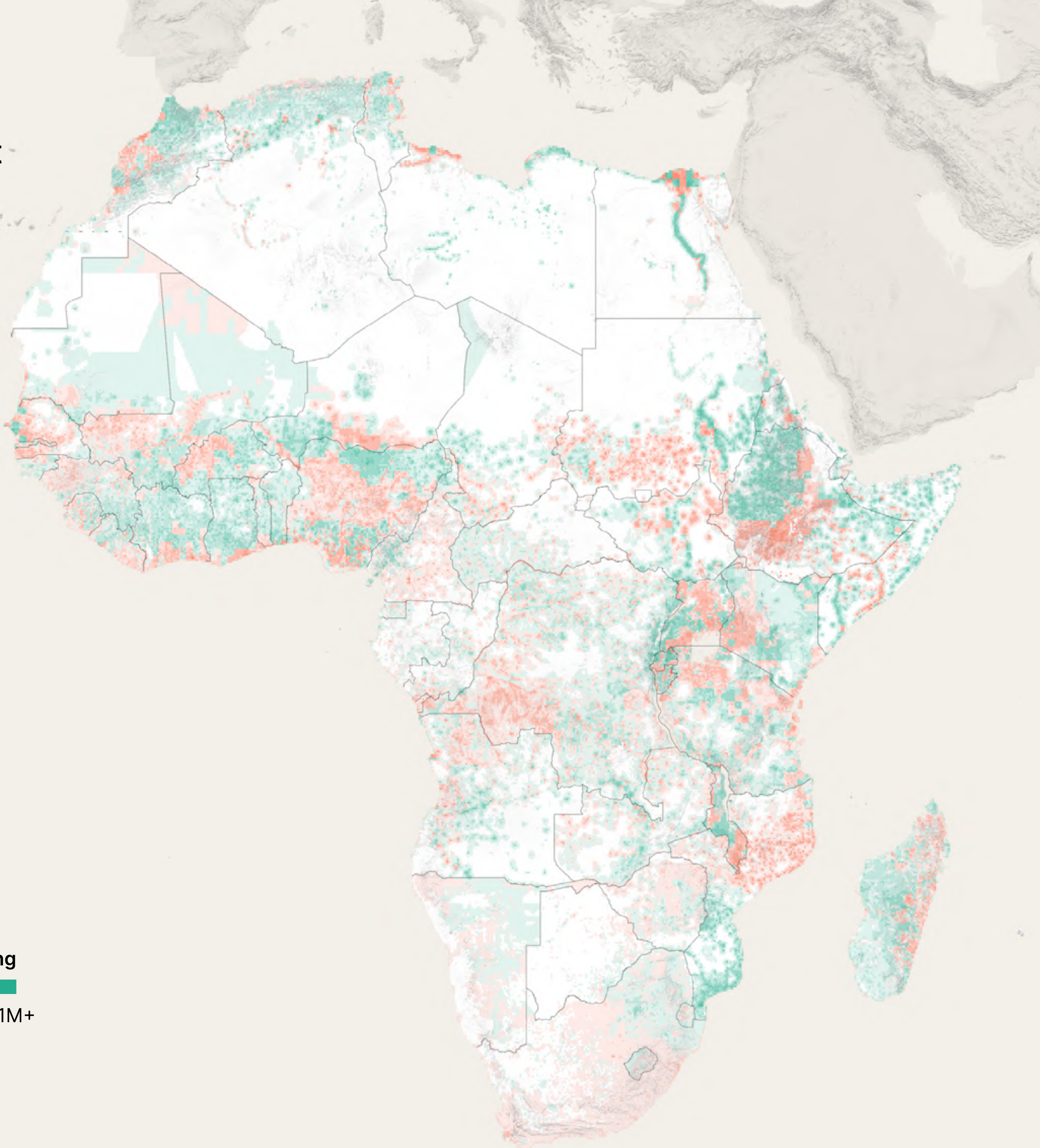
In Malawi, people are expected to depart areas in the south, while the middle and northern parts of the country gain population. Mozambique may see many climate arrivals in its southern regions along its borders with Eswatini and South Africa. Along the Niger-Nigeria border, the population is forecast to increase on the Nigerian side of the border.

a This excludes Rwanda, which under the modelling's definition of borderlands as the spaces that are within 50 km on each side of an international border, was considered almost entirely made up of border area.

↓ **Figure 18**
Internal climate mobility hotspots (movements within countries). Density of colours indicates number of people per square kilometre. Climate mobility projections assume people will move based on push and pull factors associated with climate impacts. Where impacts will be negative, projections show movement out of those regions. Where impacts are projected to result in comparatively better conditions (such as suitability for certain crops), projections indicate movement to, and a growth of population in, such areas. Total numbers represent deviations between the climate impacts and no climate impacts projections, which represent, in turn, differences in population distributions in the respective years, and therefore a cumulative shift in population distribution.

Figure 18

## Continental hotspots depicting the number of people moving out of and into specific areas owing to climate impacts



**Internal climate mobility hotspots by 2050 under the Rocky Road scenario**

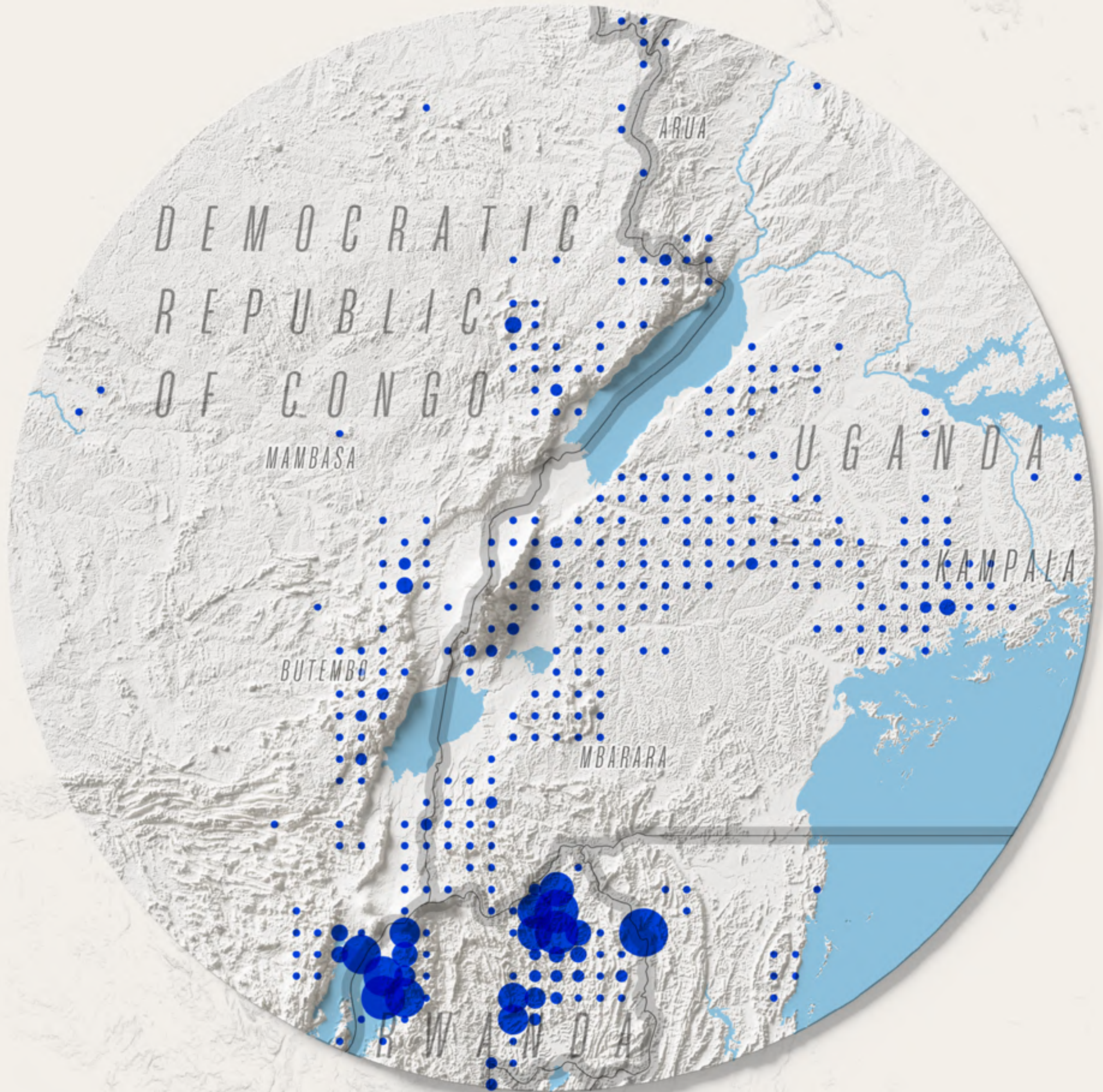
| **Leaving** | | | | | **Total migrants** | | | | | **Ariving** |
|---|---|---|---|---|---|---|---|---|---|---|
| 1M+ | 100k | 10k | 1k | 100 | 0 | 100 | 1k | 10k | 100k | 1M+ |

Source: ACMI Africa Climate Mobility Model, 2022.

# 1.1M

Borderlands around the Rift Valley are projected to become major climate mobility hotspots. Rwanda's border area with Uganda could see up to 1.1 million new arrivals by 2050. However, particular locations within the same area will see incoming mobility of a comparable magnitude, as borderlands will continue humming with activity.

**RIFT VALLEY, UGANDA**




**People leaving**

Expected number of people moving to this areas due to climate change by 2050 under the Rocky Road scenario (1k – 700k people)

## 3.3.2

# Spaces of refuge and friction

Climate impacts and climate mobility can add stress to border communities that are already experiencing violence, instability and underinvestment. Many African borderlands are already spaces of refuge that host large numbers of refugees and internally displaced people (Figures 19A & B). Refugee and IDP camps are often located along borders as people try to stay close to home and authorities seek to contain these populations. African communities are generally inclusive of newcomers and peaceful coexistence is the norm. Yet, in a number of borderland areas, climate and conflict dynamics intersect. Various forms of illicit trade and cattle rustling, as well as state border security measures make border crossings perilous for pastoralists. Restrictive border policies trap herders in areas where they are more exposed and vulnerable than if they had been able to migrate. This risks bringing them into conflict with state authorities, other pastoralist groups, or communities that are settled[138].

It will be important to understand how climate impacts might increase tensions and the potential for political violence in certain border areas (Figure 19B). For example, the border of Burkina Faso and Mali has seen increasing tensions in recent years as Islamist groups have become active in this area. Camps for internally displaced people (IDP) and refugees across these borderlands are likely to see people move out over the coming 30 years, in response to climate factors, a trend that may be accelerated by conflict. The number of people expected to leave Burkina Faso's border with Mali, for instance, could be as many as 133,000. This is in stark contrast to projected climate in-mobility on its borders with Niger, Benin, Togo, and Cote d'Ivoire.

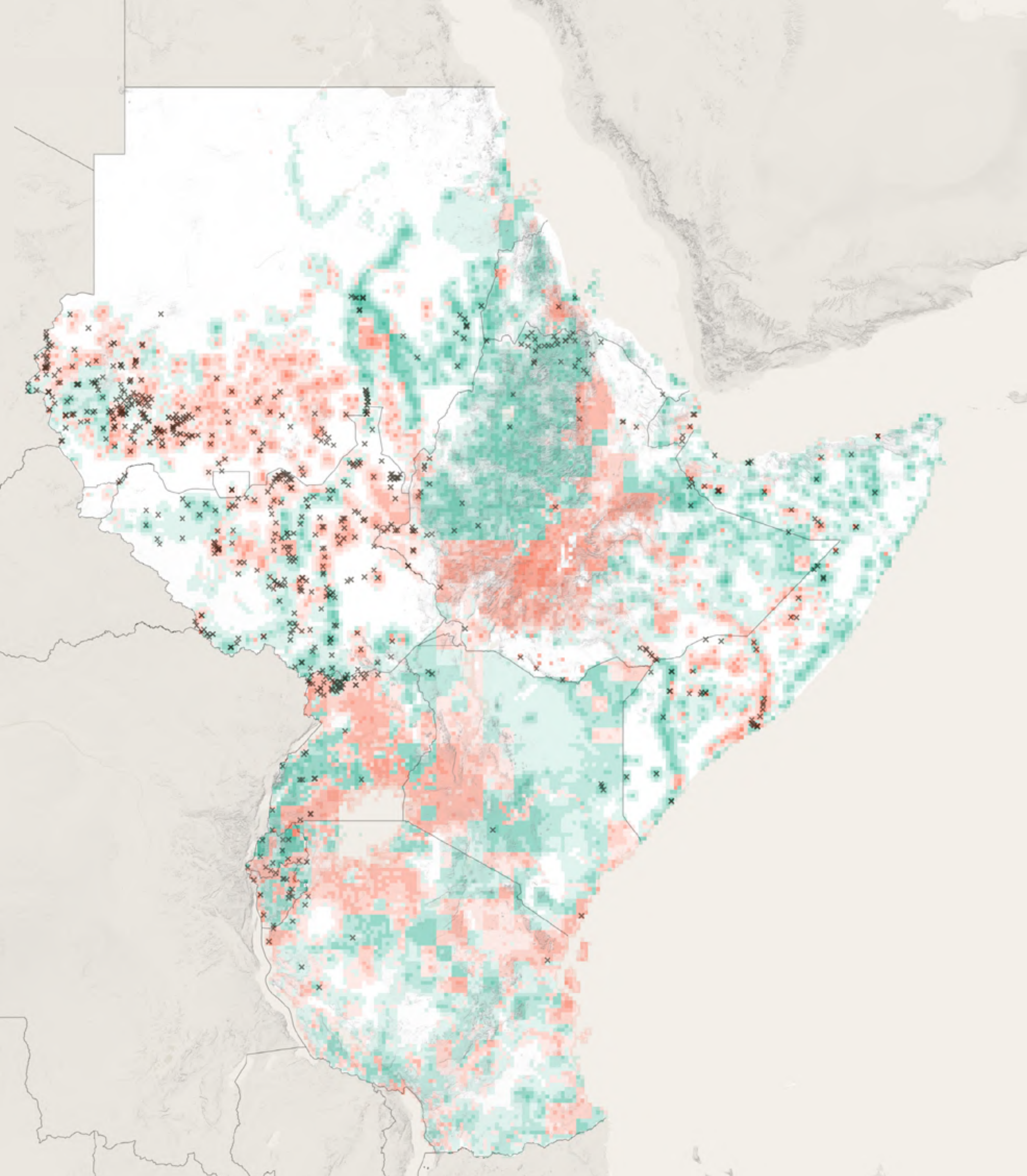
Targeted investments in borderland areas that extend national government authority and provide services throughout the national territory, as well as decentralised and place-based approaches to development, including joint transboundary development planning, could address some of the challenges facing remote border areas.

Climate services and early warning mechanisms are also highly relevant, as levels of climate literacy and an understanding of climate risks are particularly low in many border areas.

↓ **Figure 19A & B**
The number of people moving out of (orange) and into (green) specific areas owing to climate impacts. Borderland areas in both East and West Africa that already see large-scale displacement are forecast to be hotspots for climate mobility in the future. Density of colours indicates number of people per square kilometre. Each '×' on the maps indicates current locations of refugee and internally displaced persons (IDPs camps). Climate mobility projections assume people will move based on push and pull factors associated with climate impacts. Where impacts will be negative, projections show movement out of those regions. Where impacts are projected to result in comparatively better conditions (such as suitability for certain crops), projections indicate movement to and a growth of population in such areas. Total numbers represent deviations between the climate impacts and no climate impacts projections, which represent, in turn, differences in population distributions in the respective years, and therefore a cumulative shift in population distribution.

Figure 19A

## Internal climate mobility hotspots areas in East Africa showing also current locations of refugee and internally displaced persons camps



**Internal climate mobility hotspots by 2050 in East Africa under the Rocky Road scenario**

**Leaving** **Total migrants** **Arriving**

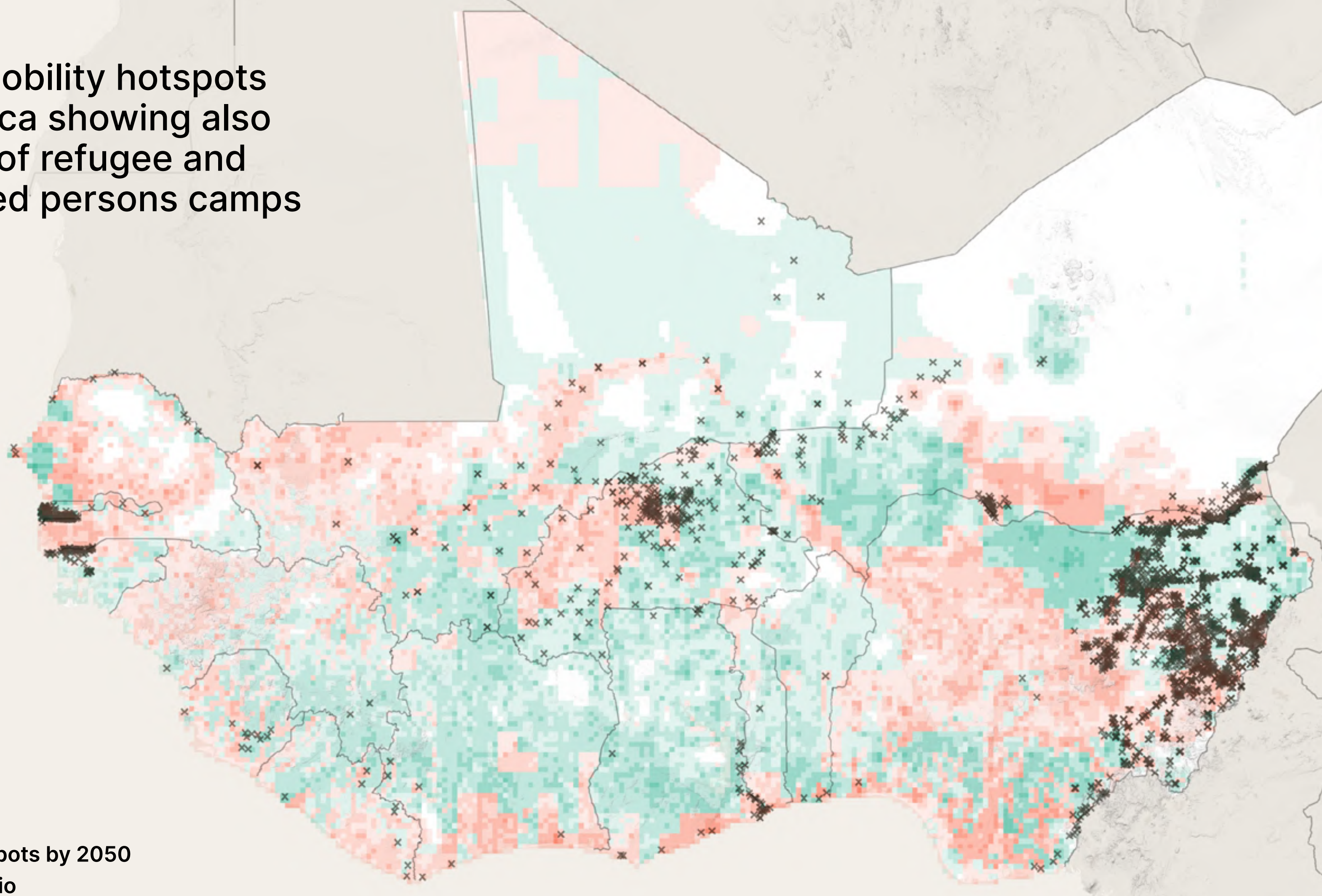
1M+ 100k 10k 1k 100 0 100 1k 10k 100k 1M+

× Internally displaced people and refugee camps (UNHCR)

Source: ACMI Africa Climate Mobility Model, 2022.

Figure 19B

## Internal climate mobility hotspots areas in West Africa showing also current locations of refugee and internally displaced persons camps



**Internal climate mobility hotspots by 2050 under the Rocky Road scenario**

| Leaving | Total migrants | Arriving |
|---|---|---|
| 1M+ 100k 10k 1k 100 | 0 | 100 1k 10k 100k 1M+ |

× Internally displaced people and refugee camps (UNHCR)

Source: ACMI Africa Climate Mobility Model, 2022.

3.4

# Pivotal Cities: Cities and towns will be dynamic hubs as people move to, within, and out of urban settlements

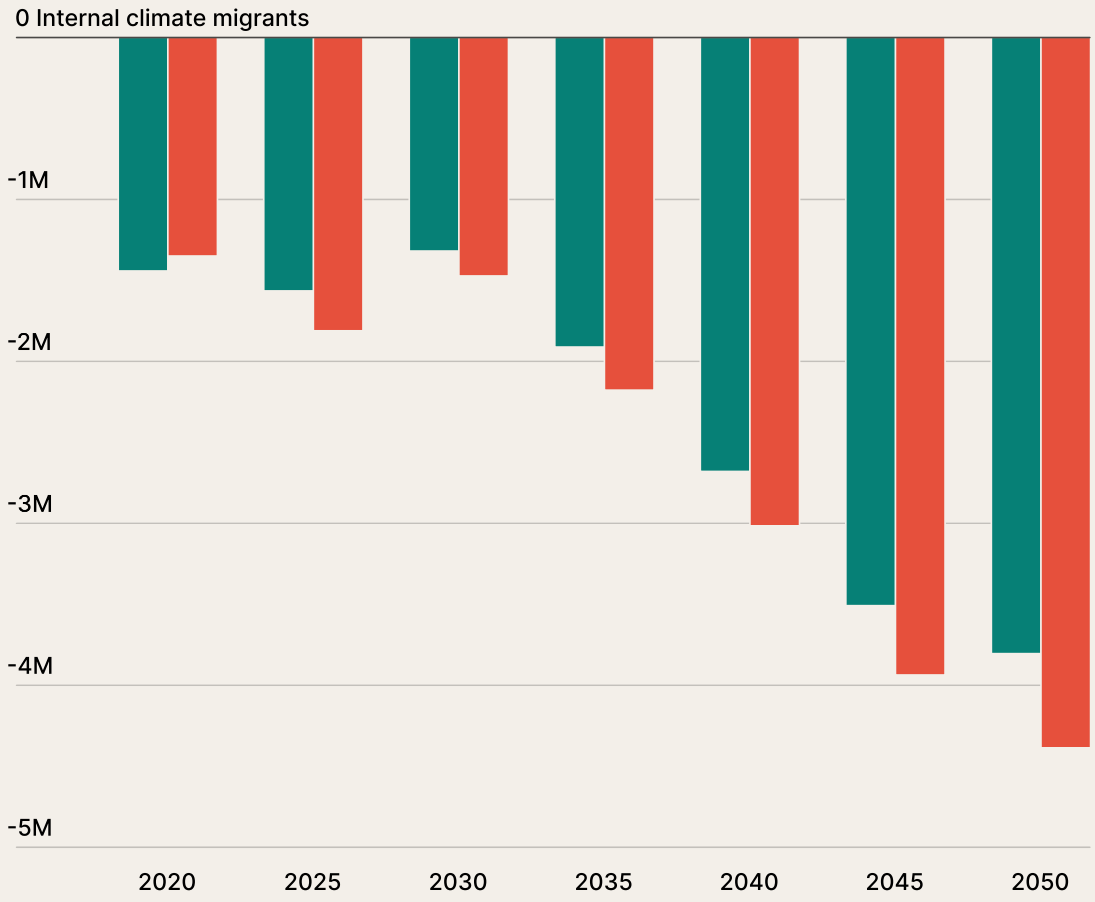
Within 25 years, Africa's urban population will be larger than that of North America, Europe, or Latin America[139]. Africa is the most rapidly urbanising region globally and is expected to become a majority urban population in the 2030s, reaching 748 million urban dwellers. This will rise to 60 percent by 2050[99]. The bulk of Africa's urban population growth until 2035 will take place in towns with fewer than 500,000 residents[139]. However, there are large differences across regions. Southern Africa is likely to be 77 percent urbanised, whereas East Africa will only be about 47 percent urban by 2050[99].

Africa's rapidly growing cities will be hotspots for climate risks as they experience compounding shocks of extreme events that will damage human settlements and critical infrastructure[7]. Compared to 2000, urbanisation is projected to increase the extent of urban land exposed to arid conditions by around 700 percent and exposure to high-frequency flooding by 2,600 percent across West, Central and East Africa by 2030[7]. Urban flooding has been growing on the continent[140]. Urban population exposure to extreme heat is expected to increase dramatically, when measured in terms of the annual average number of days with a maximum temperature above 40.6°C, multiplied by the number of people exposed to that temperature. From a 1985–2005 baseline of 2 billion person-days per year, heat exposure could rise to between 45 and 95 billion person-days per year by the 2060s, assuming 1.7°C global warming and low population growth[7]. Populations in rapidly urbanising areas, especially in informal settlements, are particularly affected by extreme heat, flooding, extreme rainfall, sea level rise, and erosion[7].

Figure 20

# Projected internal climate mobility out of urban areas compared with 2015 baseline

At continental scale, across all cities, Africa will see urban population losses due to climate mobility, driven by increasing risks to urban areas.




**Internal climate mobility in urban areas in Africa**

High Road scenario
Rocky Road scenario

Source: ACMI Africa Climate Mobility Model, 2022.

## 3.4.1

# Climate mobility will slow growth in some cities, but rapid urbanisation continues in general

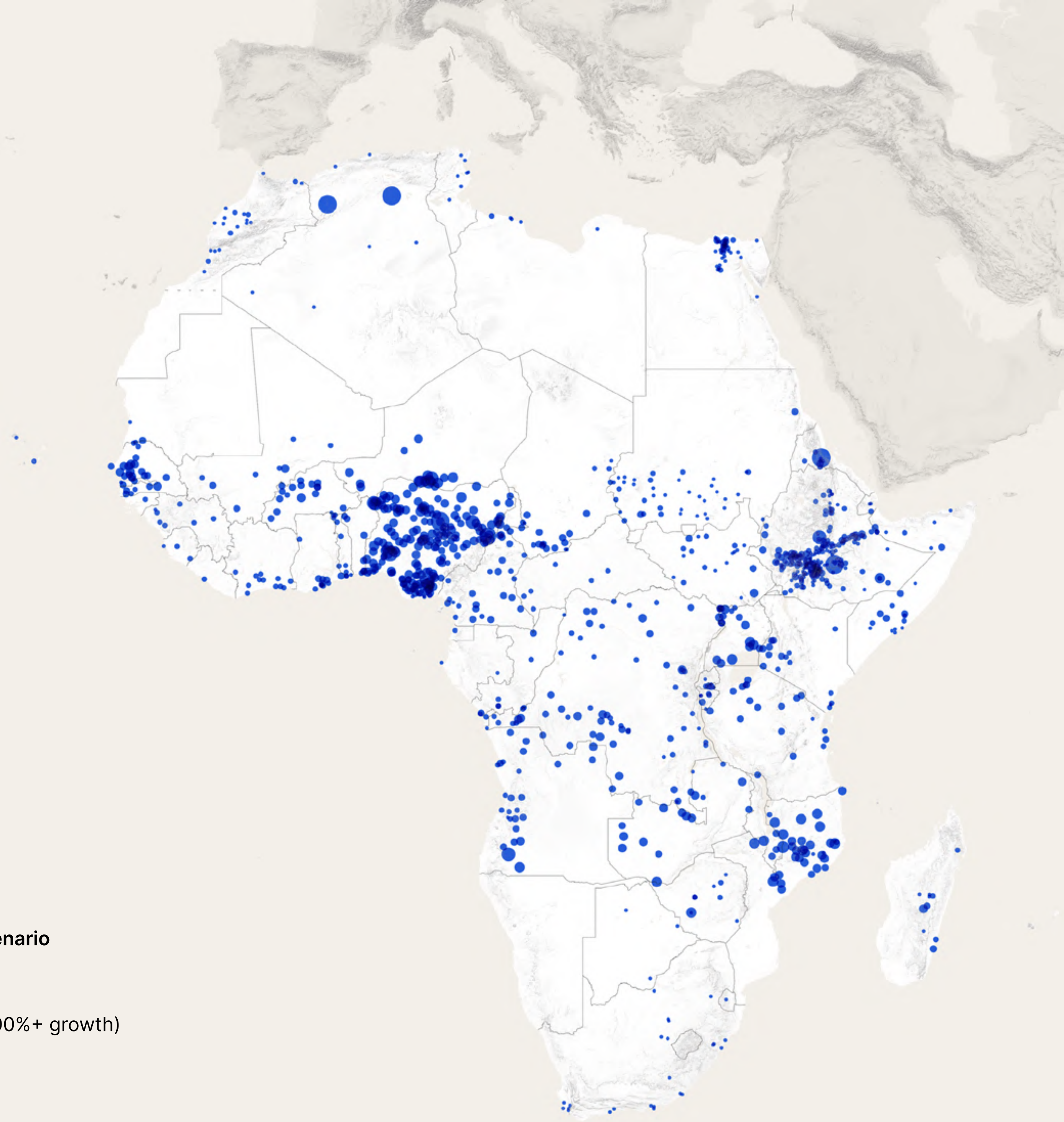
Africa's urban areas are forecast to largely be climate mobility source areas by 2030, across all model scenarios (Figure 20). By 2050, these negative trends are projected to continue, with the Rocky Road scenario — which assumes lower urbanisation and higher population growth across the continent — forecasting that up to 4.2 million people could leave cities. However, given the overall projected urban growth of 1.5 billion people by 2050, even this high-end projection of climate-related movements away from cities would only slightly reduce urban populations[99].

Most cities that are forecast to see outward mobility due to adverse climate impacts will continue to grow, raising the prospect of more people remaining in areas at risk (Figure 21). Much of the population growth in African cities will occur in informal settlements that absorb both climate and non-climate driven rural-urban migration[141–144]. Many of these settlements are in areas exposed to climate hazards such as floods, landslides, sea level rise and storm surges in low-lying coastal areas, or alongside rivers that frequently overflow[7]. Most migrants from rural areas are not formally educated or skilled, and often end up working in the informal sector, which accounts for 93 percent of all new jobs and 61 percent of urban employment in Africa[145]. Incomes from the informal sector are by their very nature low and intermittent. Consequently, by moving to the city migrants often replace one set of vulnerabilities with another as they try to make ends meet[23,61,84,146].

Figure 21

## Growing cities that will see climate out-mobility by 2050

Numerous cities across the continent will continue to grow despite losing population to climate mobility as people depart due to negative climate impacts, highlighting the need to support a growing population that remains in at-risk areas.



**Population growth by 2050 under the Rocky Road scenario in cities with outgoing climate mobility**

Growing cities with outgoing mobility (10% to 500%+ growth)

Source: ACMI Africa Climate Mobility Model, 2022.

## 3.4.2
## Some cities will shrink due to climate mobility

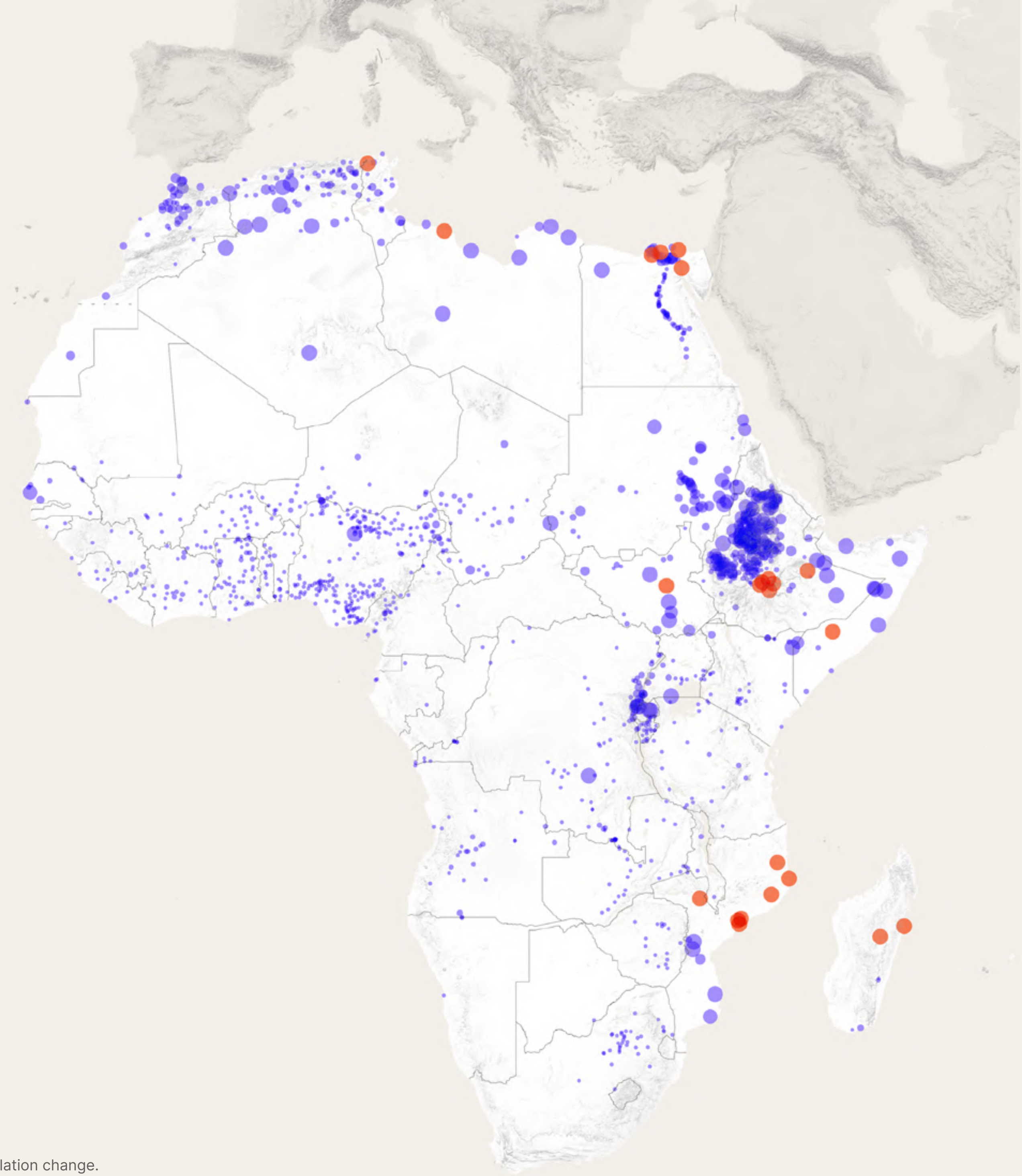
Several cities will see climate impacts drive people out of urban areas or away from more exposed to less risky areas within the city. Of the top four climate mobility source cities — Accra, Desouk, Casablanca and Asmara — the first three are coastal or on major rivers and are projected to experience increases of either sea-facing or river system flooding. Asmara and Casablanca are in semi-arid environments and are likely to see declines in water availability and crop production. Abidjan is the largest among the top ten climate mobility source cities and is projected to see outward mobility due to impacts from sea level rise and flooding.

In Casablanca, under the Rocky Road and High Road scenarios, climate mobility reinforces an overall population decline in the city by 2050. There are other African cities where climate mobility contributes to an actual decline in population over the next decades. These are primarily in Algeria, Ethiopia, Madagascar, Morocco and Mozambique (Figure 22).

Figure 22

# Cities and towns that could see an overall population change due to climate mobility by 2050

While the effect of internal climate mobility will generally contribute to urban growth, it could be a major driver of population decline in cities in the north and east of the continent.



**Climate mobility contribution to urban population change in 2050 under the Rocky Road scenario**

Growing cities (5% to 75% contribution change)
Declining cities (5% to 75% contribution change)

Source: ACMI Africa Climate Mobility Model, 2022.
The size of circles ranges between 5 and 75% contribution of climate migration to population change.

3.4.3

## In many cities, climate mobility adds to population growth

Many African cities and towns will see climate mobility accelerate rural-urban migration and contribute to population growth (Figure 23).

Khartoum, Maputo, Goma, Tripoli and Kigali emerge as important climate mobility destinations on the continent. Maputo could grow by up to 1.5 million people due to climate mobility by 2050 under the Rocky Road scenario as water availability and crop production in northern Mozambique suffer from negative climate impacts. Similarly, Khartoum is projected to receive migrants affected by climate impacts in the hinterlands.

In Lusaka, flood impacts in surrounding areas could drive people into the city, under both the High Road and Rocky Road scenarios (Figure 24). Under the Rocky Road scenario climate migrants make up 1 percent of the city's projected population in 2050.

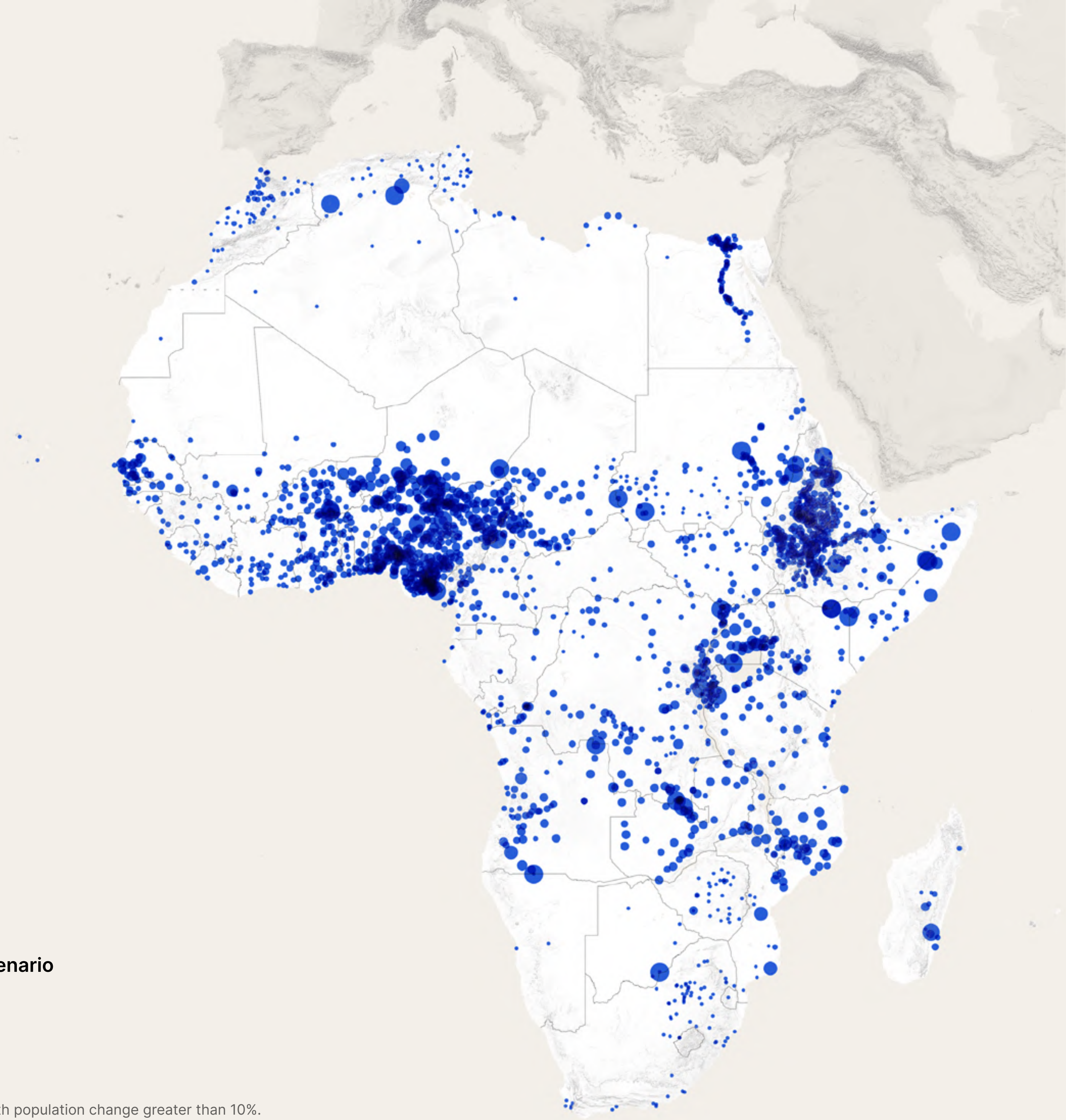
The impact of climate mobility on overall urban population growth will be particularly pronounced in smaller cities and towns. In Juba, South Sudan, and Jijiga, Ethiopia, climate mobility is projected to account for virtually all urban growth by 2050.

Managing climate mobility into these smaller cities will present an increasing challenge, as many municipalities lack the necessary institutional, financial and technological capacity to cope with their already rapidly growing populations[7,139,147]. However, if they are proactive, small cities have time to address residents' basic infrastructure and service needs before the magnitude of the service gap becomes too overwhelming. Small cities that are growing rapidly also offer critical opportunities to bypass old technologies and implement efficient, ecologically sound practices that can contribute to shaping a more sustainable future[139].

Figure 23

# Population growth in cities by 2050

Following long-term trends, cities across the continent will most likely continue to grow in population over the next decades.



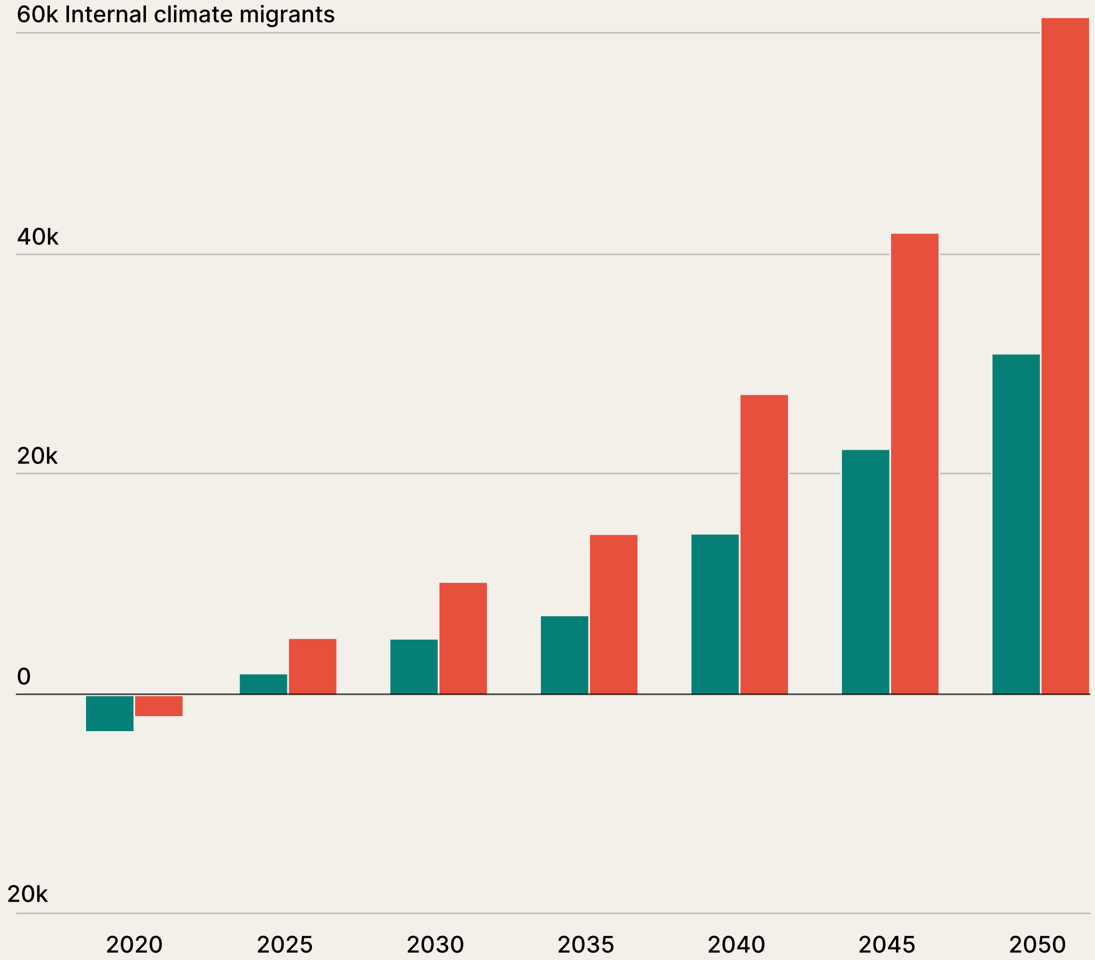
**Population growth by 2050 under the Rocky Road scenario**

Growing cities (10% to 500%+)

Source: ACMI Africa Climate Mobility Model, 2022. Showing only cities with population change greater than 10%.

Figure 24

# Climate mobility into Lusaka, Zambia, by 2050 due to increased flooding in the city's hinterlands




**Internal climate mobility in Lusaka, Zambia**

High Road scenario
Rocky Road scenario

Source: ACMI Africa Climate Mobility Model, 2022.

# 82k

Lusaka is projected to become a climate mobility destination for up to 82 thousand people evading flood risk in the surrounding areas by 2050. However, not all urban areas in the continent will become safer, as some (particularly coastal) cities might be at greater climate risks over time.

**DAR ES SALAAM, TANZANIA**


**People arriving**

Expected number of people moving to these areas due to climate change by 2050 (50 – 30k people)

**Flood risk**

Areas at risk of floods by 2050

## 3.5

# A Coastal Dent: Sea level rise will force people to abandon some low-lying coastal areas, despite the opportunities they offer

High population growth and urbanisation in low-lying coastal zones will expose more people to sea level rise in the next 50 years, which could become a major driver of climate mobility[7].

By 2030, 108 million to 116 million people in Africa are expected to be exposed to sea level rise (compared with 54 million in 2000), increasing to 190 to 245 million by 2060[7,148]. Coastal areas are expected to be climate mobility destinations until 2030, as inland climate impacts drive mobility into coastal zones. But as sea level rise and increasing riparian flooding begin to affect coastal areas, the trend will turn, and by 2050 people are projected to leave these areas (Figure 26).

↓ **Figure 25**
Multiple large African cities will be exposed to sea level rise. Selected examples include: (a) Dar es Salaam, Bagamoyo and Stone Town in Tanzania (east Africa), (b) Lagos in Nigeria, and Cotonou and Porto-Novo in Benin (west Africa) and (c) Cairo and Alexandria in Egypt (north Africa). Orange shows built-up area in 2014. Shades of blue show permanent flooding due to sea level rise by 2050 and 2100 under low (RCP2.6), intermediate (RCP4.5) and high (RCP8.5) greenhouse gas emissions scenarios. RCP8.5 and RCP 4.5 were not used in the Africa climate mobility model (see Appendix for reasons), however they are included in this Figure together with RCP2.6 to show the potential range of sea level rise and risk by 2050 and 20100 even for ranges lower than RCP6.0. Darker colours for higher emissions scenarios show areas projected to be flooded in addition to those for lower emissions scenarios. The figure assumes failure of coastal defences in 2050. Some areas are already below current sea level and coastal defences need to be upgraded as sea levels rise (e.g., in Egypt), others are just above mean sea levels and they do not necessarily have high protection levels, so these defences need to be built (e.g., Dar es Salaam and Lagos). Blue shading shows permanent inundation surfaces predicted by Coastal Digital Elevation Model (DEM) and Shuttle Radar Topography Mission (SRTM) given the 95th percentile K14/RCP2.6, RCP4.5 and RCP8.5, for present day and 2050 sea level projection for permanent inundation (inundation without a storm surge event), and RL10 (10-year return level storm). Low-lying areas isolated from the ocean are removed from the inundation surface using connected components analysis. Current water bodies are derived from the SRTM Water Body Dataset. Orange areas represent the extent of coastal human settlements in 2014 (recreated from and used with permission from IPCC7).

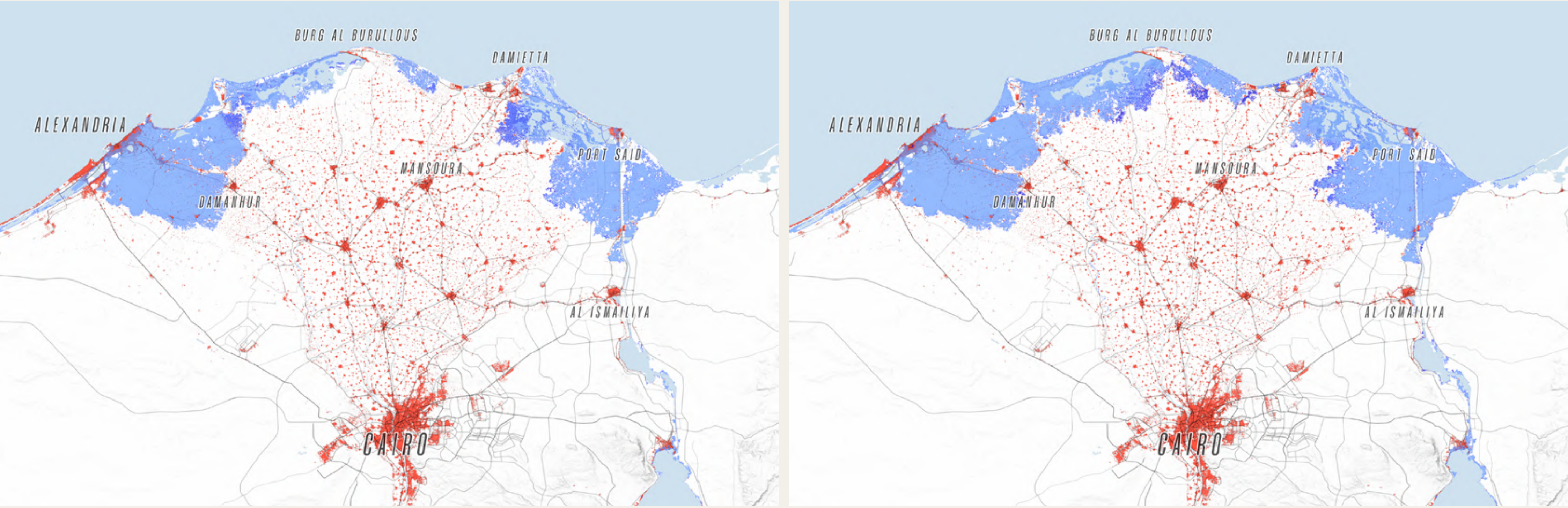
↓ **Figure 26**
There will be an initial increase in climate mobility into coastal zones up till 2030, but the trend will turn after 2030 as sea level rise and increasing riparian flooding begin to affect coastal areas, and by 2050 people are projected to leave these areas under both high emission scenarios (Rocky Road and High Road).

Figure 25A

# Multiple large African cities will be exposed to sea level rise: Cairo and Alexandria (Egypt)

2050

2100




**Sea level rise expected per scenario**

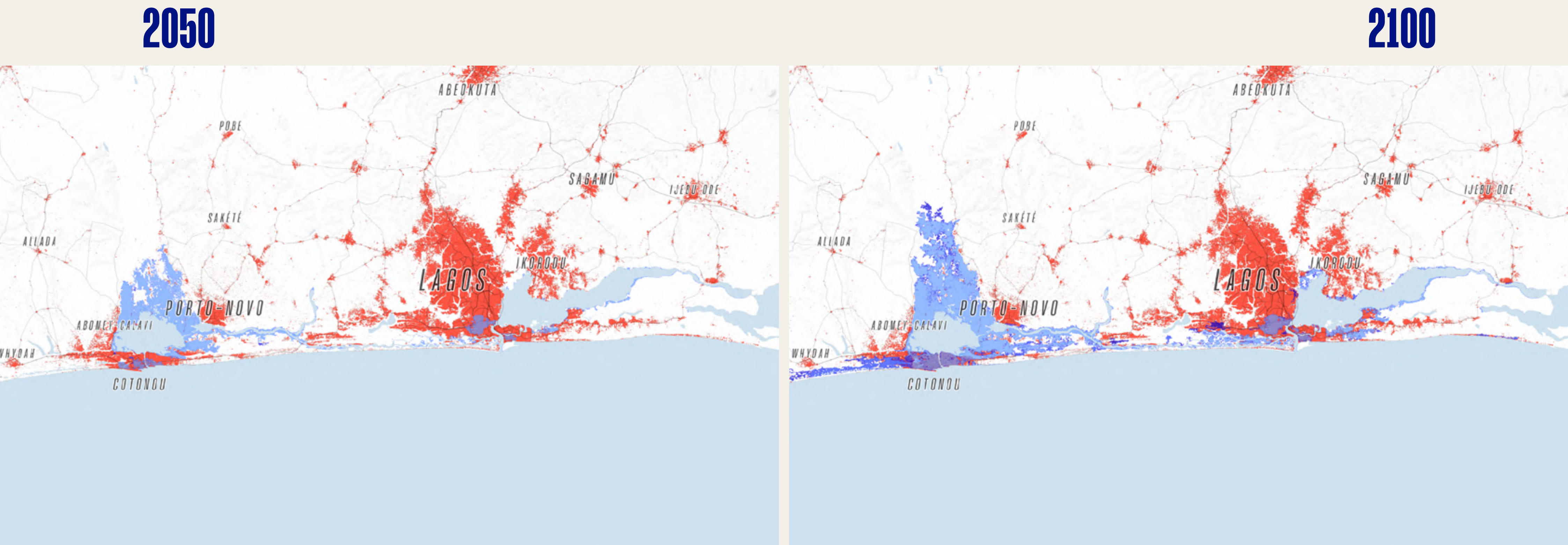
RCP 2.6 RCP 4.5 RCP 8.5

**Built-up area to year 2014**

Source: Trisos *et al.*, 2022.

Figure 25B

## Multiple large African cities will be exposed to sea level rise: Lagos (Nigeria) and Cotonou and Porto-Novo (Benin)




**Sea level rise expected per scenario**

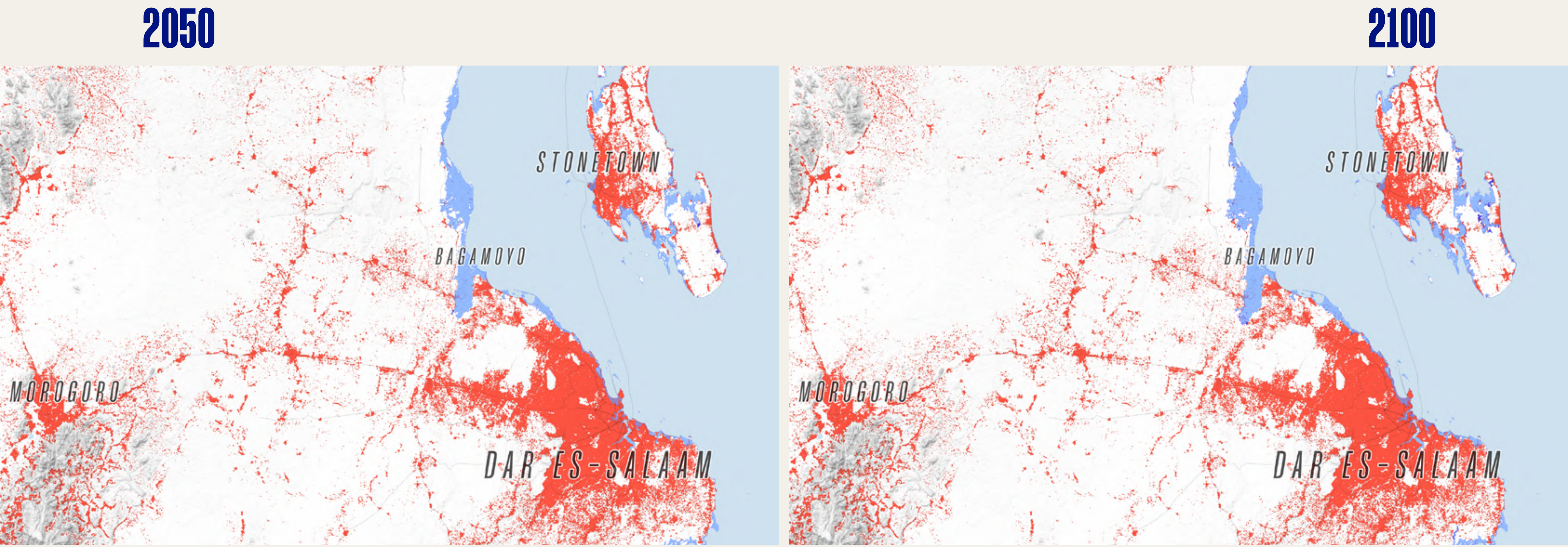
RCP 2.6 RCP 4.5 RCP 8.5

**Built-up area to year 2014**

Source: Trisos *et al.*, 2022.

Figure 25C

# Multiple large African cities will be exposed to sea level rise: Dar es Salaam, Bagamoyo and Stonetown (Tanzania)




**Sea level rise expected per scenario**

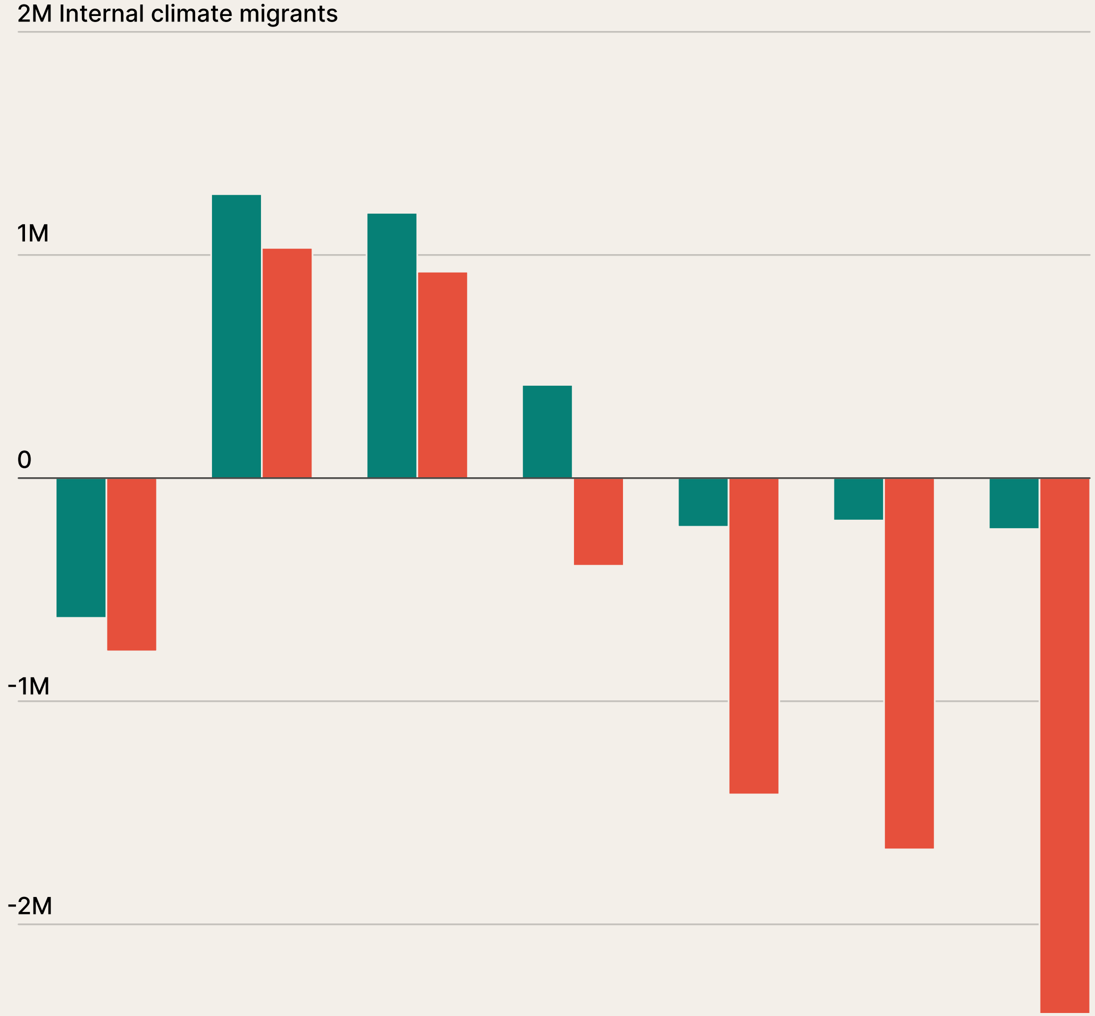
RCP 2.6 RCP 4.5 RCP 8.5

**Built-up area to year 2014**

Source: Trisos *et al.*, 2022.

Figure 26

# Climate mobility into and out of Africa's coastal zones by 2050




**Internal climate mobility in coastal areas in Africa**

High Road scenario
Rocky Road scenario

Source: ACMI Africa Climate Mobility Model, 2022.

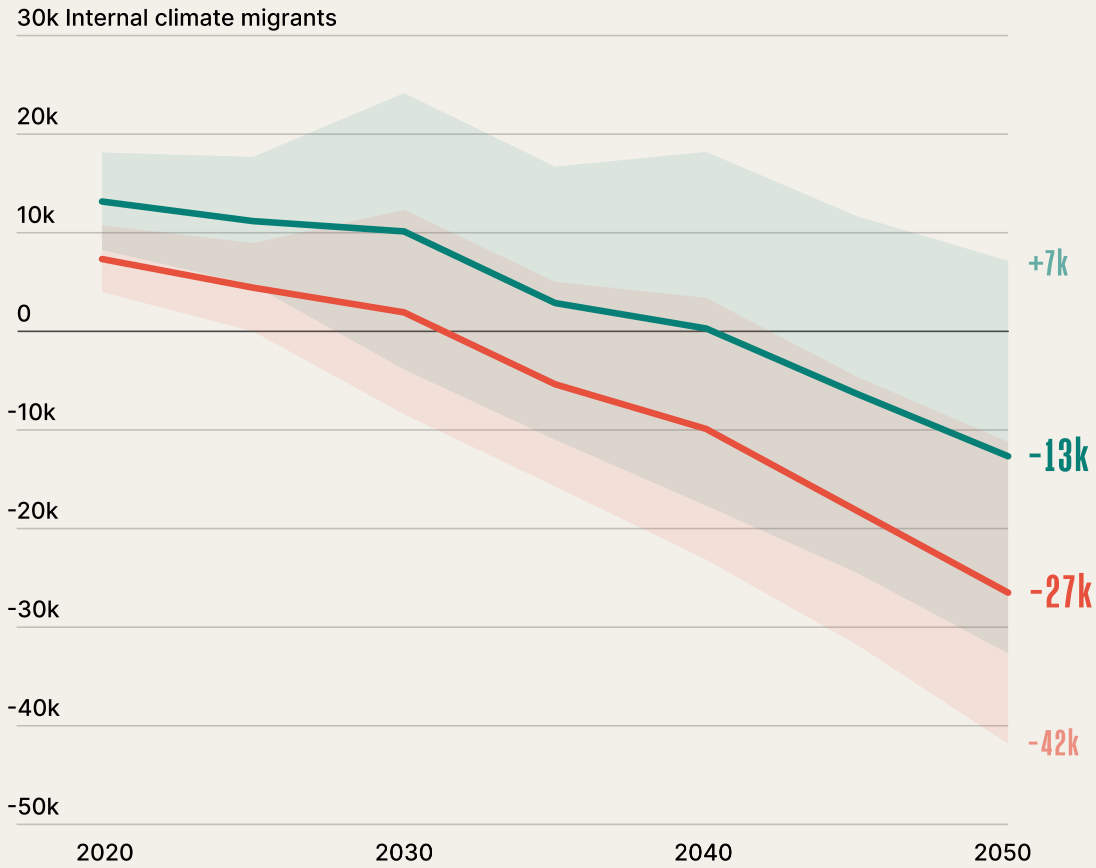
The largest areas that are likely to be inundated by episodes of coastal flooding are in Mauritania and Senegal, followed by Cote d'Ivoire and Nigeria. The Nile Delta of Egypt is also a hotspot, as are selected delta and low-lying areas along the east coast in Kenya, Tanzania and Mozambique[149]. The Gulf of Guinea will likely see the most people departing in response to climate hazards, as will the Nile Delta. Some coastal areas are forecast to attract climate mobility either because of new opportunities that arise under climate impacts, or because they are relatively more attractive than the interior areas of coastal countries.

In Mauritania, climate impacts are projected to result in out-mobility from the 5 km coastal zone, a number which could reach up to 27,000 people under the high emissions scenarios (Rocky Road scenario, 2050) (Figure 27). Sea level rise and coastal flooding, combined with more favourable agricultural potential in inland areas, are also expected to draw people away from the coasts in Benin, Togo and Sierra Leone. This contrasts with the trends in Senegal, where climate mobility towards the coasts could reach up to 600,000 people by 2050 under the Rocky Road scenario. This is largely owing to more severe climate impacts in the interior of the country, which is projected to become considerably drier by mid-century.

↓ **Figure 27**
Climate mobility dynamics in coastal areas vary across contexts.
In Mozambique, negative climate impacts on rural inland areas will drive movement towards the coast, despite the risks posed. Climate mobility projections assume people will move based on push and pull mobility factors associated with climate impacts. Where impacts will be negative, projections show movement out of those regions. Where impacts are projected to result in comparatively better areas, projections indicate movement to, and a growth of population in, such areas.
The bands around each line represent the confidence interval based on four model runs per scenario, each using different combinations of global climate models (GCMs) and impact models. Wider bands reflect higher levels of uncertainty.

Figure 27A

## Climate mobility out of the 5 km coastal zone for Mauritania




**Internal climate mobility in coastal areas in Mauritania**

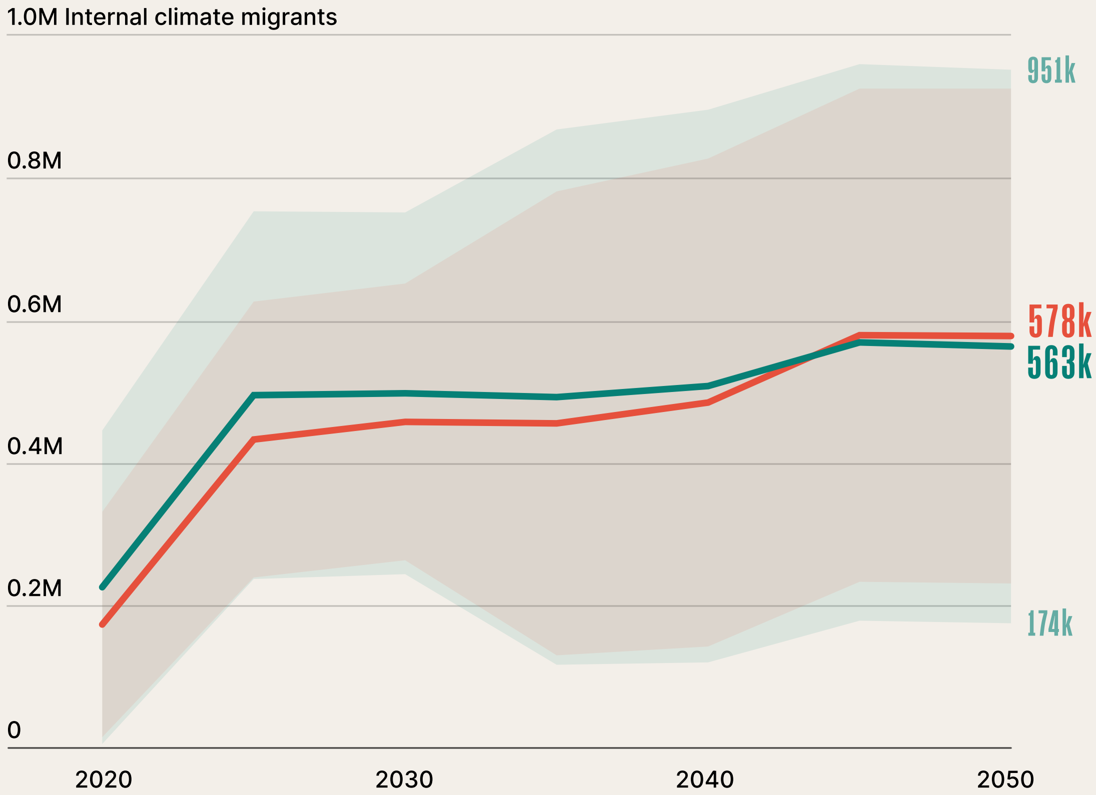
High Road scenario
Uncertainty (95% confidence)

Rocky Road scenario
Uncertainty (95% confidence)

Source: ACMI Africa Climate Mobility Model, 2022.

Figure 27B

# Climate mobility into the 5 km coastal zone for Mozambique up until 2050




**Internal climate mobility in coastal areas in Mozambique**

High Road scenario
Uncertainty (95% confidence)

Rocky Road scenario
Uncertainty (95% confidence)

Source: ACMI Africa Climate Mobility Model, 2022.

### 3.5.1

## Coastal cities are uniquely exposed

Countries along the Indian Ocean will face more frequent and severe storms, and yet despite this, could also see increased movement towards coastal cities as climatic conditions inland worsen. Mozambique is projected to see up to 900,000 people make this move by 2050 under the Rocky Road scenario. Changes in tropical cyclones making landfall in east and southern Africa could affect climate mobility in the future. These climate events are projected to become less frequent but will have higher impacts when they do make landfall, due to more intense rainfall, longer durations of intensity, a wider spread across the affected coast, and higher wind speeds as global warming accelerates[7,150,151]. However, the climate mobility effects of cyclones are hard to predict with the existing Africa Climate Mobility Model. Past experiences suggests that these kinds of rapid onset events will likely result in temporary displacement.

Many coastal cities in north, west, southern, and east Africa are likely to be hotspots of climate mobility. In west Africa and along the Gulf of Guinea, coastal cities are projected to see slower population growth due to climate mobility. Sea level rise in this region is projected to have the greatest impacts on low-lying coastal cities such as Nouakchott, as well as Cotonou and Lagos.

In Lagos under all future scenarios, climate mobility will likely reduce the rate of population growth. In Freetown and Monrovia, people are projected to move away from coastal settlements to other parts of the cities. In the Nile delta, climate mobility dynamics are mixed. While the Cairo area appears as a source area of climate mobility, some nearby zones in the Nile Delta and the Mediterranean coast, including Alexandria, appear as destination areas based on their attractiveness, relative to many other cities (Figure 28). For some coastal cities, beyond sea level rise, flood risk from rivers will also result in significant displacement.

### 3.5.2

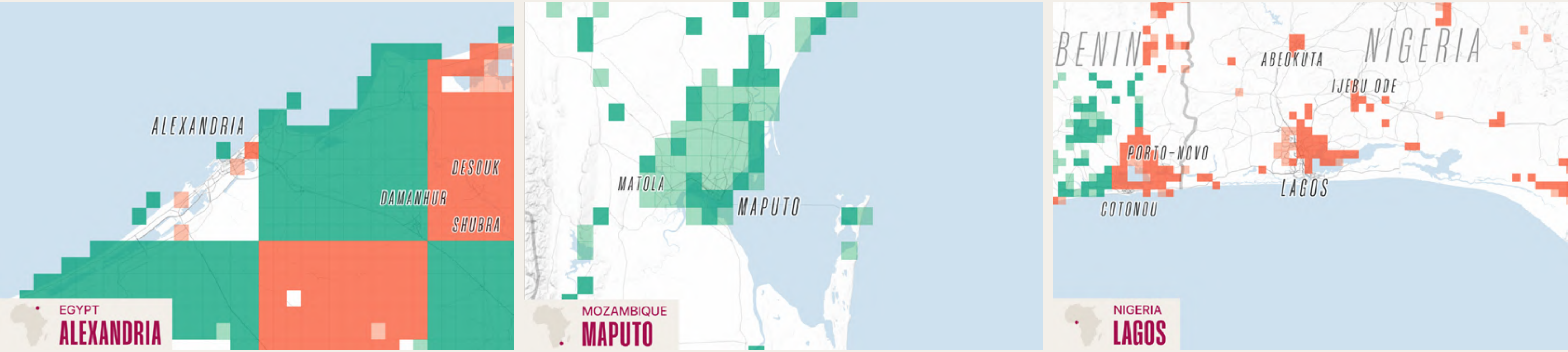
## Staying coastal despite the risks

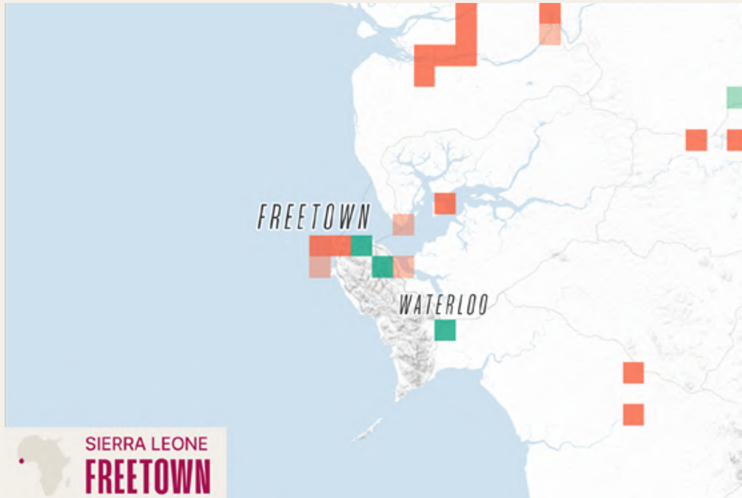
The climate mobility projections for coastal areas suggest that, despite growing risks, people will move to and remain in cities along the coasts, tolerating flooding, erosion and other climate risks as the price to pay for access to opportunities. Many migrants take a calculated risk when they compare the potential gains and losses of migration with those of staying, given the conditions in their home communities[100]. Many of those who are willing and capable of absorbing the considerable financial and physical risks of moving in the near-term do so to achieve a multi-generational leap in social mobility[100]. This has important implications for policy. People may claim a right to remain in vulnerable and hazard-prone areas and reject efforts at moving them, such as through planned relocation. This is particularly true if they are not able to meet their economic and livelihood needs otherwise, and if they are not able to address the non-material loss and damage associated with displacement[23,152].

↓ **Figure 28**
Coastal cities will be major hotspots of climate (and overall) mobility, and the direction of migration (incoming or outgoing) will vary among locations. For some areas the results of multiple scenarios agree on the direction of population change (increase vs. decrease or arrivals vs. departures). Those areas where the results of the Africa Climate Mobility Model are consistent across three or more future scenarios are represented by levels of confidence of likely and very likely internal (within country) climate mobility. The projected magnitude and direction of internal climate mobility will vary across space and time, and across future scenarios.

Figure 28

## Climate mobility into Alexandria and Maputo, out of Lagos, and across Freetown due to sea level rise and other coastal impacts




**Internal climate mobility hotspots by 2050**

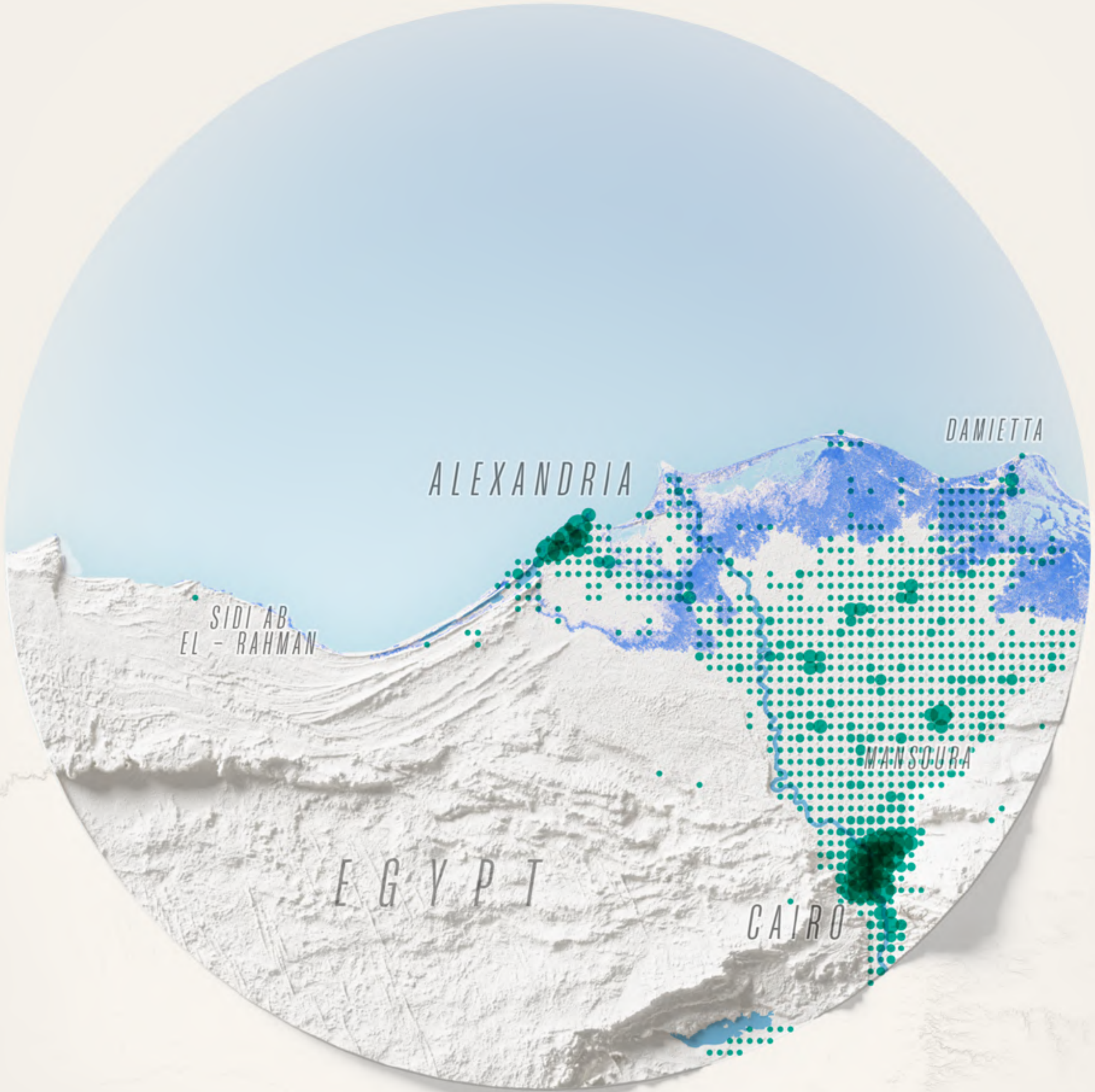
| **Origins** | | | **Destinations** |
|---|---|---|---|
| Very likely | Likely | Likely | Very likely |

Source: ACMI Africa Climate Mobility Model, 2022.

# 5.3M

A significant part of the population in the Nile delta will be exposed to sea level rise risk, including part of the 5.3 million people projected to live in Alexandria and surroundings by 2050. However, the majority of people might prefer to stay due to their ties to the land or the means they might lack to move and start over in a different location.

**ALEXANDRIA, EGYPT**




**Population**
Projected population by 2050 under the Rocky Road scenario (5k – 500k inhabitants)

**Sea level rise**
Areas at risk of 2m sea level rise

Table 2

## Comparing ACMI findings with the IPCC Sixth Assessment: How ACMI Report aligns with or extends the findings of the IPCC

| ACMI Findings | IPCC |
| --- | --- |
| Climate mobility levels up to 2050 will increase both for internal and cross-border mobility, but with the cross-border mobility generally being a fraction of the numbers for internal mobility. | Aligns with IPCC that climate mobility has been mainly within African countries and projects an increase in internal and rural-to-urban climate mobility. |
| Many Africans prefer to stay where they live, despite growing climate risks. | Some findings suggest that in low-income countries high temperatures 'trap' people at home and lower migration rates[7]. |
| The most vulnerable risk being stranded in high-risk places. | Exposure to climate hazards can trap poorer households in a cycle of poverty and poor people in Africa are often more exposed to climate hazards than non-poor people[7].<br>Vulnerability is high for many food producers dependent on rainfall and temperature conditions, including subsistence farmers, the rural poor, and pastoralists[7].<br>Migration responses to climate change tend to be stronger among wealthier households, as poorer households often lack financial resources necessary to migrate[7]. |
| Traditionally mobile pastoralism is disrupted. | Farmers and pastoralists perceive the climate to have changed and over two-thirds of Africans perceive climate conditions for agricultural production have worsened over the past 10 years[7].<br>Pastoralists in Africa perceive the climate as already changing and report more erratic and reduced rainfall, prolonged and more frequent droughts and a rise in temperature[7]. |
| Climate impacts increase stressors for African women, who move as a last resort. | Across regions with food systems highly vulnerable to climate change, female farmers, cocoa farmers, pastoralists, plantain farmers, coastal zone communities, rural households, and forest communities in central Africa indicate higher vulnerability[7]. |

| ACMI Findings | IPCC |
|---|---|
| Women who stay behind face additional burdens and innovate to adapt. | Migration of men from rural areas can aggravate the work burden faced by women[7].<br>Male migration can increase burdens of household and agricultural work, especially for women[7]. |
| Young Africans are more likely to embrace moving, and can lead the way in harnessing climate mobility. | Some evidence indicates people who leave tend to be more educated, possibly leading to 'brain drain'[7]. |
| Climate impacts will force more Africans to move, mostly within their countries. | Most climate-related migration and displacement observed currently is within countries or between neighbouring countries, rather than to more geographically distant high-income countries[7]. |
| By mid-century, the number of people migrating in response to climate impacts in Africa is expected to increase to anywhere between 69 and 98 million, depending on the future scenario. | With 1.7°C global warming by 2050, 17 to 40 million people could migrate internally in sub-Saharan Africa, increasing to 56 to 86 million for 2.5°C (>60 percent in West Africa) due to water stress, reduced crop productivity and sea level rise. This is a lower-bound estimate excluding rapid-onset hazards such as floods and tropical cyclones[7]. |
| Both low emissions scenarios (based on RCP 2.6) produce higher internal climate mobility forecasts for the continent than the high emissions scenarios (RCP 6.0). This suggests that adverse climate conditions depress rather than spur climate mobility within countries. | Not assessed in IPCC Sixth Assessment Report. |
| The impacts will be unequally distributed. | In rural Africa, poor and female-headed households face greater livelihood risks from climate hazards. In urban areas, growing informal settlements without basic services increase the vulnerability of large populations to climate hazards, especially women, children and the elderly[7]. |
| Few people will move across borders. | Most climate-related migration and displacement observed currently is within countries or between neighbouring countries, rather than to more geographically distant high-income countries[7]. |

| ACMI Findings | IPCC |
| --- | --- |
| Impacts on agriculture drive people from rain-fed farming areas, leading to large population shifts in pastoral areas. | Particularly vulnerable groups include pastoralists, fishing communities and small-scale farmers[7]. |
| Changes in water availability and crop yields will be a major driver of climate mobility. | Deteriorating economic conditions caused by climate hazards can encourage out-migration[7].<br>The influence of rainfall on rural–urban migration increased since decolonisation, possibly due to more lenient legislation on internal mobility, with each 1 percent reduction in precipitation below a long-term average associated with a 0.45 percent increase in urbanisation[7].<br>In poor and agriculturally dependent countries, high temperatures encourage international out-migration[7]. |
| Climate mobility could reshape the population in pasturelands. | Not assessed in IPCC Sixth Assessment Report. |
| Climate impacts drive movement into and out of border areas, increasing the need and potential for cross-border cooperation. | Not assessed in IPCC Sixth Assessment Report. |
| Cities and towns will be dynamic hubs as people move to, within, and from urban settlements. | The rate of rural–urban migration is anticipated to increase[7].<br>Climate-related displacement is widespread in Africa, with increased migration to urban areas in sub-Saharan Africa linked to decreased rainfall in rural areas, increasing urbanisation and affecting household vulnerability. Much of this growth can occur in informal settlements which are growing due to both climatic and non-climatic drivers, and which often house temporary migrants, including internally displaced people. Such informal settlements are located in areas exposed to climate change and variability and are exposed to floods, landslides, sea level rise and storm surges in low-lying coastal areas, or alongside rivers that frequently overflow, thereby exacerbating existing vulnerabilities[7]. |
| Climate mobility will slow growth in some cities, but rapid urbanisation continues. | Not assessed in IPCC Sixth Assessment Report. |
| Some cities will shrink due to climate mobility. | Not assessed in IPCC Sixth Assessment Report. |

| ACMI Findings | IPCC |
|---|---|
| Sea level rise will force people to abandon some low-lying coastal areas, despite the opportunities they offer. | Sea level rise and associated episodic flooding are identified as key drivers of projected net migration of 750,000 people out of the east African coastal zone between 2020 and 2050[7]. |
| Coastal cities are uniquely exposed. | In the absence of any adaptation, Egypt, Mozambique and Nigeria are projected to be worst affected by sea level rise in terms of the number of people at risk of flooding annually, other notable cities include those listed in Table 9.8[7]. |
| Staying despite the risks. | Not assessed by in IPCC Sixth Assessment Report. |
| Closing the climate information gap could help people adapt. | Climate information services that are demand driven and context specific (e.g., for agriculture or health) combined with climate change literacy can be the difference between coping and informed adaptation responses[7]. |
| Greater climate literacy and access to actionable climate information can increase people's sense of agency. | Around 71 percent of Africans who are aware of climate change agree it should be stopped[7]. |

# AGENDA FOR ACTION

Injustice is at the heart of Africa's experience of the climate crisis. Historically, the continent has contributed less than 3 percent to global greenhouse gas emissions, and yet it is one of the most climate-vulnerable regions.

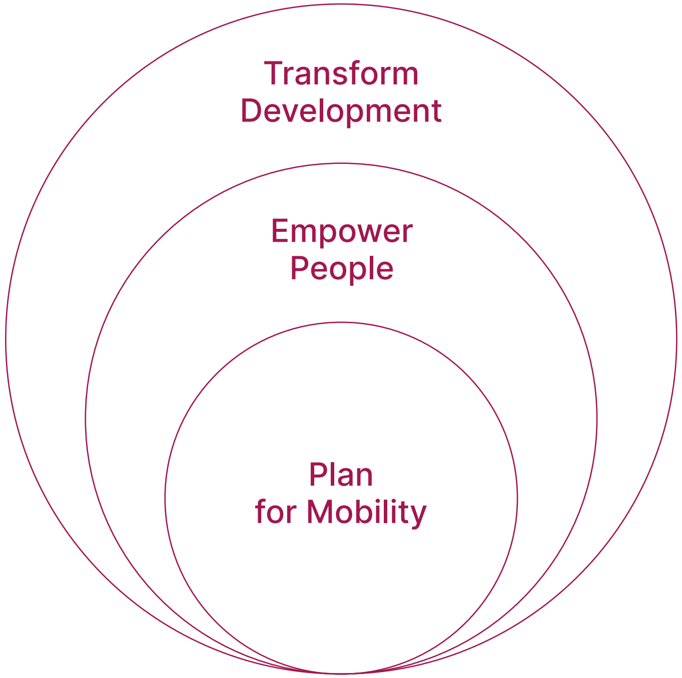
Because of its low emissions, Africa cannot do much in the near-term to slow the current rate of global heating. Yet, the continent urgently needs collective efforts to keep this heating inside the UN-determined guardrail of 1.5°C. Every fraction of warming avoided will protect Africans against further loss and damage to their livelihoods, economies, agriculture, health and ecosystems.

People are already moving in response to sudden and slow-onset disasters linked to climate change. This trend will only accelerate as the planet continues to heat. Africans generally want to remain in their communities and continue their way of life. Yet, climate change may make this increasingly impossible. Whether people stay or move, they will need to confront big shifts. Moving is an age-old human coping strategy and is one way for Africans to reduce vulnerability and adapt to worsening climatic conditions. By embracing climate mobility as part of its adaptation efforts, the continent can plan for it, and manage it better, so that people have more agency in making movement decisions that lead to more positive outcomes.

4.1

# Plan, Empower and Transform

The Africa Climate Mobility Agenda for Action is built on three key tenets for action that can guide African policymakers and stakeholders as well as their international partners in addressing climate mobility as an engine for climate adaptation and resilience-building in the continent.




## Plan for Mobility

Intensifying climate disruptions combined with Africa's growing population are forecast to propel increased movement on the continent in the coming decades.

If unplanned and poorly managed, population shifts could add stress in already fragile places, potentially heightening tensions around land and water resources. Sudden and large movements affecting African cities could undermine planning efforts and social cohesion.

And yet, a worse outcome could unfold if people become stranded in hazardous conditions due to poverty and age, disability, or legal barriers that prevent them from moving out of harm's way.

Climate mobility on the continent will be predominantly internal, putting adaptation and development actions, including countries' Nationally Determined Contributions (NDCs) and National Adaptation Plans (NAPs), as well as more localised strategies, at the forefront of supporting affected communities and the people who move. Recognising and supporting mobility as a legitimate coping and adaptation strategy can allow communities to remain rooted in place, while pursuing new livelihood and income opportunities.

Many African households already have members spread out in various locations, not only to mitigate climate and other risks, but also to take advantage of opportunities in different places[140]. Although it is difficult to quantify rural-urban migration, estimates suggest that 50 to 80 percent of rural households in sub-Saharan Africa have at least one migrant member[95]. By embracing 'multilocality', and the new connections forged between people and places, Africa can fortify its climate resilience[28, 141, 142], and advance its long-held ambitions for political and economic integration.

Countries already tend to trade with and invest more in countries from which they receive migrants[88]. Diaspora networks in destination countries are likely to boost demand for goods produced in people's home countries, such as specific food items[88]. A 2019 Afrobarometer survey across 34 African countries found that one in five people (21 percent) were at least 'a little bit' dependent on remittances sent from others who had migrated[143]. Researchers estimate that remittances from climate mobility can increase per capita income by up to 2.6 percent per year in climate-exposed locations of Africa until 2050[38]. With much of climate mobility happening over short distances, within countries, in borderlands, and between neighbouring states, cooperation structures must mirror and harness these more localised dynamics.

By planning for climate mobility, governments at all levels can prevent maladaptive outcomes and loss and damage from climate change. To support mobility as a strategy for resilience, adaptation actions must be locally anchored, context-specific, and informed by community priorities. At the same time, they can create shared benefits and prevent negative side effects only by working across communities and localities.

Laws and policies on migration, refugees and displacement have a part to play in addressing climate mobility in the continent. They can facilitate the movement of people across borders and ensure the protection of those who are forcibly displaced due to climate shocks. Africa is well positioned to use its existing institutions and forward leaning legal frameworks, including the OAU and Kampala Conventions as well as free movement agreements, to find cooperative climate mobility solutions.

IGAD member states are leading the way by recently ratifying the Protocol on Free Movement in the IGAD Region, which provides for the entry of persons 'in anticipation of, during or in the aftermath of disaster' (Article 16). It also calls on its members to facilitate the stay of IGAD citizens when their country of origin remains impacted by disaster and return is not possible. These provisions could inform ongoing discussions within other regional economic communities on ways to protect their citizens amidst the climate crisis.

## Empower People

Climate effects do not occur in a vacuum. Discrimination and marginalisation undermine people's ability to cope with climate risks, including their capacity to move. Responses to climate mobility must be embedded in existing efforts to advance rights and support disadvantaged groups.

When confronting climate shocks, women can be held back by social norms, traditions, and institutions that limit their autonomy and agency, including their property rights, financial access, climate literacy, and adaptation options. These constraints also limit their agency in mobility decisions. This can enhance their vulnerability to climate risks and lead to unplanned or forced movements, increasing the risk of negative outcomes. Targeted actions are needed to ease the climate adaptation burden for women. These should include equal access to rights, expanded social protection, and improved climate services, especially for women farmers.

By mid-century, more than half of Africa's population will be younger than 25. Young Africans have high aspirations to improve their living conditions. As climate risks increase and communities seek to cope, young people are typically the first to move in search of livelihood opportunities. Investing in green skills and jobs for youth will advance the wider societal effort for climate adaptation and for a green and just transition.

When addressing climate mobility, adaptation strategies must account for the specific vulnerabilities and adaptive capacities of different groups, including women, youth, and disadvantaged communities. Participatory governance and transparent decision-making will prove to be an important factor in ensuring effective and successful adaptation. This is particularly important when decisions about adaptation measures concern already disenfranchised populations, particularly those in the informal sector.

People in many parts of Africa lack knowledge about the connections between climate change and the impacts on livelihoods they observe in their lives. Current coping responses are therefore unlikely to prove sustainable. People are deciding to stay or move without adequate information on the risks of remaining in place or those associated with relocation. Empowering people to confront the climate crisis must start with user-friendly and context-specific information about climate change and climate risks, and the available adaptation options.

## Transform Development

As the world confronts the climate crisis and works towards delivering the Sustainable Development Goals, a new consensus is needed. To deliver on existing promises and ensure no one is left behind, adaptation and development efforts must merge to advance common goals and approaches and forge a new paradigm of climate-resilient development.

Africa will be essential to achieve this promise. Africa needs inclusive development to cope with and adapt to increasingly severe climate impacts. Yet, with every increase in global warming, the costs of adaptation will grow, threatening to divert much needed resources from development investments.

Africa's natural resources have fuelled growth around the world and will be critical for transitioning to a new, low-carbon future. However, going forward, it is the continent's people, their hopes and aspirations, that must be at the centre not only of policy making in Africa but also its relations with the world. Investing in the continent's human capital will yield the workforce, ideas, innovations, and solutions needed to achieve the green transition and build climate-resilient economies. For climate-resilient development to be people-centred, it must have an African fingerprint.

Climate-resilient development that empowers people must honour their 'right to remain' by protecting, and investing in, the places they call home. To be protective, investments must be risk-informed and anticipatory, considering how actions and impacts in one place might affect another place. Shared resources, such as Africa's 60 international or shared river basins, open communities and countries up to transboundary climate risks, but also create the potential for common benefits, such as for hydroelectric power generation and regional food security[130–134].

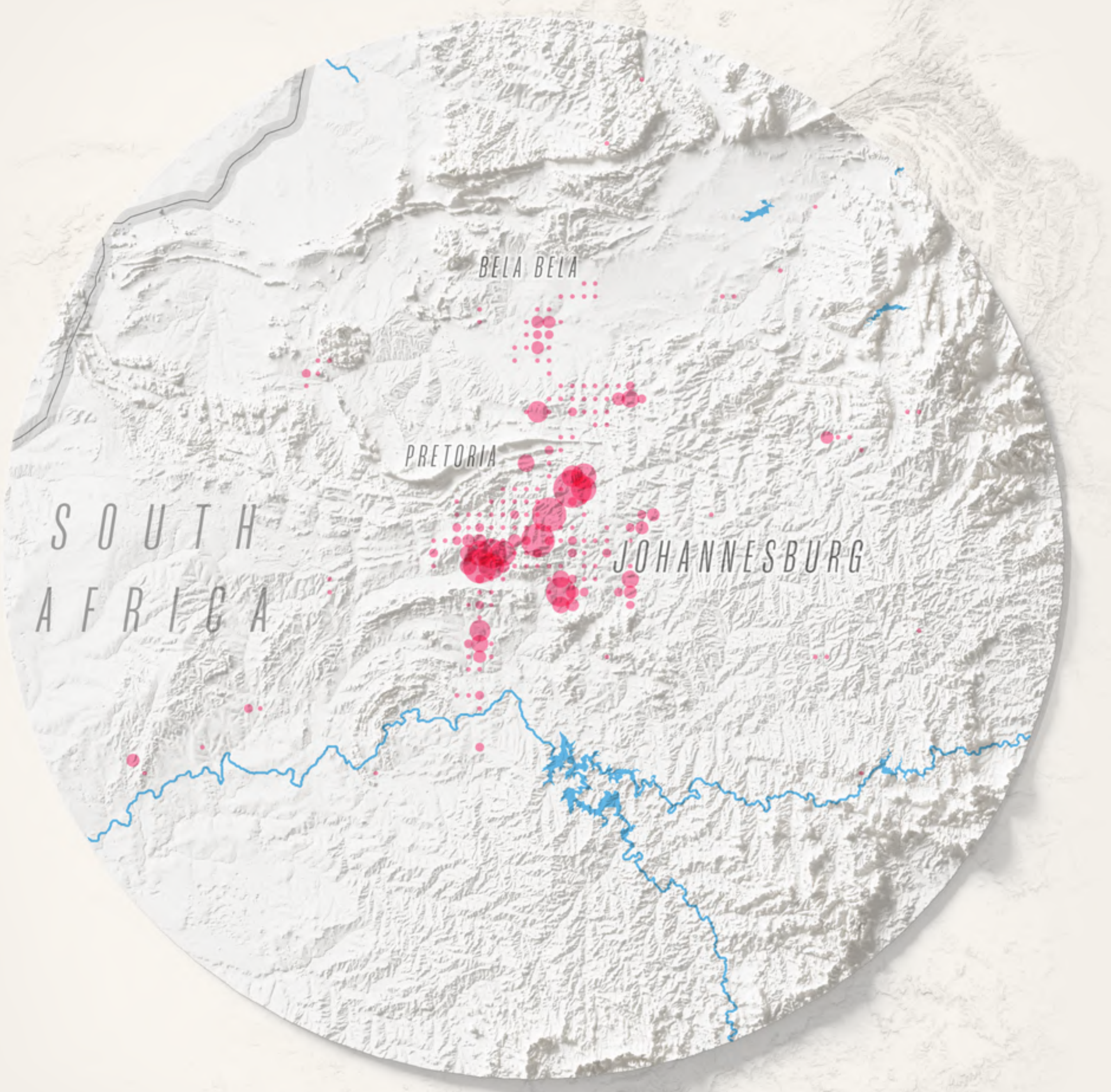
New models of joint resources stewardship are already emerging. In the western Indian Ocean, the Great Blue Wall Initiative (GBW) aims to create a regional network of interconnected protected and conserved marine areas ('seascapes') to counteract the effects of climate change, while creating livelihood opportunities for coastal communities in the blue economy[144]. The GBW promotes the participation of local communities in the governance and management of the connected seascapes network to secure their rights to access and benefit from natural resources[144]. The goal is to deliver both socioeconomic and conservation outcomes by 2030.

Climate mobility will contribute to reshaping the landscape of connections between people and places. By creating stronger rural-urban ties, it increases the need, and opportunities, for integrated spatial planning, flexible social service delivery and safety nets, and for cooperation on food systems and food security in both rural and urban areas[145,146]. Collaborative and transboundary strategies for climate resilient-development can mitigate the risks and harness the benefits of increased mobility and connectivity.

# 1.3M

Stronger rural-urban connections could help Johannesburg – projected to see 1.3 million people move into the city and its surrounding areas by 2050 – adapt to climate change. Planning, empowering, transformative actions implemented by 2030 will contribute to improving the resilience of those who will move and those who will stay.

**JOHANNESBURG, SOUTH AFRICA**




**People arriving**

Expected number of people moving to these areas due to climate change by 2050 under the Rocky Road scenario (5k – 60k people)

4.2

# Deadline 2030: Eight actions for the next eight years

Guided by the three outlined tenets, the Agenda for Action presents eight key actions for the next eight years (2023–2030), in line with the Decade for Action to achieve the 2030 Sustainable Development Goals and the Paris Agreement. The Agenda for Action also outlines concrete measures to advance each of the eight Actions. It is primarily directed at African leaders across sectors and levels of governance, as well as African and international stakeholders from civil society, the research community, philanthropy and impact investors, and international partners, including bilateral donors, the UN System, and International Financial Institutions.

The ACMI will work to build coalitions of champions to drive progress on each of the eight actions and the measures needed to advance them. It will continue to nurture the climate mobility policy ecosystem in the continent to drive the development and exchange of knowledge, scaling of good practices and joint advocacy by affected communities. By bringing different actors together and forging collective action, the Global Centre for Climate Mobility (GCCM) will galvanise a people-centred, locally led, and integrated approach to migration governance, climate action, and climate-resilient development in the continent. To this end, the GCCM will advance four Flagship Programmes focusing on:

1. Climate Literacy for Stronger Agency
2. Green Skills for Inclusive Transition
3. Water Solutions for Resilient Communities
4. Data and Knowledge for Local Impact

ADDRESSING CLIMATE MOBILITY

# The GCCM will galvanise a people-centred, locally-led, and integrated approach to migration governance, climate action, and climate-resilient development

ACTION 1

# ANTICIPATE AND PLAN FOR CLIMATE MOBILITY

Anticipate and plan for climate-forced displacement and migration, including permanent relocation, to foster social cohesion in affected communities, prevent involuntary immobility, drive economic growth, sustain peace, and protect people on the move.

Intensifying climate impacts threaten to make living conditions harder in many parts of Africa[7]. However, people and communities often have deep attachments to their land and livelihoods, and have no intention to permanently leave even highly risky areas. The progressive depletion of natural resources and people's assets risks transforming situations of voluntary immobility, where people choose staying over moving, into forced migration or displacement. Conflict dynamics that could emerge in more fragile environments increase this risk. On the flip-side, people without the means to move could become stranded in place[33·54]. Both outcomes leave those affected more vulnerable and in need of protection. To prevent greater vulnerability, governments will need to embrace a role in facilitating mobility with dignity[79]. They can do so by preserving people's agency in making climate mobility decisions, helping them cope with climate impacts, and ensuring safe reception for those who move, including by creating legal opportunities for cross-border movement and settlement.

Social protection programmes can address inequalities that limit people's agency in mobility decisions, whether based on gender, age, ability, income, employment, education, or otherwise[7]. Social protection measures that can increase resilience to climate change include cash and in-kind transfers, public works programmes, social insurance, micro-insurance schemes, and improved healthcare access[7·147]. Evidence from Ethiopia, Kenya and Uganda shows that national social protection programmes improve individual and household resilience to climate-related shocks, regardless of whether they aim specifically to address climate risks[7].

In some places, the prospect of long-term adaptation to climate impacts may be in doubt. Anticipating and planning for the relocation of households or whole communities early, can increase the quality and acceptance of the process. It allows for community buy-in and co-design of the process, and for justice considerations to be duly included[148]. Similarly, prospective destination areas for climate mobility can, with proper planning, improve reception conditions for those who move, their families, and for vulnerable populations in receiving communities[22,149]. Thus, policies that anticipate and treat climate mobility as a legitimate coping and adaptation mechanism can save lives, maximise the positive potential of migration, and promote social cohesion.

Over the coming eight years, progress in anticipating, managing and harnessing climate mobility can be made through partnerships that:

**A** Use forecasting methods and shared analysis to identify potential climate mobility hotspots and start early consultations with local populations on anticipatory actions for risk mitigation, including contingency planning for evacuations and protocols between neighbouring countries and communities. Such effort should also consider long-term planning for relocations where the limits of local adaptation may be reached, taking account of emerging lessons and good practices from around the world.

**B** Facilitate regular, safe and orderly cross-border climate mobility, including in the context of regional free-movement agreements and the OAU Convention, using refugee, humanitarian, family, education, and work-related grounds, as appropriate, to facilitate people's admission and stay, while working to keep families together.

**C** Refrain from returning people to countries experiencing acute disasters and find solutions for cases where adaptation in or return to the country of origin is not possible.

**D** Support receiving communities of both internal and cross-border climate mobility through anticipatory planning, community engagement, and by aligning humanitarian and development assistance to advance locally led strategies for strengthening public infrastructure and services, promoting labour market inclusion of newcomers, and pursuing social cohesion.

**E** Support the expansion of social protection programmes to mitigate climate vulnerability, improving coverage of rural areas and ensuring eligibility to social services regardless of migration status.

**F** Encourage the use of remittances for building household and community resilience and support trade and productive links as well as collaboration between communities and countries connected by climate mobility.

ADDRESSING CLIMATE MOBILITY

## Social protection programmes can address inequalities that limit people's agency in mobility decisions, whether based on gender, age, ability, income, employment, education, or otherwise

ACTION 2

# INTEGRATE CLIMATE MOBILITY IN CLIMATE ACTION AND FINANCE COMMITMENTS

Recognise and support mobility as a legitimate strategy for climate adaptation in local, national, regional, and international policies, and build cross-sector partnerships to support people and communities in staying, moving, and receiving.

A growing number of national climate strategies and policies reference migration[150]. Yet, many national adaptation and disaster risk reduction policies do not view migration positively or plan for it proactively[151–154]. Nor do they necessarily consider the specific needs and vulnerabilities of displaced persons[155]. On the flip-side, few countries have migration policies that facilitate the movement of people for climate-related reasons[156–160]. Programmatic approaches to address climate mobility are emerging around the globe and a range of existing financial instruments for risk reduction and management are relevant and can be applied to address the issue[161]. Yet global climate investments remain heavily skewed towards mitigation over adaptation. The scale of efforts underway is in no way commensurate with the scale of the challenges facing the most vulnerable countries and regions.

Africa will need significant amounts of financing — an estimated US$18 billion to US$30 billion a year over the next two decades — to adapt to and mitigate the impacts of climate change and extreme weather patterns[162]. However, most of the existing climate finance is going to infrastructure-focused projects to reduce greenhouse-gas emissions. This leaves out the poorest and most vulnerable nations that have not built up emission-intensive industries[162]. Sub-Saharan Africa receives just 5 percent of total climate finance outside the OECD. Less than 10 percent of finance from global climate funds is dedicated to local action[163].

Over the coming eight years, progress in addressing climate mobility in the African continent can be made through partnerships that:

**A** Recognise and support mobility as a legitimate strategy for climate adaptation in local, national, regional, and international climate strategies, plans and policies, including National Adaptation Plans (NAPs) and Nationally Determined Contributions (NDCs), through actions that support in situ adaptation, movement with dignity, reception in communities, and multilocal and transnational household risk management strategies.

**B** Pursue cross-sector collaboration to harness new sources of data for improving the monitoring and forecasting of climate risks and climate mobility patterns in Africa.

**C** Significantly increase funding and financing for climate adaptation in the most vulnerable cities, countries, and regions, and pursue cross-sector alliances to scale up the use of innovative financing instruments, including green and blue bonds, municipal bonds, CAT bonds and parametric insurance, as well as debt-for-climate and nature swaps.

**D** Create a dedicated funding vehicle to support anticipatory action on climate mobility, in particular planned relocations that meet criteria around community participation, equity, justice and sustainability.

**E** Work with migrant-led organisations and displaced people — especially the most vulnerable — to co-design and drive local climate adaptation and mobility solutions that reflect their needs and aspirations.

Empower People

ACTION 3

# INFORM PEOPLE OF CLIMATE RISKS

Enhance public understanding of climate risks and threats, including through building climate change literacy, the co-production of actionable climate information services and access to early warnings, to support informed decisions on how to adapt, whether and when to move, and where to settle.

Supporting communities with improved and equitable access to climate information, education and training to build capacity, and early warning systems could support vulnerable groups in adapting their livelihoods to climatic changes[7]. The African Union Climate Change and Resilient Development Strategy and Action Plan (2022–2032) identifies climate literacy as central to integrating climate change into core national and sub-national developmental agendas in Africa, which will support more inclusive and climate-resilient development pathways[21]. Factors that influence climate change literacy, such as levels of education and poverty, often overlap with broader developmental challenges on the continent. Policies targeting these factors can yield potential co-benefits for both climate change adaptation and progress towards the SDGs, particularly those targeting education, shelter, food and water security, child protection and poverty[7,52,164].

Climate services are designed to give tailored climate information to the end user, such as those working in the agriculture, urban or health sectors. As such, they complement progress in climate change literacy by generating, tailoring, and providing climate information for use in decision making at all levels of society[7]. General awareness of climate change and climate risks, together with access to localised climate information, can help people make better informed decisions on how to cope and adapt, including by moving, either temporarily or permanently[7,52].

Over the coming eight years, progress on promoting climate literacy can be made through partnerships that:

**A** Increase the availability of African-owned, localised, and timely weather and climate data through improved data collection, analysis, and forecasting capabilities.

**B** Raise awareness of the human-made nature of climate change, its localised impacts and adaptation options, particularly among vulnerable and marginalised populations and trusted information and service providers, such as agricultural extension officers, radio hosts, local authorities, faith leaders, youth and migrant-led networks, cultural institutions, and professional associations.

**C** Ensure climate information is child-friendly, available in languages that minorities and migrant and displaced populations understand, and is shared through communication channels that are accessible.

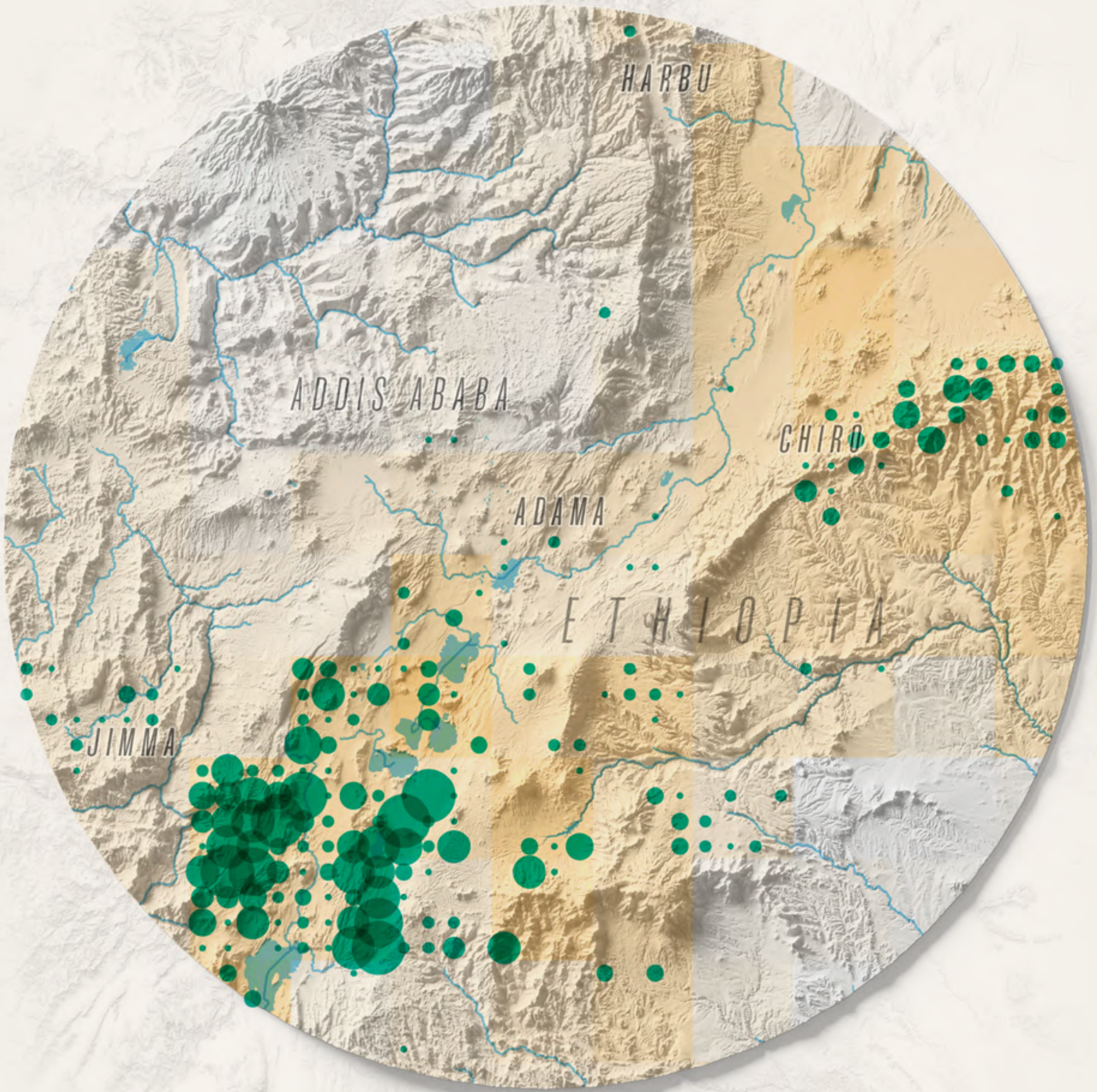
**D** Harness local, traditional, and indigenous knowledge to co-develop climate adaptation solutions that are compatible with people's culture and belief systems.

**E** Ensure nationally and locally owned disaster and climate risk early warning mechanisms and response protocols that account for the needs of migrants and displaced people, as well as other potentially marginalised populations such as the poor, less-educated, children, women, and ethno-linguistic minorities.

# 750k

Around 750 thousand people may need to leave Ethiopia's Adama Valley by 2050 as a result of climate risks like droughts. Most of these people will end up moving elsewhere within Ethiopia as people throughout the continent will generally prefer to stay within their countries.

**ADAMA, ETHIOPIA**




**People leaving**
Expected number of people leaving their home due to climate change by 2050 (5k – 150k people)

**Drought risk by 2050**
Moderate Severe

ACTION 4

# AMPLIFY WOMEN'S AGENCY

Empower women with climate information, adaptive skills, social and legal protection to bolster their agency in decisions on climate adaptation and in climate mobility.

Climate stressors compound the risks facing African women, whether they stay or move. A large percentage of African women is employed in the climate sensitive agricultural sector. They rely on natural resources for their livelihood, making them more vulnerable to adverse climate impacts. Deteriorating environmental conditions also increase the time and difficulty for women to complete household tasks. Women in urban informal settlements often confront exposure to climate hazards such as extreme heat and flooding, poor services, challenges in finding jobs, low wages, as well as difficulties in accessing information and housing for single women.

Extreme weather and climate impacts increase the health safety risks for women, especially pregnant and nursing women. In emergency situations, including during disasters and displacement, women and girls face elevated risks of gender-based violence and exploitation. Other challenges include difficulty accessing sanitation, sexual and reproductive health services, and mental health support.

Human mobility can magnify existing inequalities between women and men. Traditional gender roles that expect men to be a family's primary breadwinner and women to be caretakers, significantly affect their respective agency in decisions to migrate, and their experiences of migration in the context of climate change[86]. As recently as 2016, married women in 12 African countries, were not allowed to apply for a passport without their husband's consent[90]. Women are also less likely to be involved in decisions about how to prevent, mitigate, and cope with climate change, including decisions on whether and when to leave home[80].

Resilience-building efforts should be gender-sensitive and gender-transformative to support women's agency in climate adaptation decisions at all levels, particularly in sectors affecting climate mobility such as access to information and education, land and water, health, food systems, and livelihoods[74, 79].

Over the coming eight years, progress in empowering women as agents of change can be made through partnerships that:

**A** Prioritise women and girls for climate information services, risk-reduction measures, and green economy training and employment opportunities to improve their adaptive capacities in the face of increasing climate risk.

**B** Improve legal, social and physical protection of women and girls on the move, including cross-border traders, migrant, refugee, and displaced women, as well as returning women.

**C** Boost age and sex-disaggregated data collection, research and local awareness-raising on the gender-specific ways in which climate change risks, including climate displacement, disproportionately affect women and girls, and establish clear, context-specific targets and indicators for reducing their vulnerability in collaboration with the affected communities.

**D** Take targeted actions to ease the climate adaptation burden for women, especially caregivers and female-headed households, by expanding social protection and health services, safe access to water, sanitation, and renewable sources of energy, and climate information and agricultural extension services for women active in smallholder agriculture and livestock keeping.

**E** Scale up financial and technical support to local and national women's groups and rights organisations that work to build power among women, including migrant and displaced women, to secure their access to livelihood opportunities and decision-making processes, and to shift gender norms and practices.

**F** Work with champion men and boys — including cultural, community, camp and religious leaders — to drive change in attitudes and norms among peers and foster a culture that denounces all forms of violence and discrimination against women and girls.

ACTION 5

# HARNESS THE AMBITIONS OF THE YOUTH

Foster and leverage the creativity and potential of Africa's already-mobile youth, to build resilience, economic prosperity, and advance the green transition.

Africa's growing population of young people will play a decisive role in shaping the continent's future trajectory. African youth are already active climate advocates and entrepreneurs involved in developing solutions that help their communities weather the climate crisis. Yet many lack opportunities to realise their aspirations and potential where they live, driving a desire to move[90]. Others may be tasked to find income opportunities away from home, moving out of a duty of care to their families and communities. Youth who have been forced to move — whether living in protracted internal displacement, refugee camps, or informal settlements — often face a host of new and additional vulnerabilities, including exposure to adverse climate impacts[79·165].

Interventions must support young people where they are and build pathways that allow them to develop and contribute their skills, experiences and ideas to the wider societal effort to achieve climate-resilient development. This includes public works programmes and entrepreneurship support to protect fragile ecosystems, promote sustainable 'climate smart' agricultural practices and the transition to greener cash-based economies in urban areas. By joining forces to build centres of excellence and creating legal pathways for labour and skills mobility within the continent, countries can incentivise youth with technical and academic skills to remain in Africa and advance its prosperity and resilience.

Over the coming eight years, progress in empowering children and young people to be leaders in shaping climate adaptation strategies and driving development can be made through partnerships that:

**A** Develop climate literacy from an early age by incorporating climate and environmental science insights and knowledge into school curricula and other educational offerings for children and youth and engaging young people as climate educators and ambassadors.

**B** Invest in, replicate and significantly scale up solutions and programmes developed by and with African youth, including migrants and displaced youth, to advance climate and environmental action, such as waste collection and recycling, tree planting, urban greening and farming, forestry, and coastal ecosystem restoration.

**C** Strengthen the ecosystem that supports youth with the development of green skills and entrepreneurship in green sectors, and promote the generation green jobs on the continent, including as part of efforts to make the agriculture, energy, construction and mining sectors more sustainable.

**D** Work with the private sector, interested sectors of industry, training institutes, and labour unions to improve the transferability of skills and worker mobility within and across Africa's regions, exploring innovative skills and training schemes for young people between places of origin and destination, with a focus on upskilling for jobs of the future and advancing the low carbon transition.

**E** Enable youth from all backgrounds — including those on the move — to effectively participate in local, national, regional and African Union deliberations and decisions on climate strategies and inclusive climate action by developing leadership skills for youth and creating inclusive platforms that elevate youth voices and promote their engagement as climate negotiators.

ACTION 6

# BUILD FROM THE LOCAL

Pursue community-led solutions for climate-resilient development, disaster response and climate mobility across the continent, and invest in locally anchored climate adaptation and resilience pathways, including strong connections in border areas.

Community-level structures and local governance are key to managing climate mobility. Adaptation is more effective and feasible across Africa when it is informed by local knowledge and when the social infrastructure is strong. Africa's diverse indigenous and local knowledge systems give a rich foundation for adaptation actions at local scales[7]. Community-led natural resource management in pastoral communities, by involving community members in decision-making, has been shown to increase their capacity to respond to climate change[166]. Decentralised management, strong community structures, and informal support networks[7,134] are part of the soft infrastructure Africa needs to build climate resilience.

Border areas offer opportunities for harnessing existing community ties for enhanced cooperation[167,168]. Countries' official administrative borders do not always align with what are in fact integrated spaces that straddle national borders and where people are connected by historical and social ties, shared ecological resources, cultural affinities, economic activity, livelihoods, and mobility. Many border areas are highly dynamic, with trading and economic activities flourishing by taking advantage of arbitrage opportunities that arise from the existence of the border[168]. If they are supported with the right connecting infrastructure and services, existing community ties in border areas can be harnessed to boost trade, build value chains, and transform border towns into engines of economic growth that can provide opportunities[168]. However, as things stand, top-down approaches to policy making too often prevail and local actors are rarely in the driver's seat when it comes to leading adaptation efforts[163].

Over the coming eight years, progress in localising solutions for climate adaptation and climate mobility can be made through partnerships that:

**A** Strengthen inclusive and shock-responsive services and take measures to keep essential services running after disaster strikes to provide non-discriminatory access to services, including food, education, healthcare, child protection and water and sanitation, regardless of age, sex, ethnicity or status.

**B** Empower and promote locally led cooperation and development strategies in borderland areas that are forecast to be hotspots of climate mobility, focusing on the provision of basic services, shared infrastructure, inclusive natural resource management, trade and value chain development and support to community organisations promoting social cohesion.

**C** Ensure that climate finance is allocated to the local level and involves community participatory processes, by mapping the baseline of climate finance that reaches the local level in Africa and use it to set an Africa-wide goal for local climate finance, targeting the most climate vulnerable areas and communities.

**D** Leverage local resources by bringing together stakeholders from public, private and research sectors to explore how best to support community priorities, facilitating dialogue, building coalitions, and sharing skills, technology, and knowledge.

**E** Invest in local capacities for community-led data collection and analysis, fundraising and financial management, and the monitoring and assessment of programmes and policies.

ACTION 7

# INVEST IN RESILIENT AND CONNECTED CITIES

Enable cities with the actionable data, financial and technical resources — and the political agency needed to facilitate planned, resilient and inclusive urban growth, social inclusion and social protection — while building stronger ties across cities, and between cities and rural areas and economies.

Cities are first responders in the inclusion of newcomers, be they internal or international migrants, refugees or internally displaced persons. Rural-urban movement has traditionally driven development by bringing workers into more productive employment and cash-based economies. Yet an influx of people can also exacerbate vulnerabilities in cities, especially if available land and housing are sparse, leading people to occupy hazard-prone areas. Though some African cities drive their national and regional economies, many provide too-few jobs and livelihood opportunities to lift increasing numbers of residents out of poverty[169]. Cities across the continent face barriers in accessing national and international investments. As a result, not enough physical and social infrastructure is built to provide basic and social services to growing urban populations and to ‘climate-proof’ African cities, especially those situated along vulnerable coastlines. Government presence and investment tend to be concentrated in large capital cities, while smaller, more remote cities and towns are absorbing most of the urban growth in the continent.

Governance reforms across Africa have led to the growing devolution of responsibilities to lower levels, yet without always conferring commensurate powers and resources onto sub-national and city governments. And, while African mayors and cities are active in regional and global city networks focused on climate change, sustainability and migration, they largely remain at a distance from Africa’s regional and continental governance structures. This leaves the African Union and regional economic communities without a direct link to efforts on the ground that are needed to effectively implement policy frameworks related to climate action, sustainable development, and migration and displacement.

Planned adaptation initiatives in African cities since 2006 have been predominantly driven from the national level, with negligible participation of lower levels of government[7]. Adaptation action directed specifically at vulnerable populations is also rare[7]. There are emerging examples of cities that are developing planned climate adaptation measures including eThekwini[170] and Cape Town[171,172] in South Africa, and Lagos in Nigeria[173]. In Mozambique, Maputo is a good example of community-led projects[174], implemented with support from policy networks and dialogue forums[175,176]. These researched cities can be lighthouses for wider exchange, and the basis for peer learning among cities[7].

Over the coming eight years, progress in enabling cities to address climate mobility dynamics, promote the inclusion of migrants and displaced people, and mitigate climate impacts on marginalised communities and fast-growing, at-risk urban areas can be made through partnerships that:

**A** Involve city governments in, and harness their lessons for, national, regional and AU-level deliberations and policy processes related to climate action, disaster risk reduction, sustainable development and migration, refugees, and displacement.

**B** Plan for greater urban growth and density by overhauling outdated zoning laws and codes to match contemporary urban needs and realities and by designating and equipping areas of prospective settlement with basic infrastructure and transportation links to economic opportunities.

**C** Ensure natural and built environment planning and regulatory practices are transparent and led by sub-national and city governments, allowing for more context-appropriate plans and practices as well as greater oversight of local adherence to land use rules and regulations.

**D** Support the development of Africa's intermediary cities, by providing incentives, such as additional funding from national budgets, to encourage collaborative governance among regional networks of local governments that agree to share personnel and pool resources to deliver local infrastructure and public services more efficiently.

**E** To ensure the provision of infrastructure and inclusive public services, support African cities, in particular smaller cities, in increasing own revenue generation, including the use of technology to collect data, fees and taxes and enhance the transparency of transactions, as well as allowing cities access to international and private financing through intermediary institutions and pooled funding mechanisms.

**F** Improve the availability of localised data on population dynamics, climate risks and vulnerabilities, including the profile of migrant and displaced populations, to inform urban planning and support participatory, community-level priority-setting for urban development in the context of intensifying climate risks.

**G** Reinforce rural-urban links for inclusive food systems, by ensuring market access and supporting value chain development for small-scale producers, especially women farmers, to address the food needs of urban dwellers and by supporting transport and market infrastructure in poor urban neighbourhoods.

ADDRESSING CLIMATE MOBILITY

## Cities are first responders in the inclusion of newcomers, be they internal or international migrants, refugees or internally displaced persons.

ACTION 8

# PURSUE NATURE-POSITIVE DEVELOPMENT

Manage land, water, and other shared natural resources cooperatively and sustainably to support agricultural and ecosystem-based livelihoods and boost productivity, while reducing environmental impact and harnessing ecosystems and biodiversity protection for economic development and climate resilience.

Land governance in Africa is a complex problem[177], yet addressing it will be critical in shaping climate mobility dynamics. Land is at the core of people's livelihoods and cultural identity. Disputes over land can contribute to conflict and displacement, with climate disruptions acting as an additional stressor. Lack of access to land reinforces the vulnerability of rural households that lack collateral for accessing financing and pushes people in cities to settle in risk-prone locations. Similarly, water and its management will be key to addressing climate mobility in Africa[134,171,178]. Most climate displacement happens due to the scarcity or over-abundance of water in the form of drought and flooding, or is driven by longer-term shifts, e.g. in groundwater availability. Access to water is driving changes in land use patterns and can bring different users into conflict. Water and sanitation are also critical for health outcomes in the context of climate mobility, including public health in dense, informal urban settlements.

Land and water underpin agriculture and food production on the continent, as well as ecosystem services on which communities rely[7]. Africa's development over the coming decades will depend on finding ways to use this natural resource base more sustainably to support its growing population. 'Nature-positive' development goes beyond limiting damage to the environment from human activity and towards developing economic models that help restore degraded ecosystems and reverse biodiversity loss[179]. Ecosystem-based adaptation can reduce climate risk and prevent the escalation of tensions over the use of natural resources, while providing social, economic and environmental benefits[7]. Investing in ecosystem protection and restoration, conservation agriculture practices, sustainable land management, and integrated catchment management can support long-term climate resilience[7]. Ecosystem-based adaptation and green infrastructure can also cost less than grey infrastructure in human settlements, for instance through using wetlands and mangroves as coastal protection[7].

Over the coming eight years, progress in reducing the climate vulnerability of people and the ecosystems they rely on can be made through partnerships that:

**A** Create or reinforce national and local structures for the cooperative governance of shared and cross-boundary water resources, adopting the river basin as the unit for water-resources management; strengthening river-basin and aquifer management; and creating an enabling environment for cooperation between countries sharing international water basins, including management at the lowest appropriate level and institutional arrangements for full stakeholder participation.

**B** Introduce transparency and flexibility in land governance and encourage context-appropriate and conflict-sensitive solutions to manage a continuum of land rights and use needs, using technology to map and record land rights and uses, knowledge networks to share information and good practices, and mediation mechanisms to mitigate land conflicts and address the marginalisation of women and female-headed households under traditional land tenure arrangements.

**C** Roll out Sustainable Land and Water Management Practices for agriculture and food security across the continent by promoting systematic data collection, monitoring and evaluation of practices, knowledge-sharing and peer-learning among farmers, and capacity-building for the communities and institutions managing land and water resources.

**D** Build research and development (R&D) capacity in the agricultural sector in Africa to ensure better alignment between R&D and the needs and conditions of African countries and communities and improve adoption rates of climate resilient agricultural practices and technologies.

**E** Protect oceans and build coastal resilience at scale through the creation of connected seascapes that foster regional collaboration for ecosystem restoration and protection and mobilise resources for blue economy development to generate sustainable livelihood opportunities in coastal communities.

# APPENDICES

A.1

# Modelling projection methods

We deploy a pioneering model for projecting future climate change-related displacement and migration in Africa out to 2050. The model combines pathways for emissions reductions and development progress to generate four possible climate impact scenarios by 2030, 2040, and 2050: low growth-high emissions (Rocky Road; low progress on both fronts), high growth-high emissions (High Road; one-sided progress on development), low growth-low emissions (one-sided progress on emissions but low growth), and high growth-low emissions (progress across the board) scenario. The development scenarios used in the model — or shared socioeconomic pathways (SSPs) — represent two different plausible futures for Africa, one of relatively rapid economic growth and a more rapid demographic transition characterised by higher economic growth, urbanisation and education levels (SSP1), and the other of continued rapid population growth, combined with low levels of economic growth, urbanisation, and education (SSP3). For each scenario, the model projects future population distribution across the continent, including places that stand to gain and lose population.

Specifications for the Africa Climate Mobility Model were developed in 2020 with input from the AUC, UN, and the World Bank, along with the Technical Advisory Group (TAG) of experts from a wide range of disciplines. The modelling work builds on pioneering methods developed for the World Bank's *Groundswell* series of reports[18·110·111·153], with some important improvements. This technical appendix begins with a brief description of the premises behind a gravity model as it is applied to mobility modelling, and then describes the modelling inputs and methods.

A.1.1

## Premises behind the Africa Climate Mobility Model

The Africa Climate Mobility Model is based on a gravity modelling approach. Derived from Newton's law of gravity, gravity models are used to predict the degree of interaction between two places. 'Bodies' and 'masses' in Newton's law are replaced by 'locations' and 'importance', where importance can be measured in terms of population numbers, GDP, or other variables. Gravity models in demography seek to simulate aggregate human behaviour. A gravity model of migration is based on the idea that as the importance of one or both of the locations increases, movement between them increases. Movement between two locations is lower the greater the distance or geographic/political barriers between them. This phenomenon is known as 'distance decay'. In the aggregate, locational choice can be tied to factors such as economic opportunity, transportation infrastructure, proximity to family, the presence of social amenities, and intangibles, such as place attachment[181–183]. Changes in spatial distributions over time reflect changing perceptions. The tendency of populations to gravitate toward larger urban agglomerations, reflected in high rates of urbanisation globally, supports the notion that the presence of population is indicative of relative attractiveness.

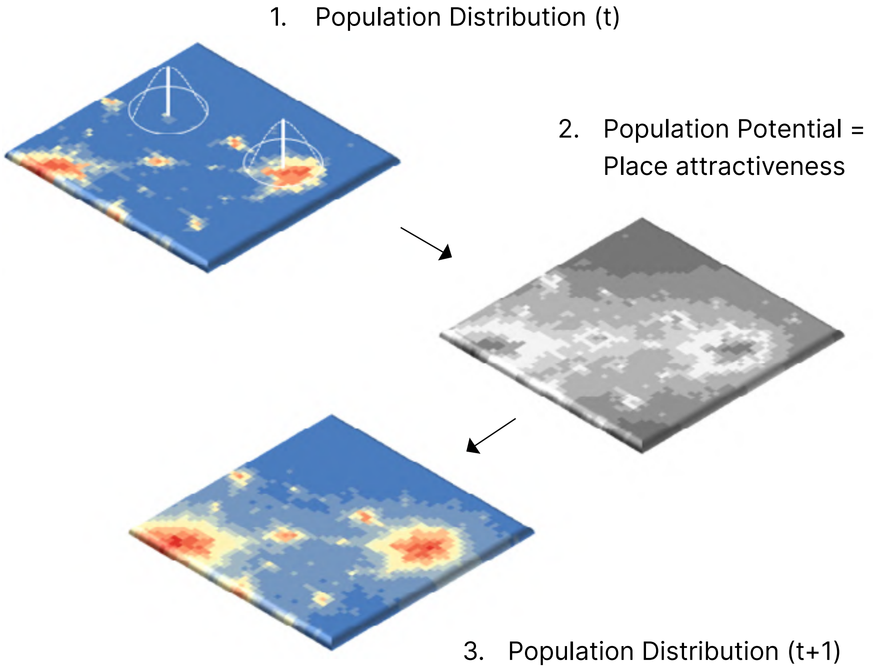
The Africa Climate Mobility Model focuses on three types of mobility: permanent climate mobility (from more voluntary to more forced), internal displacement, and cross-border displacement. We are unable to capture seasonal migrant flows, pastoral movements, and other temporary forms of mobility that are common in Africa.

Broadly, a gravity model assumes that larger settlements have more amenities (e.g. jobs, schools, services) that make them attractive, and that attractiveness translates to the *population potential* of a location. However, larger cities will not always be the most attractive. Population potential will decline as large cities approach 'saturation', the point at which population density is high enough that further population growth becomes unlikely or impossible (in the model this point is roughly equal to the highest present-day population densities, found in cities like Hong Kong and Singapore). In the gravity modelling approach used in this work, we assume that sectoral climate impacts along with conflict will impact the relative attractiveness (or population potential) of locations. The sectoral impacts include changes from the historical baseline in water availability, crop production (gap filled with ecosystem productivity), flood risk and sea level rise. Conflict risk is based solely on the past incidence of conflicts, since it was not deemed feasible to project conflicts into the future.

Gravity modelling can be applied to different units of analysis, from nation states down to smaller administrative units within countries. For this work, the model uses grid cells as the unit of analysis, and applies the gravity model on a country-by-country basis. The model begins with inputs of various resolutions that are resampled or aggregated so that all input data are on a 2.5 arc-minute (approximately 5 km) grid. The modelling is carried out in five-year increments from 2010, the last year for which accurate census data were available for selected countries in Africa (at the time the modelling began in 2020), up to the year 2050 (Figure A1). Outputs from the model run projecting the change in population distribution from 2010 to 2015 are used for projecting population distribution changes from 2015 to 2020, and outputs for 2020 are fed into the model for 2020 to 2025, and so on until 2050. Projected levels of population growth for each country and future tendencies towards dispersion or concentration of the population are based on development scenarios embodied in the Shared Socioeconomic Pathways (SSPs).

In order to assess climate-induced migration, projections are carried out with and without climate impacts included. All model outputs are then aggregated to 7.5 arc-minutes (or 15 km resolution), and model runs without climate impacts are subtracted from model runs that include climate impacts, and the difference between the two is assumed to result from population movements (migration) between grid cells. Positive differences represent climate mobility into an area, and negative differences represent climate mobility out of an area. The 15 km resolution data are used because this represents a distance that accords to common definitions of migration; shorter-distance moves could result from moves between neighbourhoods in the same settlement that would not properly be thought of as 'migration'[a].

Figure A1 **Gravity modelling approach**

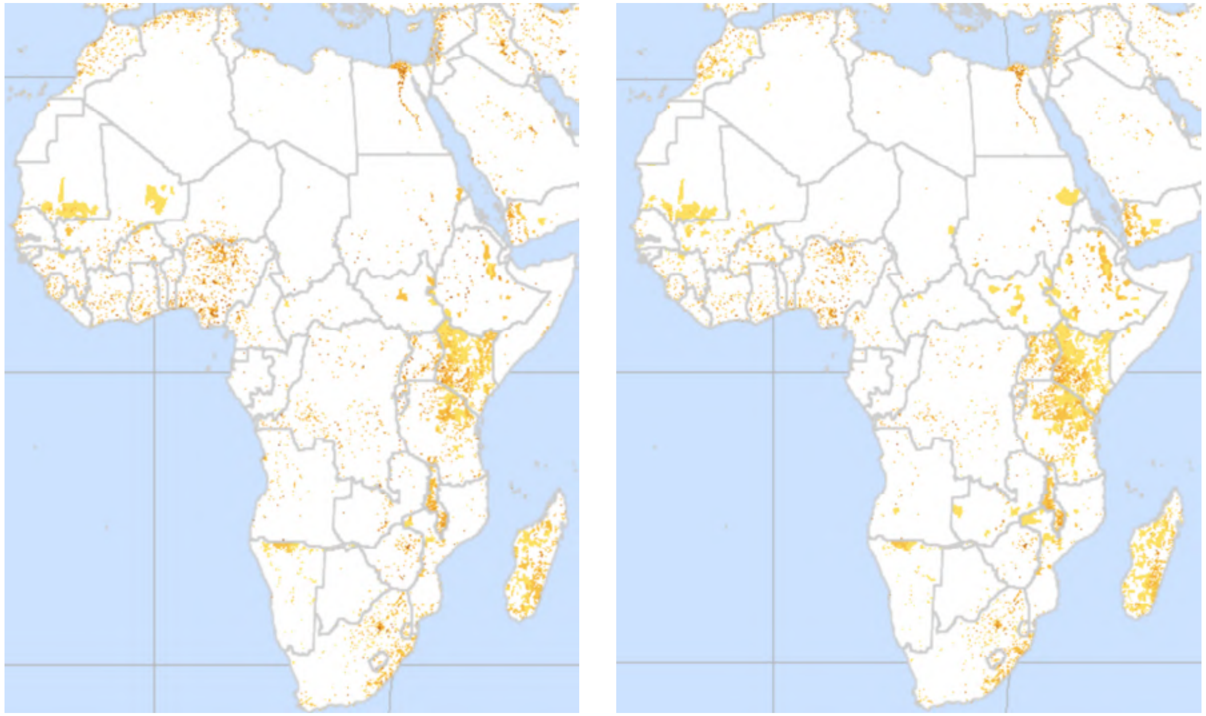



[a] Definitions of migration generally revolve around crossing of administrative boundaries, but this represents an inadequate basis for measuring the spatial dimension of migration. Niedomysl and Fransson (2014)[180] use data for Sweden, one of the few countries with population registry that tracks moves consistently over time, and find that the median move distance was only 5 km but the mean distance was 53 km in 2008. The map represents a middle ground of 15 km between these two distances.

Note that a gravity model of this kind does not rely on migration input data, which are very scarce, but rather builds on consistent time-series population grids that show how the population distribution shifts over time during the past 20 years, and which then form the baseline for projecting changes in distribution in the future[184] (Map A1). The model is calibrated by assessing the sensitivity of past shifts in population distribution to the sectoral climate impacts (as well as non-climate related drivers. It then uses those coefficients in combination with projected deviations in sectoral impacts on a grid-cell basis to alter the place attractiveness (population potential) of each grid cell in five year increments out to 2050. Since each country has different historic sensitivities to climate impacts, ideally the calibration would be done for every country in Africa. But in reality, the underlying census data in Africa vary considerably among countries, so we choose countries within each region based on best available data and apply their coefficients to other countries in the same region (Table A1).

To summarise, in the ACMI modelling approach, development scenarios drive population and urbanisation trends in a gravity model that distributes population change according to the place attractiveness of different locales over time. Two models are run in parallel, and in one the future population distribution is influenced by climate impacts on the water and agriculture sectors, ecosystem impacts, future flood risk, and sea level rise, all of which influence attractiveness. The model estimates the number of climate migrants and their future locations by comparing the population distributions that incorporate climate impacts with scenarios based on development trajectories only. Next, we describe the scenarios and data inputs in more detail.

Map A1 **Population distribution in Africa for 1990 (left) and 2015 (right)**



Source: JRC and CIESIN 2021

Table A1 **Countries used for calibration of the reference country in column**

| | Calibration 1 | Calibration 2* |
|---|---|---|
| **Eastern Africa** | | |
| Burundi | Malawi | |
| Djibouti | Ethiopia | |
| Eritrea | Ethiopia | |
| Ethiopia | Ethiopia | |
| Kenya | Kenya | |
| Madagascar | Kenya | Malawi |
| Malawi | Malawi | |
| Mozambique | Kenya | Malawi |
| Rwanda | Kenya | Malawi |
| Somalia | Ethiopia | Kenya |
| South Sudan | Ethiopia | Kenya |
| Uganda | Kenya | |
| Tanzania | Kenya | |
| Zambia | Zambia | |
| Zimbabwe | Zimbabwe | |
| **Central Africa** | | |
| Angola | Gabon | Zambia |
| Cameroon | Cote d’Ivoire | Gabon |
| Central African Republic | Cote d’Ivoire | Senegal |
| Chad | Cote d’Ivoire | Senegal |
| Congo | Cote d’Ivoire | Gabon |
| DR Congo | Gabon | Zambia |
| Equatorial Guinea | Cote d’Ivoire | Gabon |
| Gabon | Gabon | |
| **Southern Africa** | | |
| Botswana | South Africa | Zimbabwe |
| Eswatini | South Africa | |
| Lesotho | South Africa | |
| Namibia | South Africa | |
| South Africa | South Africa | |

| | Calibration 1 | Calibration 2* |
|---|---|---|
| **West Africa** | | |
| Benin | Cote d’Ivoire | Ghana |
| Burkina Faso | Ghana | Senegal |
| Cabo Verde | Senegal | |
| Côte d'Ivoire | Cote d’Ivoire | |
| Gambia | Senegal | |
| Ghana | Ghana | |
| Guinea | Cote d’Ivoire | Senegal |
| Guinea-Bissau | Cote d’Ivoire | Senegal |
| Liberia | Cote d’Ivoire | |
| Mali | Senegal | |
| Mauritania | Senegal | |
| Niger | Senegal | |
| Nigeria | Cote d’Ivoire | |
| Senegal | Senegal | |
| Sierra Leone | Cote d’Ivoire | Senegal |
| Togo | Cote d’Ivoire | Ghana |
| **Northern Africa** | | |
| Algeria | Morocco | |
| Egypt | Egypt | |
| Libya | Egypt | |
| Morocco | Morocco | |
| Sudan | Ethiopia | Kenya |
| Tunisia | Morocco | |
| Western Sahara | Morocco | |

* If more than one calibration country is listed, we take the average of the coefficients for the two calibration countries.

A.1.2
# Modelling inputs

The Africa Climate Mobility Model projections are informed by combinations of development and emissions scenarios. We discuss the scenarios and then describe the Intersectoral Impacts Model Intercomparison (ISIMIP) model data used as modelling inputs, followed by other inputs.

A.1.2.1
## The development scenarios

The development scenarios informing the climate mobility model are based on the Shared Socioeconomic Pathways (SSPs), a framework for describing socioeconomic and demographic developments in Africa and globally. We chose two contrasting SSPs. The first is a 'sustainability' scenario (SSP1) that is characterised by low population growth, high urbanisation, medium GDP, and high education across Africa. Under SSP1, rapid economic growth in low-income countries reduces the number of people below the poverty line. The world is characterised by an open, globalised economy, with relatively rapid technological change directed toward environmentally friendly processes, including clean energy technologies and yield-enhancing technologies for land. This is an optimistic development pathway for the continent, and results in a total continental population in 2050 of 1.75 billion people (up from 1 billion in 2010) that is relatively concentrated in urban areas.

The second scenario is the 'regional rivalry' scenario (SSP3), which is characterised by high population growth and low urbanisation, as well as low GDP and education across much of sub-Saharan Africa. This is a world failing to achieve global development goals, and with little progress in reducing resource intensity, fossil fuel dependency, or addressing local environmental concerns such as air pollution. Inequality remains high both across and within countries, and economies are relatively isolated, leaving large, poor populations in developing regions highly vulnerable to climate change with limited adaptive capacity. The world has de-globalised, and international trade, including energy and agricultural trade, is severely restricted. By contrast with the low-income countries of Africa, middle income countries (South Africa and northern Africa) are characterised by low population growth rates, high urbanisation, moderate GDP, and low education levels. For this scenario, Africa's population grows to 2.3 billion people by 2050 (500 million more than under SSP1) and remains largely rural.

A.1.2.2
## The warming scenarios

Turning to emissions or warming scenarios, the magnitude of future global warming is framed by the Representative Concentration Pathways (RCPs)[185]. RCPs are trajectories of greenhouse gas concentrations resulting from human activity corresponding to a specific level of radiative forcing in 2100[b]. For the ACMI modelling work, we chose two RCPs, a lower greenhouse gas concentration of RCP2.6 and the higher greenhouse gas concentration of RCP6.0. These imply futures where radiative forcing of 2.6 and 6.0 watts/m$^2$, respectively, are achieved by the end of the century[c]. From a baseline in the year 1990, the additional warming implied by these RCPs is a low of 0.5°C (RCP2.6) to a high of 2.0°C (RCP6.0) by 2050, with far more warming anticipated (about 2.5°C on average) by 2100 under RCP6.0 (Figure A2).

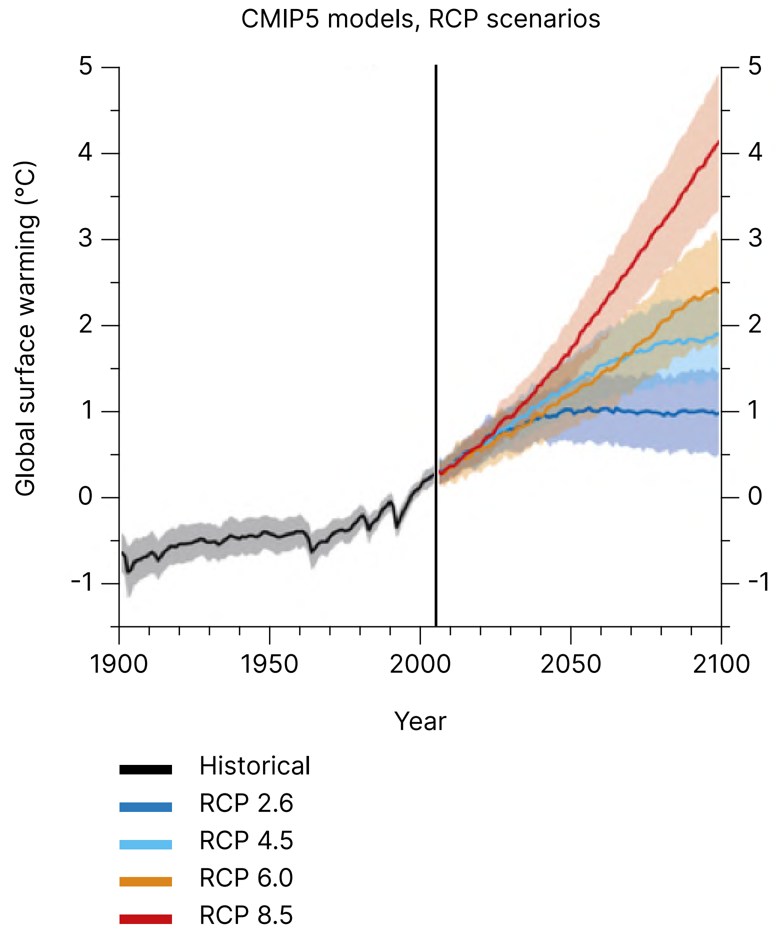
b Radiative forcing is the measurement of the capacity of a gas or other forcing agent to affect that energy balance, thereby contributing to climate change.

c These RCPs are sometimes referred to in this report as 'emissions scenarios'. They are actually 'warming scenarios', as they reflect the radiative forcing (in watts per square meter) associated with various emissions levels.

RCPs do not rely on a fixed set of scenario-specific assumptions on economic development, technological change, or population growth. Many different socioeconomic futures or pathways may lead to the same level of radiative forcing. This framework allows researchers to consider alternative policy decisions with combinations of social, economic, and technological change. A future with high population growth but rapid development of clean technology may achieve the same level of radiative forcing as a world characterised by low population growth but continued reliance on fossil fuels. This framework allows researchers to specify certain levels of temperature change and then explore alternative policy options to achieve greenhouse gas concentration levels consistent with the goal.

Some may question the choice of scenarios. RCP2.6 is considered unrealistic by many in a world that is poised to hurtle past the Paris Agreement target of limiting additional warming to 1.5°C, and where nationally determined contributions are largely insufficient to reach that target[186]. This RCP serves mainly as a contrast to the higher emission pathway, and serves also to demonstrate that even at this lower level of emissions the consequences for human mobility may be equal to or higher than RCP6.0. As for RCP6.0, while RCP8.5 was chosen as a high end scenario for past work[18], partly because it was often portrayed as a business-as-usual scenario, in reality it reflects the very high end of the Rocky Road emissions pathway, and is considered by some to be implausible[187]. Furthermore, it could not be used for this work because (a) not all ISIMIP crop models have been run under RCP8.5, and (b) it is only compatible with SSP5 (a world characterised by rapid conventional development that leads to an energy system dominated by fossil fuels), according to the current literature[106].

Figure A2 **Projected global average surface temperature change by RCP**




Source: CMIP5 models explained by the climate literacy course run by UW-Madison Office of Sustainability ↗.

### A.1.2.3

## The four climate mobility modelling scenarios

The combination of SSPs and RCPs create four plausible future internal climate mobility scenarios (Figure 9):

- **Low Growth / High Emissions** (Rocky Road) (SSP3 and RCP6.0), in which low-income countries are characterised by moderate population growth, low rates of urbanisation, low GDP growth, and low education levels. Urban growth is poorly planned, and high emissions drive greater climate impacts. This scenario poses high barriers to adaptation because of the slow pace of development and isolation of regional economies.

- **Low Growth / Low Emissions** (SSP3 and RCP2.6), which reduces climate impacts, but holds the development scenario consistent with the Rocky Road scenario.

- **High Growth / High Emissions** (High Road) (SSP1 and RCP6.0), which holds emissions where they are in the Rocky Road scenario but provides a development scenario that is more optimistic and the potential for adaptation is higher than under SSP3. Population growth is lower than in SSP3 for low-income countries, and urbanisation is more rapid, resulting in more concentrated populations.

- **High Growth / Low Emissions** (SSP1 and RCP2.6), which reduces climate impacts and provides a development scenario that is more optimistic.

### A.1.2.4

## The warming scenarios

Climate models based on the two warming scenarios (RCP2.6 and RCP6.0) drive the indicators of water, agricultural, and ecosystem sector change, as well as flood risk provided by the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP), which are incorporated in projections of future population distributions. ISIMIP is a climate-impact modelling initiative aimed at contributing to a quantitative and cross-sectoral synthesis of the differential impacts of climate change, including uncertainties. ISIMIP ↗ has compiled a database of state-of-the-art computer model simulations of biophysical climate impacts. It offers a framework for consistently projecting the impacts of climate change across affected sectors and spatial scales.

The ACMI modelling uses outputs of the ISIMIP 2a modelling work, which covers the historic period from 1970 to 2010, and ISIMIP 2b modelling effort, which has projections for 2010 to 2100[188]. Under the 2b modelling effort, the future sectoral impact models are driven by a range of general circulation models. The 2b modelling effort has the advantage over the prior ISIMIP Fast Track in that the models are bias-corrected, meaning they better capture historical means and variability in temperature and precipitation. This project uses two general circulation models that provide a good spread for the temperature and precipitation parameters of interest: the HadGEM2-ES climate model developed by the Met Office Hadley Centre for Climate Change (in the United Kingdom) and the GFDL-ESM2M produced by the Geophysical Fluid Dynamics Lab (in the United States) (see Section A.2.6 for the rationale behind our model selection).

The ISIMIP 2b collection of sectoral models includes a range of systems and sectors, such as health, coastal infrastructure, forests, and other ecosystems. The focus of this study is on crop production, water availability, ecosystem impacts, and riverine floods. The global crop, water and ecosystem simulations — at a relatively coarse spatial scale (0.5 degrees or roughly 55 km at the equator) — are an advance over purely climate model-based indicators of rainfall and temperature, because they represent actual resources of relevance to development. The flood impact model is at 500 m resolution, and is based on projected flood depth. In this work, flood impact is used as a mask to reduce the potential of affected grid cells, and therefore the likelihood of future migration into areas that are projected to suffer increasing flood risks.

These climate impacts are selected because the literature shows that water scarcity, declining crop yields, declines in pasturage, and flood impacts are among the major potential climate impacts facing low-income countries and these impacts will also be very important drivers of migration and displacement[d]. Finally, sea level rise is included as a spatial mask that does not permit people to live in areas likely to experience inundation. Each of these input layers is described in greater detail below.

The models are better at assessing long term trends rather than individual extreme events such as drought, extreme rainfall or cyclones. As devastating as they may be for rural livelihoods, short-duration, fast-onset events are not directly included. That said, the proposed five-year time step does capture the combined effects of repeated extreme events better than the original ten-year time step used in *Groundswell*[18, 110], where extremes in either direction are more likely to counterbalance each other over the course of a decade. To further assess the impact of extremes, we include projected flood impacts (described below).

Data on water availability and crop production are integrated into the Africa Climate Mobility Model using the following approach. The water sector model outputs represent river discharge, measured in cubic meters per second in daily/monthly time increments. The crop sector model outputs represent crop yield in tons per hectare on an annual time step at a 0.5° × 0.5° grid cell resolution. Crops include maize, wheat, rice, and soybeans for the GEPIC model, and those crops plus cassava/tropical roots, groundnut, millet/tropical cereals, field pea/pulses, rapeseed, sugarcane, sugarbeet/temperate roots, sunflower for the LPJmL model. For regions with multiple cropping cycles, yield reflects only the major crop production period. In conformity with the work for *Groundswell*, the data are converted to five-year average water availability and crop production (in tons) per grid cell[189, e].

We measure climate change impact by calculating at each 0.5 × 0.5 degree grid cell an index of 5-yearly deviations from a baseline period, for the following variables: Annual mean discharge (water), annual crop yield (agriculture), annual mean total net primary productivity (NPP, biomes/ecosystems). Note that crop yield is the sum over all considered crops, weighted by estimated growing areas around the year 2000[189]. Let $t_0$ be the baseline period (1970–2010), $t$ a 5-year time period (1971–1975, 1976–1980, …), and $x(t)$ the average of one of the above variables over $t$. Then the reported index $D$ is calculated as:

Equation 1
$$D_x(t) = \frac{x(t) - x(t_0)}{x(t_0)}$$

That is, $D$ is a dimensionless number ranging from -1 to +∞, where 0 means no change compared to the baseline. A value of -0.5 means a reduction by 50 percent compared to the baseline, while a value of +1 means a doubling (increase by 100 percent) compared to the baseline.

d Water availability is influenced by rainfall and rising temperatures. Crop production is a function of rainfall, temperature, $CO_2$ concentrations, irrigation, and other management practices that are incorporated in the ISIMIP models.

e The ISIMIP models seek to assess the risk that climate change will affect the potential for agriculture in a given location. For this purpose, the relative changes in average yield potential are useful.

The ISIMIP crop and water model outputs are based on different combinations of climate, crop, and water models. Applying the combinations — two global climate models driven by two different emissions scenarios, which in turn drive two sets of sectoral impact models (described below) — provides a range of plausible population projections. It also gives a sense of the level of agreement across scenarios. Because the population process is time consuming and computationally intensive, we needed to work with a reduced set of ISIMIP inputs[f]. The modelling employs the HadGEM2-ES and GFDL-ESM2M global climate models, which drive combinations of the two water and crop models: the LPJmL and GEPIC crop models and the WaterGAP2 and MATSIRO water models (Table A2). Note that because the crop models only cover parts of Africa where cropping is prevalent, we gap-fill the climate data with two models of net primary productivity (NPP) — ORCHIDEE and LPjML — that are intended to represent changes in pasture land[g] productivity[h].

The crop and water models are selected based on several criteria, including model performance over the historical period, diversity of model structure, diversity of signals of future change, and availability of both observationally driven historical (ISIMIP2a) and global climate model-driven historical and future (ISIMIP 2b) simulations. Table A2 presents the combinations of crop and water models that will be used. Section A.2.6 below provides detailed information on model selection.

Table A2 **Matrix of global climate models and crop and water model combinations**

| | | | ISIMIP Crop Models | | | |
|---|---|---|---|---|---|---|
| | | | **HadGEM2-ES** | | **GFDL-ESM2M** | |
| | **Global Climate Models (CMIP5)** | **ISIMIP Models** | GEPIC* | LPJmL** | GEPIC* | LPJmL** |
| ISMIP Water Models | **HadGEM2-ES** | WaterGAP2 | Model 1 | | | |
| | | MATSIRO | | Model 2 | | |
| | **GFDL-ESM2M** | WaterGAP2 | | | Model 3 | |
| | | MATSIRO | | | | Model 4 |

* GEPIC crop model coverage is gap-filled with the ORCHIDEE NPP model.

** LPJmL crop model coverage is gap-filled with the LPJmL NPP model.

f The models report 'pure crop yields' in tons per hectare (that is, they assume that a given crop is grown everywhere, irrespective of growing conditions or the location where crops are actually grown). These yields were multiplied by observations-based growing areas (in 2005), separately for rain-fed and irrigated yields, to obtain grid cell-level production (in metric tons). Note that potential adaptation responses are not included, since our interest is to see how mobility may evolve in the absence of adaptation.

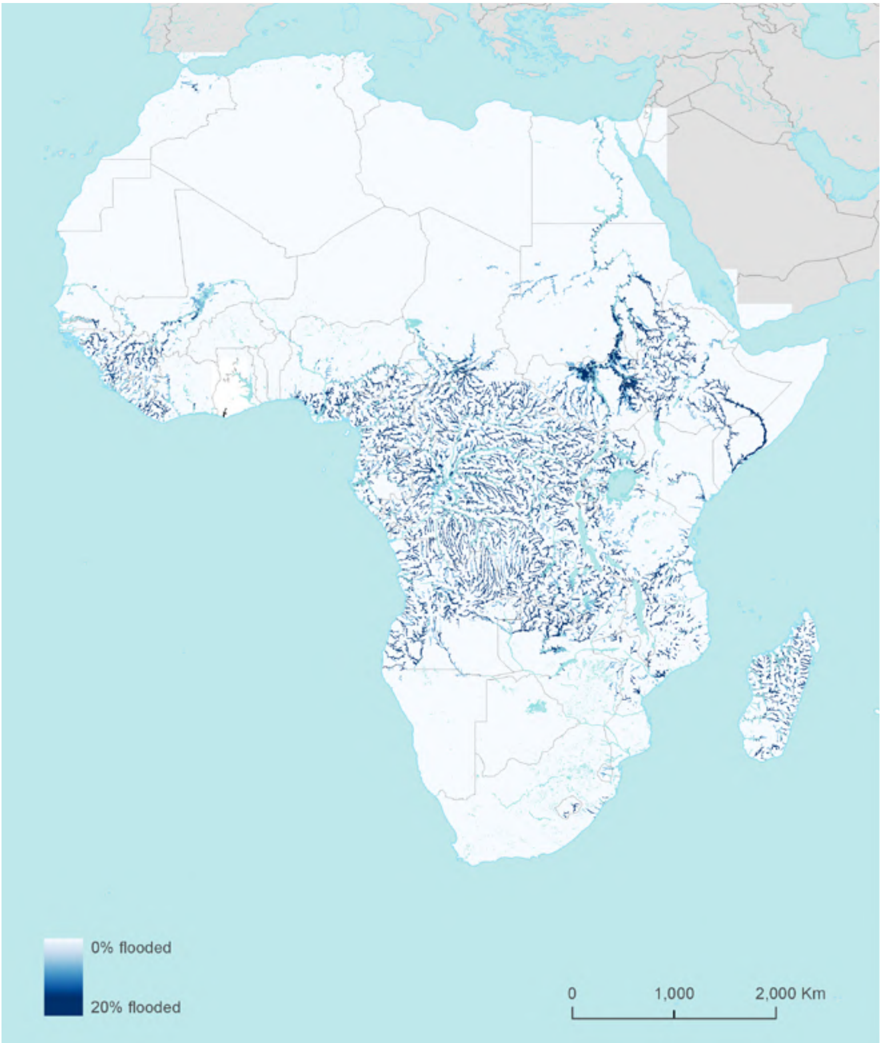
g Feeding all potential ISIMIP water and crop model outputs into the gravity model would have yielded 12,500 model runs: 2 RCPs * 5 GCMs * 25 crop model outputs * 50 water model outputs = 12,500

h The NPP change data also project changes in forest productivity, but the populations in such areas are generally far lower than savannah areas where agro-pastoral and pastoral systems are prevalent, and the projected changes in dense forest productivity are generally not that significant compared to the more climate variable pasturelands.

Maps of the projected average index values for each of the model runs for high and low warming scenarios for the period 2010 to 2050 are available in Annex B. Note that these maps are purely to illustrate the general tendencies over the 40-year modelling period. In the actual modelling work, the index values for each five-year increment (e.g. 2010 to 2015, 2015 to 2020, 2020 to 2025, etc.) are multiplied by the coefficient for that sectoral impact to modify the population potential. Recall that the coefficients for each sectoral impact are generated through the calibration process over the historical period from 1990 to 2010 (details of which are found in Section A.3.2).

The ISIMIP flood risk projections use an ensemble of the H08, LPjML, MPI-HM, Orchidee, PCR-GlobWb and WaterGAP2 models under RCP6.0. According to Zhao (personal communication), the differences between flood risk for RCP2.6 and RCP6.0 are not that great, so we chose to use projections only under RCP6.0. The map of projected flooded areas shows areas that will experience a relatively high degree of flooding by 2050, measured in terms of the reduction in population potential in each 2.5 arc-minute (5 km square) grid cell (Map A2). A maximum reduction of 20 percent was chosen, meaning all things being equal, a flooded grid cell would be 20 percent less likely to attract new population than a neighbouring unflooded grid cell.

Map A2 **Projected flood risk in 2050 (measured in terms of reduced population potential)**




Map: CIESIN, Columbia University, November 2022. Data source: Potsdam Institute for Climate Impacts Research, Ensemble of ISIMIP Flood Depth Projections using the H08, LPjML, MPI-HM, Orchidee, PCR-GlobWb, and WaterGAP2 models under RCP 6.0.

Lastly, the model incorporates projected sea level rise impacts. Parts of the continent's coastline — particularly the Niger and Nile deltas — are particularly vulnerable to sea level rise impacts[71,190–192]. The analysis also considers sea level rise (SLR) projections from the IPCC Fifth Assessment Report, augmented by an increment for storm surges. The figures in Table 4 represent the lower-, middle-, and upper-bound sea level rise by 2030 and 2050, as reported by the IPCC[193], but do not take storm surge into account. According to Dasgupta *et al.*[194]

> 'Even a small increase in sea level can significantly magnify the impact of storm surges, which occur regularly and with devastating consequences in some coastal areas'.

A comprehensive assessment of the likely levels of storm surge for all the coastal areas will be beyond the scope of this project. In any case, according to IPCC Fifth Assessment Report, Working Group II, Chapter 5, the habitability of coastal areas not immediately within the low elevation coastal zone (LECZ) will be negatively impacted through increased coastal flooding, erosion, and saltwater intrusion into estuaries and deltas, as well as increases to the water table. For simplicity in this work, we assume that sea level rise + storm surge under RCP2.6 will amount to a 1 m inundation in LECZ by 2050, and that under RCP6.0 it will amount to a 2 m inundation. These levels of inundation are progressively diminished working backwards from 2050 to 2010. The effect of SLR + storm surge is to remove land in each 2.5 arc-minute grid cell from circulation, which results in a reduction in population potential in those coastal grid cells. The source data set is NASA's Shuttle Radar Topography Mission (SRTM).

### A.1.2.5

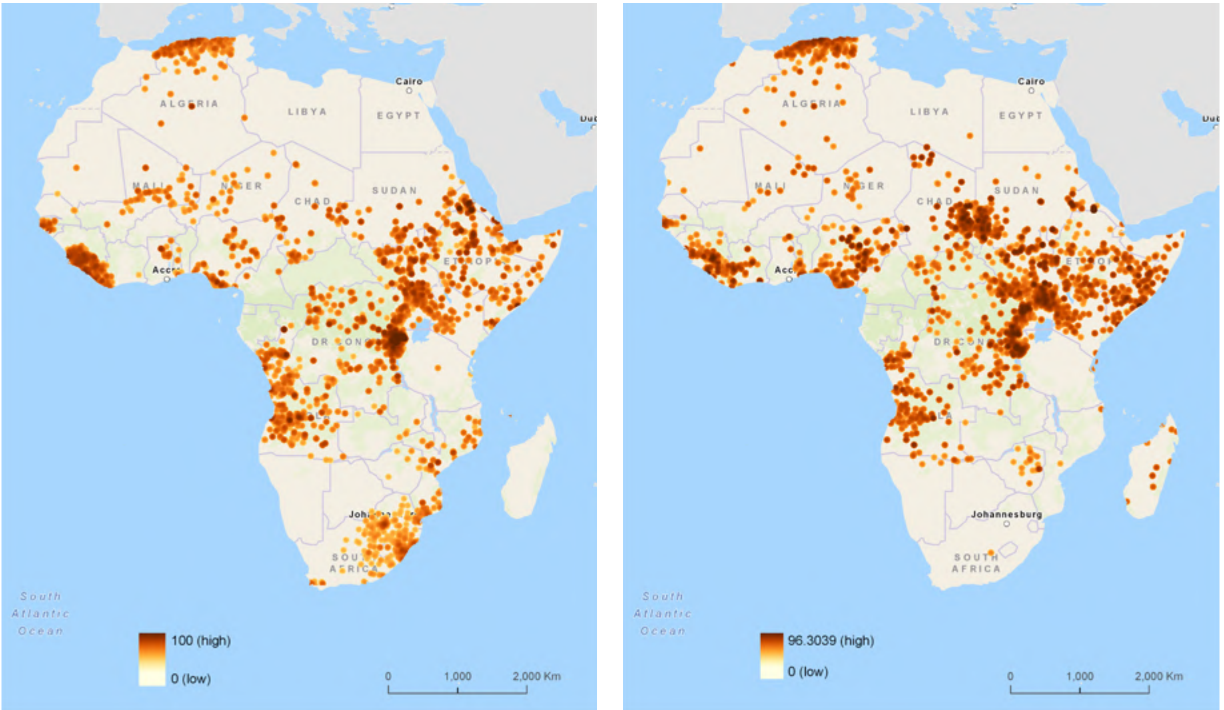
## Other data inputs

A full set of data inputs is found in Table A3, and here we describe a few of the more important data sets used in the modelling. The Africa Climate Mobility Model innovates in some other important respects. A major advance was the incorporation of modelled population grids for the calibration and the baseline for projections. Past work under *Groundswell* and *Groundswell Africa* used an unmodelled population surface, Gridded Population of the World version 4[195], which takes as its basis census inputs that are provided by countries for widely varying geographies. It uses a uniform distribution or proportional allocation that does not make use of any other geographic data in order to spatially disaggregate the census population. In the case of Africa, some countries only have state/provincial level census inputs (admin1), whereas others have much higher resolution inputs (admin4 or admin5). Coarser resolution inputs mean that GPWv4 tends to overestimate rural populations because populations are allocated (spread out) over large census units. To rectify this situation, we used a modelled population surface, Global Human Settlement Layer-Population (GHS-POP), that is available in time series for 1990, 2000, and 2015[196]. GHS-POP consists of census data from GPWv4, Revision 10 (GPWv4.10), that are spatially allocated within census units based on the percent built-up areas from GHS-BUILT, a layer constructed from Landsat and later Sentinel satellite imagery. The native resolution of GHS-POP is 30 arc-seconds (or 1 km), but in order to reduce the potential for artefacts to affect the modelling work, the data were aggregated to several different resolutions, and 2.5 arc-minutes was chosen because it presented the best balance between higher resolution and fewer errors[i].

[i] GHS-BUILT tends to have higher errors of commission, meaning it finds settlements in areas where there are actually no settlements or sparsely populated settlements owing to the spectral signature of certain kinds of land covers (rocky outcrops, lake beds, etc.), than errors of omission.

Owing to the prevalence of conflict on the continent, and the potential for conflict to affect mobility through forced displacement, data on conflict incidence are also included in the model. We use data from the Uppsala Conflict database, which has a longer and more consistent time series (1989 to present) than the Armed Conflict Locations and Events Database (ACLED) (1998 onwards). We included the historical conflict data in the calibration process (two periods 1990 to 2000 and 2000 to 2010), to assess the sensitivity of past changes in population distribution to conflict events (Map A3). In the absence of data on projected future conflict locations, we included the 2000 to 2010 conflict surface in the gravity model through 2050. While it is an unlikely assumption that future conflict will remain stationary — indeed, recent outbreaks in the Sahel are showing how volatile some regions are — there was no way to project future conflict spatially without heroic assumptions.

Map A3 **Index of deaths from armed conflicts for 1990 to 2000 (left) and 2000 to 2010 (right)**




Map: CIESIN, Columbia University, November 2022.
Data source: Uppsala Conflict Data Program.

Table A3 **Data inputs used in the Africa Climate Mobility Model**

| Product | Source Data | Resolution | Time Series | Time Step | Indicator / Purpose |
|---|---|---|---|---|---|
| Population Grids | GHS-POP[196] | 30 arc-sec converted to 2.5 arc-min | 1990, 2000, 2015 | | Calibration; population count |
| Urban Mask | GHS-SMOD[197] | 30 arc-sec converted to 2.5 arc-min | | | Calibration; dummy variable |
| Water Availability | ISIMIP2b | 0.5 deg | 1990–2050 | 5-year | Calibration; deviations from baseline |
| Crop Production | ISIMIP2b | 0.5 deg | 1990–2050 | 5-year | Calibration; deviations from baseline |
| Net Primary Productivity | ISIMIP2b | 0.5 deg | 1990–2050 | 5-year | Calibration; deviations from baseline |
| Conflict Deaths | Uppsala[198, 199] | Buffered points converted to 2.5 arc-minutes | 2000–2015 | annual | Calibration |
| Flood Hazard | ISIMIP2b | 1 km | 1990–2040 | 5-year | Mask out flooding |
| Sea level rise | SRTM[200] | 1 km | 2020–2050 | 5-year | Mask out coastal SLR |
| Water Bodies | Esri | vector | 2021 | n/a | Mask out perennial water bodies to future settlement |
| Protected Areas (PAs) | WDPA[201] | vector | 2021 | n/a | Mask out PAs to future settlement; SSP3 includes IUCN categories 1-1a-2-3, and SSP1 adds cat. 4 |
| Slope | | | | | Mask — 25 percent maximum slope for settlement |
| Elevation | | | | | Mask — highest existing settlement |

The model applies a mask to avoid rapid population growth in regions where population densities currently are below one person per square kilometre, for example in parts of the Saharan desert.

We experimented with additional possible data layers to include in the model. One was a surface of population displacement owing to disasters based on the Geocoded Disasters (GDIS) Dataset[202]. The theory was that past disaster displacement may have repelled populations from areas frequently affected by meteorological disasters (flood and drought). In reality, however, our calibration work revealed that the displacement surface always produced large and positive coefficients, which would have resulted in a 'pull' towards disaster displacement regions. This may be because flood disasters are a major type of disaster in the database and waterbodies (particularly river valleys) tend to attract populations over time, or it could be that the coarse resolution of many reported displacements resulted in geolocation errors. Ultimately disaster displacement was not included in the model.

The remainder of the data sets included in the model that are listed in Table A3 are for the purposes of removing certain areas ('masking') from future settlement. Masks effectively set the population potential of a grid cell to zero (0), meaning that no migration will occur in those areas.

### A.1.2.6
## Rationale for model selection

**Global climate models**
Four Global Climate Models (GCMs) were considered for use in the ACMI modelling work: GFDL-ESM2M, HadGEM2- ES, IPSL-CM5A-LR, and MIROC5. These models were selected for ISIMIP2b from the larger CMIP5 model ensemble, and the data were bias-corrected to remove systematic deviations of the models' historical mean climate state from observations, while preserving simulated long-term trends[188]. The four models cover a range of climate sensitivities; IPSL-CM5A-LR and HadGEM2-ES being on the warm side (equilibrium climate sensitivity (ECS) above 4°C), while GFDL-ESM2M and MIROC5 are on the cool side (ECS around 2.5°C)[203]. For our purpose, we selected two models with a view to representing a range of possible climate responses in Africa, keeping in mind that such a small number of models cannot be representative of the spread found in larger model ensembles for many important climate variables.

Changes in regional temperature relative to global mean temperature are similar across all models. The projected drying trend in the two subtropical regions of the continent, the Mediterranean and southern Africa, is also relatively robust across CMIP5 models, and well-established in atmospheric science (IPCC AR5 WG1 Chapter 12). More uncertain, yet very important for the societal impacts, is the precipitation response in tropical West Africa and East Africa. For instance, some models project strongly increasing summer (wet season) rainfall across the central and eastern Sahel region, while others project only small changes there[204]. Of the four ISIMIP2b models, MIROC5 and HadGEM2-ES both project a substantial increase in Sahel rainfall under global warming; while IPSL-CM5A-LR projects little change, and GFDL-ESM2M even projects a decrease.

In East Africa, IPSL-CM5A-LR projects by far the strongest increase in precipitation, but has been shown to be an outlier compared to the rest of the CMIP5 ensemble, and likely overestimates a feedback between sea surface temperatures and cloud cover over the Indian Ocean[205]. MIROC 5 and GFDL-ESM2M both project increasing precipitation over East Africa, while HadGEM2-ES projects relatively stable precipitation[188 supplemental material]. Thus, we chose the HadGEM2-ES and GFDL-ESM2M models because they cover both high and low ECS (i.e. overall 'intensity' of global warming), and contrasting precipitation responses in both West Africa and East Africa.

**ISIMIP crop models**

A comprehensive analysis of global crop model responses to projected future global warming shows that GEPIC is typically one of the more pessimistic models (i.e. predicting stronger declines in crop yield, on average), while LPJmL and PEPIC tend to fall near the centre of the ensemble[206]. A detailed benchmarking study, comparing historical model simulations with reported national crop yield data, indicates that LPJmL, GEPIC, and PEPIC have relatively low mean bias for maize yields in most African countries, while CLM-Crop often has larger positive biases[206 fig. s23]. For wheat, GEPIC and PEPIC exhibit larger negative biases in some countries such as Zambia, Namibia and Botswana, while LPJmL and CLM-Crop have positive biases in individual countries such as Egypt and Burundi[206 fig. s24]. In terms of year-to-year variability in yields, correlation between models and data varies and is rather low in many African countries for all of the models. However, this is at least partly due to high uncertainty in the reported yield data[206 fig. 9]. In the present work, annual yield data are not used directly, but aggregated over five-year periods, placing less importance on the timing of individual annual yields.

A global study of future risk of crop failure including LPJmL, GEPIC, and PEPIC, shows that the projected increases in population exposure to crop failure under global warming do not differ greatly between the models when forced with the HadGEM2-ES or MIROC5 climate models[207]. In the simulations forced with the other two climate models, GEPIC tends to project larger increases in exposure to crop failure than PEPIC and LPJmL.

LPJmL is the only model that simulates a number of additional crop types, some of which are widely grown in Africa: cassava (representing tropical roots), groundnut, millet (tropical cereals), field pea (pulses), rapeseed, sugarcane, sugarbeet (temperate roots), and sunflower. GEPIC and the other models only provide maize, wheat, rice and soybean yields. For this reason, we have chosen to use LPJmL and GEPIC.

**ISIMIP water models**

A recent evaluation of several global hydrological models, including five from the available ISIMIP2b ensemble (H08, LPJmL, MATSIRO, PCR-GLOBWB, and WaterGAP2), found that WaterGAP2 is best at simulating mean annual runoff in almost all hydrobelts (hydro-geographical regions on Earth), and second-best in the northern subtropical hydrobelt (which in Africa includes the Niger river basin), showing relatively small deviations from observed streamflow at observational stations around the globe[208]. This is partly expected because of the extensive calibration applied to this model, and does not necessarily imply that projected future trends in the other models are less plausible. The MATSIRO model comes second place in this evaluation of mean annual runoff.

A separate study of historical changes in global water scarcity using those same five models indicates that the portion of people estimated to be affected by water scarcity is largest with MATSIRO and H08, and lowest with PCR-GLOBWB, while the estimates from LPJmL and WaterGAP2 fall in between[209]. Under future global warming, WaterGAP2 and JULES-W1 tend to project smaller changes in drought exposure, while PCR-GLOBWB, LPJmL, and H08 tend to project larger relative increases in drought exposure[207]. However, these results depend to some extent on the underlying climate model. For instance, CLM45 projects rather large increases with GFDL-ESM2M, but relatively small increases with HadGEM2-ES. MATSIRO was not analysed in this study. For this reason, we have chosen to use MATSIRO and WaterGAP2.

An additional note is warranted about the inclusion of human impacts on the water cycle such as damming and irrigation. During calibration of the water models, the past response of population distribution to changes in water availability is calculated based on simulations that did not include changes in human impacts (HI) on the water cycle, other than those related to greenhouse gas emissions (so called no societal or 'nosoc' simulations). Such human impacts include the construction of dams and reservoirs, and the withdrawal of water for purposes such as irrigation. Changes in such impacts were excluded because they could confound the effect of climate change on water availability, which is the effect we seek to identify. In other words, we are looking to quantify the effect of climate change on human migration, not the effect of other anthropogenic interferences with the water cycle.

Accordingly, for the future projections, we use ISIMIP2b simulations that also exclude any potential changes in HI in the future, by keeping all HI fixed at 2005 levels ('2005soc'). For the historical period in ISIMIP2b (which is still driven with climate-model output and must not be confused with the observations-based ISIMIP2a simulations), only simulations accounting for changing HI ('histsoc') are available. This is not a significant problem because the results of the population modelling are presented relative to the baseline year 2015, and thus any changes related to HI prior to 2015 do not have any imprint on the modelling results. (Note that the baseline against which deviations in water availability are being measured is defined as the average of 1971–2010, and thus includes some HI-related variations, but this is not relevant for the population modelling results for the aforementioned reason.)

**ISIMIP ecosystem models**

As discussed above, the ecosystem model, more properly understood as a model of net primary productivity (NPP), is used to gap-fill areas that do not have agricultural model outputs owing to the absence of cropping. A global evaluation of carbon fluxes in the ISIMIP2a biome modes shows that the magnitude of historical Net Biome Productivity (NBP) simulated by JULES, VEGAS, ORCHIDEE and LPJmL falls well within the observationally constrained range; while DLEM, LPJ-GUESS, VISIT, and CARAIB simulations fall partly or largely outside that range, and overestimate NBP[210]. On the other hand, the observed trend in global NBP is most closely reproduced by CARAIB, ORCHIDEE and LPJmL, with VEGAS and JULES most strongly underestimating the trend, and the other models falling in between. ORCHIDEE runs on a 1 × 1 degree grid, whereas LPJmL and most other models run on a 0.5 × 0.5 degree grid. Based on this evaluation, we chose to use the ORCHIDEE and LPJmL model outputs.

A.2

# The Africa Climate Mobility Model

A.2.1
## Introduction to the model

Climate impacts on crop production, water availability, ecosystem productivity, and flood depth and extent, have important impacts on the population potential of locations in the gravity model, as described in this section. The modelling work is based on a modified version of the National Center for Atmospheric Research-CUNY Institute for Demographic Research INCLUDE gravity model[184·j].

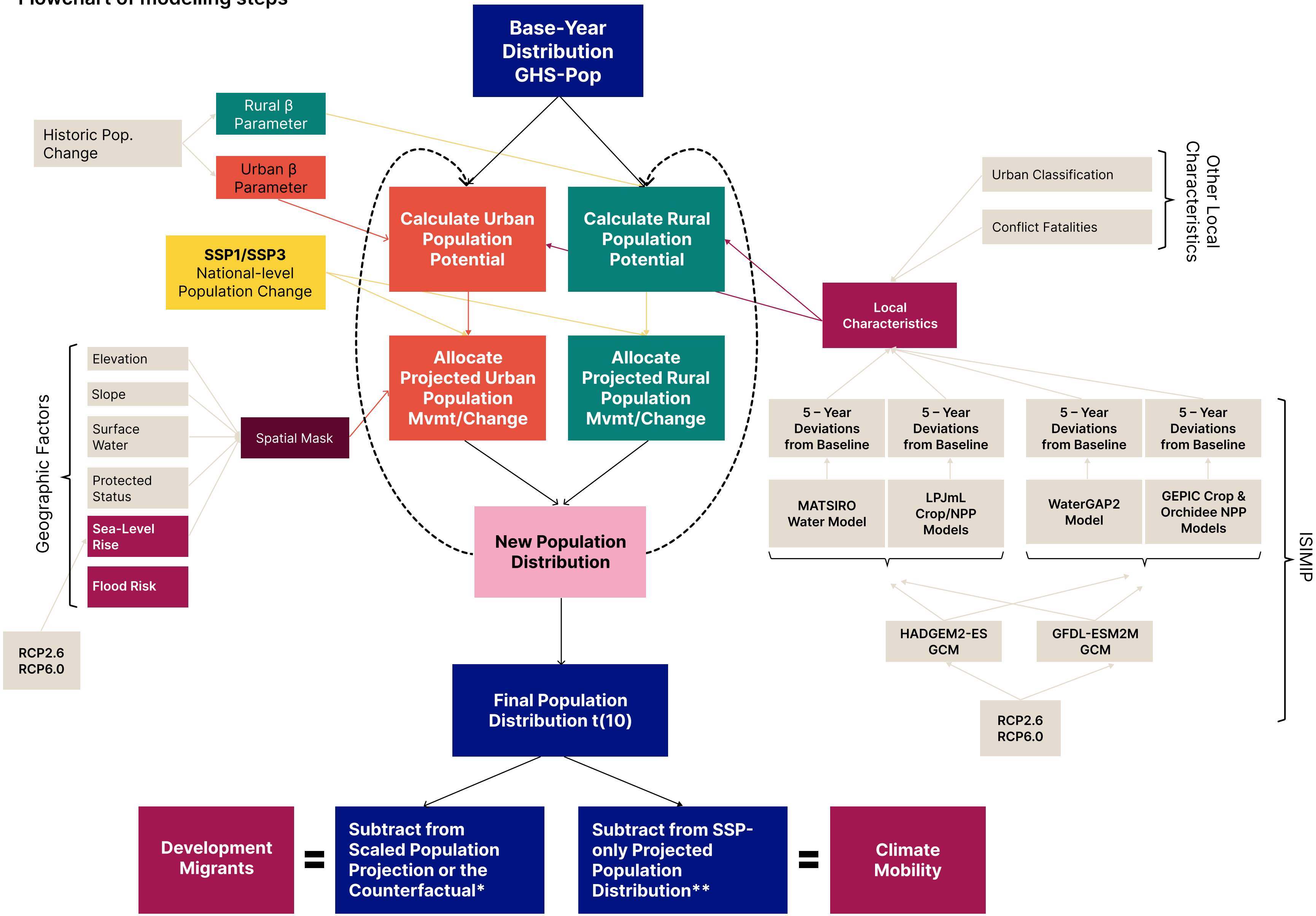
The original INCLUDE model is a gravity-based approach that downscales national population projections to subnational raster grids[184] as a function of geographic, socioeconomic and demographic characteristics of the landscape and existing population distribution. Gravity-type approaches are commonly used in geographic models of spatial allocation and accessibility. They take advantage of spatial regularities in the relationship between population agglomeration and spatial patterns of population change. These relationships can then be characterised as a function of the variables known to correlate with spatial patterns of population change.

The INCLUDE model uses a modified form of population potential, a distance-weighted measure of the population taken at any point in space that represents the relative accessibility of that point (for example, higher values indicate a point more easily accessible by a larger number of people). Population potential can be interpreted as a measure of the influence that the population at one point in space exerts on another point. Summed over all points within an area, population potential represents an index of the relative influence that the population at a point within a region exerts on each point within that region, and can be considered an indicator of the potential for interaction between the population at a given point in space and all other populations[211]. This potential will be higher at points closer to large populations. Potential is thus also an indicator of the relative proximity of the existing population to each point within an area[212]. Such metrics are often used as a proxy for attractiveness, under the assumption that agglomeration is indicative of the various socioeconomic, geographic, political and physical characteristics that make a place attractive.

In the Africa Climate Mobility Model, the calculation of population potential is modified primarily by adding variables that describe local conditions, including climate impacts, and weighting the attractiveness of each location (grid cell) as a function of the historic relationship between these variables and observed population change. Figure A4 is a flowchart of the modelling steps; boxes in red show the addition of climate impacts (or results incorporating climate impacts), demographic characteristics, and conflict-related fatalities. Population potential is, conceptually, a relative measure of agglomeration, indicating the degree to which amenities and services are available. In the original model, this value shifts over time as a function of: the population; assumptions regarding spatial development patterns (for example, sprawl vs. concentration); and certain geographic characteristics of the landscape. The choice of SSP influences each of these factors. For example, in the model the agglomeration effect is enhanced or muted as a function of the characteristics discussed above that aid in differentiating between places, as well as the SSPs: for example, SSP1 results in higher concentration of population than SSP3.

j Data for the original SSP-only population projections, using a different baseline population and set of modelling approaches, are available for download via the NASA Socioeconomic Data and Applications Center (SEDAC) ↗. Projections produced using the INCLUDE model for the *Groundswell* report series are available via SEDAC ↗.

Figure A4 **Flowchart of modelling steps**




Note: Boxes in burgundy represent the addition of climate impacts into the modelling framework or results that reflect climate impacts.

* The counterfactual population projection simply scales the population distribution in 2010 to country-level population totals appropriate to each SSP.

** The no climate impacts population projection represents the population projection without climate impacts (i.e. based only on the development trajectories embodied in the SSPs and the conflict and age and sex characteristics of the baseline population).

Beginning with the 2010 gridded urban/rural population distribution for each country[k], the proposed modelling incorporates the influence of climate impacts on relative attractiveness in the following manner:

1. Calculate an urban population potential surface (a distribution of values reflecting the relative attractiveness of each grid cell).
2. Calculate a rural population potential surface.
3. Allocate projected urban population change to grid cells proportionally based on their urban potentials.
4. Allocate changes in the projected rural population to grid cells proportionally based on their rural potential.
5. Because the allocation procedure can lead to some redefinition of population from rural to urban (e.g. rural population allocated to a cell with an entirely urban population is redefined as urban), this step entails redefining population as urban or rural as a function of density and contiguity of fully urban/rural cells to match projected national-level totals.

These steps are then repeated for each 5-year time interval. Figure A1 illustrates steps 3 and 4 for a hypothetical population distribution. Note that population potential surfaces, urban and rural, are continuous across all cells; each cell may thus contain urban and rural populations.

Based on the modified INCLUDE model, population potential ($v_i$) is calculated as a parametrised negative exponential function:

Distance Parameter | Distance | Population Parameter – Local Characteristics

Equation 2
$$v_i = l_i \left[ \left( \sum_{j=1}^{m} P_j e^{-\beta d_{ij}} \right) + \alpha_i P_i \right]$$

Spatial Mask | Population

It is weighted by a spatial mask[l] ($l$) that prevents population from being allocated to areas that are protected from development or unsuitable for human habitation, including areas that will likely be affected by floods and sea level rise between 2010 and 2050. $Pj$ is the population of all grid cells $j$ within distance m of cell $i$, and $Pi$ is the population of grid cell $i$; d is the distance between two grid cells. The distance parameter ($\beta$) is estimated from observed patterns of historical population change (for the urban and rural populations, separately). The $\beta$ parameter is indicative of the shape of the distance–density gradient describing the broad pattern of the population distribution (for example, sprawl versus concentration), typically a function of the cost of travel (with lower costs leading to residential patterns more indicative of sprawl). The population parameter $a$ is a weight on the population of cell $i$ that reflects the relative attractiveness of each grid cell $i$ as a function of the socioeconomic, demographic, political, and climate-related characteristics that make a place more or less attractive. Both $\beta$ and $a$ are calibrated from historic data, however the former is a universal parameter while the latter is cell-specific.

k Urban and rural population change need to be calculated separately because the factors that influence growth of urban and rural areas are distinct. Data on the evolution of population distributions show that historically urban and rural populations exhibit very different patterns of spatial population change. The former tend towards agglomeration over smaller geographic areas that can take several different forms (e.g., dispersion/concentration), while the latter occurs over larger geographic areas, varies across a wider range of patterns (including uniform and proportional) than urban populations, and is subject to periods of substantial population decline. Furthermore, in fitting the model to historical data we find substantial variation in many of the parameters driving spatial population change. These two factors, taken together, suggest that modelling urban and rural populations as separate but interacting components of the total population is advantageous in comparison to considering the entire population as a single entity.

l Spatial masks are used in geospatial processing to exclude areas from consideration. The effect is that the algorithm is not applied in these areas. Examples in this instance would include protected areas or places where the terrain is too rugged to inhabit.

The SSPs include no climate impacts on aggregate total population, urbanisation, or the subnational spatial distribution of the population. The INCLUDE approach is modified by incorporating additional spatial data including the ISIMIP sectoral impacts and the distribution of conflict-related and disaster-related fatalities, all of which are likely to affect population outcomes. The index is a weight on population potential that is calibrated to represent the influence of these factors on the agglomeration effect that drives changes in the spatial distribution of the population. All of the data are incorporated into the model as 15 km gridded spatial layers. The ISIMIP data represent 5-year deviation from long-term baseline conditions, and conflict-related and disaster-related fatalities are interpolated from point data. The value $a_i$ is calculated as a function of these indicators. Numerically it represents an adjustment to the relative attractiveness of (or aversion to) specific locations (grid cells), reflecting current water availability, crop yields, and ecosystem services relative to 'normal' conditions, and the likelihood of dangerous conflict and disaster. As previously noted, the model is calibrated over two time periods (1990 to 2000 and 2000 to 2015) of observed population change relative to observed climatic and demographic conditions as well as safety (e.g. conflict-related fatalities).

A.2.2

## Model calibration

The value $a_i$ (from equation 2) is calculated as a function of the climate impact indicators, and represents an adjustment to the relative attractiveness of (or aversion to) specific locations (grid-cells) reflecting projected water availability, crop yield, and net primary production relative to 'normal' conditions, in addition to flood risk, sex ratio, median age, and risk of conflict. In order to carry out the procedure, an estimate of the $\beta$ parameter for the urban and rural populations is necessary, and (equation 2) must be fully calibrated. Two separate procedures are employed and carried out both for the urban and rural population distributions separately. As mentioned in Section A.2.1, urban and rural populations interact in the model, but changes in both are projected separately at the grid-cell level in the same manner. Here the procedure is described once and, unless otherwise noted, the process is redundant for urban/rural components.

The $\beta$ parameter is designed to capture broad-scale patterns of change found in the distance-density gradient, which is represented by the shape/slope of the distance decay function (parabolas) depicted in equation 2. The negative exponential function described by equation 2 is very similar to Clark's[181] negative exponential function which has been shown to accurately capture observed density gradients throughout the world[213, 214]. To estimate $\beta$, the model in equation 2 is fitted to the 1990–2000 urban and rural population change from GHS-POP and to the 2000–2010 urban and rural population change data from GHS-POP, and we compute the value $\beta$ that minimises the sum of absolute deviations:

Equation 3 $$S(\beta) = \sum_{i=1}^{n} \left| P_{i,t}^{mod} - P_{i,t}^{obs} \right|$$

Where $P_{i,t}^{mod}$ and $P_{i,t}^{obs}$ are the modelled and observed populations in cell $i$, and $S$ is the sum of absolute error across all cells.

We fit the model for two decadal time steps (1990–2000 and 2000–2010) and take the average of the $\beta$ estimates.

In this modified version of the population potential model the index is a cell-specific metric that weights the relative attractiveness of a location (population potential) as a function of environmental and/or socio-economic conditions. The modelling approach requires that the relationship between the different sectoral impact, flood risk, demographic, and conflict indicators is estimated. Each are hypothesised to impact population change. When $\beta$ is estimated from historical data (e.g. observed change between 2000 and 2010), a predicted population surface is produced that reflects the optimised value of $\beta$, such that absolute error is minimised. Figure A5 includes a cross-section (one-dimension) of grid cells illustrating observed and predicted population for 10 cells. Each cell contains an error term that reflects the error in the population change projected for each cell over a 10-year time step. It is hypothesised that this error can at least partially be explained by a set of omitted variables, including environmental/sectoral impacts.

Box A1 **Calibration of the Gravity Model in brief**

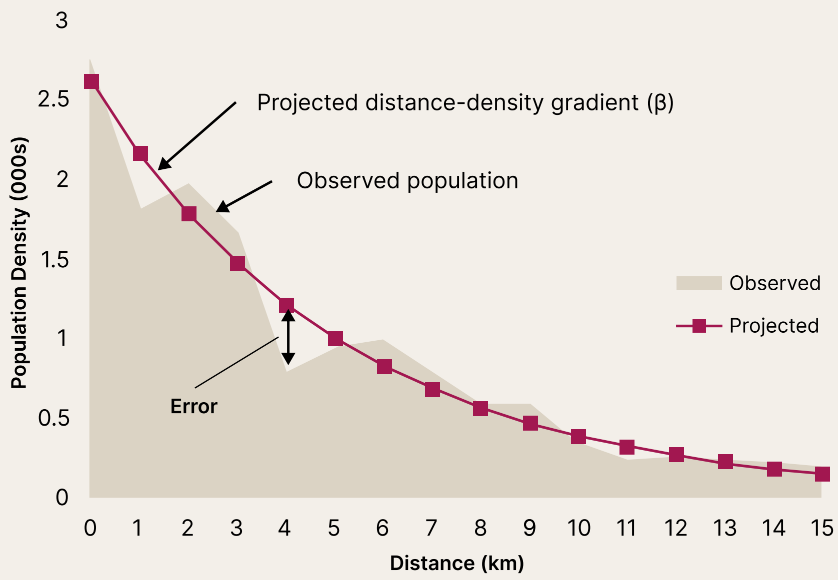
The following steps are taken:

1. Using the 1990 GHS-POP population grid, we use the gravity model to project forward the population between 1990 to 2000, and using the 2000 GHS-POP population grid, we project forward the population between 2000 to 2010
2. We compare the modelled population to the actual GHS-POP distributions in 2000 and 2010
3. We hypothesise that prediction errors (differences between the projected population distribution and GHS-POP population in the target years) can be explained, in part, by local environmental characteristics.

The parameter $\beta$ is estimated from historical data by minimising the sum of absolute deviations.

For each cell *i* there will be an error in projected population. We hypothesise that these errors can be explained, in part, by local environmental characteristics, which are used to estimate the *a* parameter.

For each cell *i* we calculate the value of a necessary to eliminate ε. We call this value the observed *a*.




$$S(\beta) = \sum_{i=1}^{n} \left| P_{i,t}^{mod} - P_{i,t}^{obs} \right|$$

To incorporate these effects, we first calculate the value of $a_i$ such as to eliminate $\varepsilon_i$ (from Figure A5) for each individual cell (which is labelled observed):

Equation 4 $$\Delta P_{i,t}^{obs} = obs_{\alpha_i} * \Delta P_{i,t}^{mod}$$

Where $\Delta P_{i,t}^{obs}$ and $\Delta P_{i,t}^{mod}$ are the observed and modelled population change for each cell $i$ and $a_i$ is the factor necessary to equate the two.

The second step is to estimate the relationship between observed index and the different potential drivers of spatial population metrics by fitting a spatial lag model:

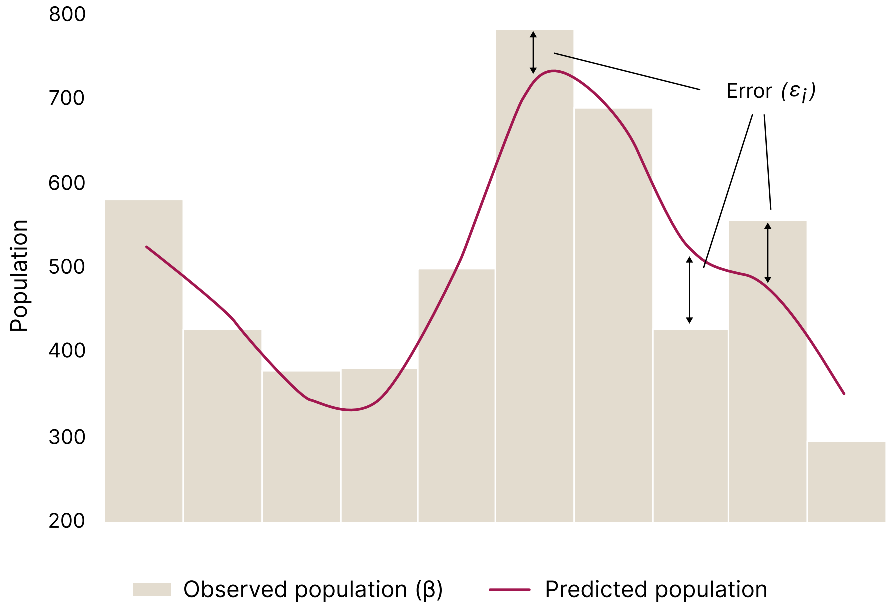
Equation 5

$$obs\_a_{i,t} = \rho W A_{i,t} + \beta_1 C_{i,t} + \beta_2 H_{i,t} + \beta_3 N_{i,t} + \beta_4 U_{i,t} + \beta_5 K_{i,t} + \varepsilon_{i,t}$$

where $C$, $H$ and $N$ are the five-year deviations from the historic baseline on crop yield, water availability, and net primary production, $U$ is a dummy variable reflecting the status of each grid cell as urban (1) or rural (0), and $K$ is the conflict-related fatalities metric. Together these five variables, and their respective coefficients constitute the set of explanatory variables that go into producing the index $a_i$. Note that for any grid cell in which $C$ (crop yield) is a non-zero value, the value of $N$ (net primary production) is automatically set to zero, so that only one of the two variables is contributing to the index $a_i$. Finally, $p$ is the spatial autocorrelation coefficient and $W$ is a spatial weight matrix. From this procedure, a set of cell specific $\alpha$ values is estimated for both urban and rural population change.

For future projections (for urban and rural populations), projected values are used of $C_{i,t}$ , $H_{i,t}$ , and $N_{i,t}$ and current values of $U_{i,t}$ and $K_{i,t}$ are used along with their respective coefficient estimates from Equation 5 to estimate spatially and temporally explicit values of $a_i$. Finally, to produce a spatially explicit population projection, estimates of $\beta$ are adjusted to

Figure A5 **Cross-section of grid cells illustrating observed and projected population distributions**




Note: The error term is used to calibrate the index $a_i$

reflect the SSPs (e.g. the SSP4 storyline implies a more concentrated pattern of development than SSP5, see Jones and O'Neill[184]) to produce estimates of the agglomeration effect, to which the spatio-temporally variant estimates for the RCPs described above are applied, and finally exogenous projections of national urban and rural population change are incorporated in the model applied as specified in Equation 2.

It is important to note that, as a result of testing, cells meeting certain criteria are excluded from the calibration procedure. First, cells that are 100 percent restricted from future population growth by the spatial mask (*l*, Equation 2) are excluded, as the value of *l* in these cells (0), renders the observed value of $a_i$ inconsequential. Second, the rural and urban distributions of observed $a_i$ were found to include significant outliers that skewed coefficient estimates in Equation 2. In most cases, these values were found to correspond with very lightly populated cells where a small over/under-prediction of the population in absolute terms (e.g. 100 persons) is actually quite large relative to total population within the cell (e.g. large percent error). The value of $a_i$ (the weight on potential), necessary to eliminate these errors, is often proportional to the size of the error in percentage terms, and thus can be quite large even though a very small portion of the total population is affected. Including these large values in Equation 5 would have a substantial impact on coefficient estimates. To combat this problem, the most extreme 2.5 percent of observations are eliminated on either end of the distribution. Third, because the model is calibrated to urban and rural change separately, cells in which rural population was reclassified as 100 percent urban over the decade (2000–2010) were excluded, as the effect would be misleading (in the rural distribution of change it would appear an entire cell was depopulated, while in the urban change distribution the same cell would appear to grow rapidly). It would be incorrect to attribute these changes to sectoral impacts when, in fact, they are the result of a definitional change. In most cases these exclusions eliminate 5 to 10 percent of grid cells.

The coefficients in Table A4 are the results of applying the calibration procedure to countries for which the appropriate, high resolution census data were available over at least two consecutive time periods. Positive values indicate that the driver has a positive influence on local attractiveness (e.g. improved water availability or crop yields leads to increasing attractiveness), and a negative value indicates a negative influence on attractiveness (e.g. a larger number of conflict related deaths leads to a less attractive location). In general, the larger the value (positive or negative), the larger the influence of the driver. However, the coefficients are taken in conjunction with future estimates of each climate-related driver, or in the case of conflict, on present day conditions, and thus a larger coefficient does not necessarily indicate a larger weight on *P(i)*. The value of *a(i)* for each grid cell at each time t is calculated as:

Equation 6

$$a_{i,t} = 1 + \beta_1 C_{i,t} + \beta_2 H_{i,t} + \beta_3 N_{i,t} + \beta_4 U_{i,t=1} + \beta_5 K_{i,t=1}$$

Where the values *β(n)* are the coefficients on each driver, $C_{i,t}$ , $H_{i,t}$ , and $N_{i,t}$ are the projected deviations in crop yields, water stress, and net primary production for each cell *i* at each time *t*, and $U_{i,t=1}$ and $K_{i,t=1}$ are the present day values of urban classification and conflict fatalities. The assumed value of *a(i)* in the absence of any local attractive or repulsive characteristics is 1, thus any positive values will increase local attractiveness, and negative values will decrease local attractiveness.

Table A4 **Coefficients derived from historical calibration**

| | Cote d'Ivoire | Egypt | Ethiopia | Gabon | Ghana | Kenya | Malawi | Morocco | Senegal | South Africa | Zambia | Zimbabwe | **Mean** | **Std. Dev** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Urban** | | | | | | | | | | | | | | |
| Water | 0.653 | 2.648 | 2.514 | 0.581 | 0.346 | 0.694 | 1.638 | 0.852 | 0.570 | 0.055 | 0.281 | 0.042 | 0.938 | 0.823 |
| Conflict | -0.005 | n/a | -0.002 | n/a | 0.000 | -0.003 | -0.061 | -0.045 | -0.002 | -0.006 | -0.006 | -0.012 | -0.015 | 0.021 |
| **Rural** | | | | | | | | | | | | | | |
| Crop/NPP | 2.082 | 1.345 | 1.342 | 1.727 | 1.433 | 0.480 | 1.069 | 1.820 | 0.915 | 0.206 | 1.642 | 2.124 | 1.349 | 0.572 |
| Water | 0.973 | 2.353 | 1.876 | 1.429 | 0.404 | 1.552 | 0.419 | 2.225 | 2.948 | 2.178 | 1.070 | 1.833 | 1.605 | 0.751 |
| Conflict | -0.005 | n/a | -0.031 | n/a | -0.002 | -0.020 | -0.035 | -0.358 | -0.011 | -0.069 | -0.169 | -0.096 | -0.080 | 0.105 |

Note: Coefficient estimates derived from fitting the spatial autoregressive model to historic population distribution change data for the periods 1990–2000 and 2000–2010 for each of the potential drivers of spatial population change. Coefficients for Water and Crop/NPP can be interpreted similarly, but the coefficients are not normalised for Conflict.

A.2.3

## Characterising the model

This modelling provides credible, spatially explicit estimates of changes in the population distribution (and indirectly migration) as a function of climate, demographic, and development trends. It is important to understand what the model does and does not do.

Gravity models, in their simplest form, can be used to reconstruct and quantify the past evolutions of population distributions based on observed agglomeration effects over large geographic regions, under varying conditions, and at alternative spatial scales. They can also be refined and expanded to incorporate additional details, such as environmental parameters that affect the relative attractiveness of locations, typically improving the capacity of the model to accurately replicate past trends and thus, theoretically, project into the future.

Gravity models do not directly model internal migration. Instead, internal migration is assumed to be the primary driver of deviations between population distributions in model runs that include climate impacts (in our model crop production, ecosystem productivity, water availability, and flood risk) and the development-only (also referred to as the SSP or 'no climate' models that include only the demographic and conflict metrics). Both types of model include the agglomeration effect. Migration is a 'fast' demographic variable compared with fertility and mortality; it is responsible for much of the decadal-scale redistributions of population. Without significant variation in fertility/mortality rates between climate-mobility populations and non-migrant populations, it is fair to assume that differential population change between the climate impact scenarios and the development-only scenarios occur as a function of migration. Another way of saying this is that the model assumes that fertility and mortality rates are relatively consistent across populations in a locale. Note that the model does not provide any information about the directionality of migration. In other words, it cannot be inferred that migrants are moving from a given area of out-migration (e.g. a 'hotspot' of climate out-migration) to a given area of in-migration. Rather, the model reflects broader changes in the spatial distribution of population as a result of climate impacts, with the distribution changing incrementally with each time step.

For each climate migration scenario, the model produces a range of estimates that reflect variation in the underlying inputs to the model, which in turn reflect scientific uncertainty over likely future climate projections and impacts and development trajectories. In any scenario, outcomes are a function of the global climate models and the sectoral impact models that drive climate impacts on population change. For each of the four scenarios, there are four models, consisting of different global climate model/ISIMIP combinations. The ensemble mean (or average) of the four models is reported as the primary result for each scenario. Uncertainty is reflected in the range of outcomes (across the four models) for each grid cell and at different levels of aggregation. While some may prefer to have just one figure, in a complex issue like climate-related migration, a scenario-based approach of plausible outcomes is preferable. It would be desirable to have even more scenarios, to better assess the uncertainty (or conversely confidence) in the results.

The model is analysed at spatial and temporal scales that capture migration well. With grid cells of about 15 square kilometres at the equator, population shift can be considered a form of short-distance migration. The temporal scale of 5-year increments from 2015 to 2050 is adequate to capture the longer-term shifts in population caused by changes in water availability, crop conditions, ecosystem productivity, and flood risk. The five-year temporal resolution of the model corresponds to the temporal resolution most national censuses consider when attempting to capture and quantify migration trends[m]. Shorter-term and/or seasonal migration are not captured by the model.

m Migration data are sporadic in national censuses, but when present, they are typically based on a 'five-year question', which prompts respondents to indicate where they lived five years ago.

Box A2 **Sources of uncertainty in modelling climate migration**

The climate migration modelling results incorporate five main sources of uncertainty that can affect the estimated number of migrants that are moving in response to climate impacts or the differences between the four scenarios and the development-only scenario.

ISIMIP impacts vary across models. The differences result in different effects in the gravity model: models with the highest negative impacts repel more people from affected areas than those projecting less extreme outcomes. Similarly, in isolated cases (a small number of grid cells) different ISIMIP models can disagree on the positive/negative nature of changes, leading one model to attract population and the other to repel.

Variations between the two global climate models — HadGEM2-ES and GFDL-ESM2M — can amplify the ISIMIP differences. The global climate models were selected in part because their future precipitation trends differ substantially in magnitude, and partly even in sign (see Section A.2.6). This variance in precipitation has an impact on the water, crop, and NPP models.

The modelling has a temporal component that can influence population distribution trajectories. Stronger sectoral impacts early in the 40-year projection period will have greater influence than the same impacts later in that period, because those early impacts affect the gravitational pull of locations, creating 'temporal' momentum over which later climate impacts may have less influence. Similarly, the timing of population change (growth or decline) projected by the SSPs relative to the development of sectoral impacts can influence outcomes. For example, for most countries in the study, projected population growth is greatest during the first decade; if conditions are also predicted to deteriorate severely during that period, the impact on migration will be greater than if the deterioration took place during a more demographically stable period.

If the 'no climate impacts' model finds that a place is relatively attractive and the sectoral climate impacts are positive or neutral (relative to other areas that see negative impacts), it will have the effect of reinforcing the attractiveness of that area. Conversely, in remote areas experiencing population decline and negative climate impacts, 'push' factors will be reinforced. This phenomenon creates spatial momentum.

Model parameterisation affects the results. The model is calibrated using actual population changes in association with actual climate impacts (represented by ISIMIP model outputs) for two periods, 1990–2000 and 2000–2010. This calibration was done using the two separate sets of model combinations: the Matsiru and WaterGAP water models, the LPJmL-Crop and GEPIC crop models, and the LPJmL-NPP and ORCHIDEE ecosystem models. Different parameters correspond to the different models. If the parameter estimates are close together across the different crop or water models, there will be less variation in the population distribution projected by each model; the uncertainty around the ensemble mean (measured using the coefficient of variation) will therefore be lower. Conversely, if parameter estimates are not close together, there will be greater uncertainty around the ensemble mean.

The use of GHS-POP, which is a modelled population surface where population is allocated based on remote sensing imagery, may have introduced issues in the model calibration, whereby the GHS-POP population surface recorded false positives ('built-up' areas that were in fact rock outcrops or dried lake beds) or false negatives (places where small settlements were missed). These problems affected a relatively very small fraction of country territory, and we chose countries for calibration that had fewer of such issues. False positives with large values, typically a function of the GHS-Pop algorithm placing the majority of an administrative units population in a small number of cells where there is no large settlement, have the potential to skew the calibration results. To avoid this problem, we spot checked grid cells with large populations outside of known urban centres using ESRI base map imagery (satellite imagery of the landscape). If grid cells with large populations did not correspond to large settlements in the base map imagery, they were eliminated from the calibration procedure.

The focus is on the 30 years between 2020 and 2050. This period represents a meaningful planning horizon, especially when considering social dimensions of migration. Chapter 4 of the *Groundswell* report considers water and agriculture sector impacts beyond 2050 by examining ISIMIP outputs for 2050–2100[18]. They suggest that, if anything, the climate signal will become far stronger toward the end of the 21st century.

The model cannot forecast all future adaptation efforts or conflict, cultural, political, institutional, or technological changes. Discontinuities are likely to arise as a result of political events and upheavals that can heavily influence migration behaviour. Armed conflict itself may have non-linear links to climate variability and change, but models are generally not yet sophisticated enough to forecast the changing nature of armed conflict or state failure with any precision. The scenario framework is not designed to predict shocks to any socioeconomic or political system, such as large-scale war or market collapse. The models can also not anticipate new technologies that may dramatically affect adaptation efforts to the degree that climate impacts become negligible. The SSPs, as well as output from the global climate model and ISIMIP, reflect plausible futures that span a wide range of global trajectories, with the caveat that extremely unpredictable or unprecedented events are explicitly excluded. The SSPs assume certain levels of adaptation and a continuation of the business as usual, and the projected scale of migration is not cast in stone. The scenario-based results should be seen as a plausible range of outcomes rather than precise forecasts — to spur policy and action to counter distress-driven climate migration.

A.2.4

## ISIMIP maps

The maps in this annex reflect the average changes in projected water availability, crop production and net primary productivity (NPP) for the 40-year period from 2010 to 2050 relative to baseline conditions from 1970 to 2010. The index is calculated as follows:

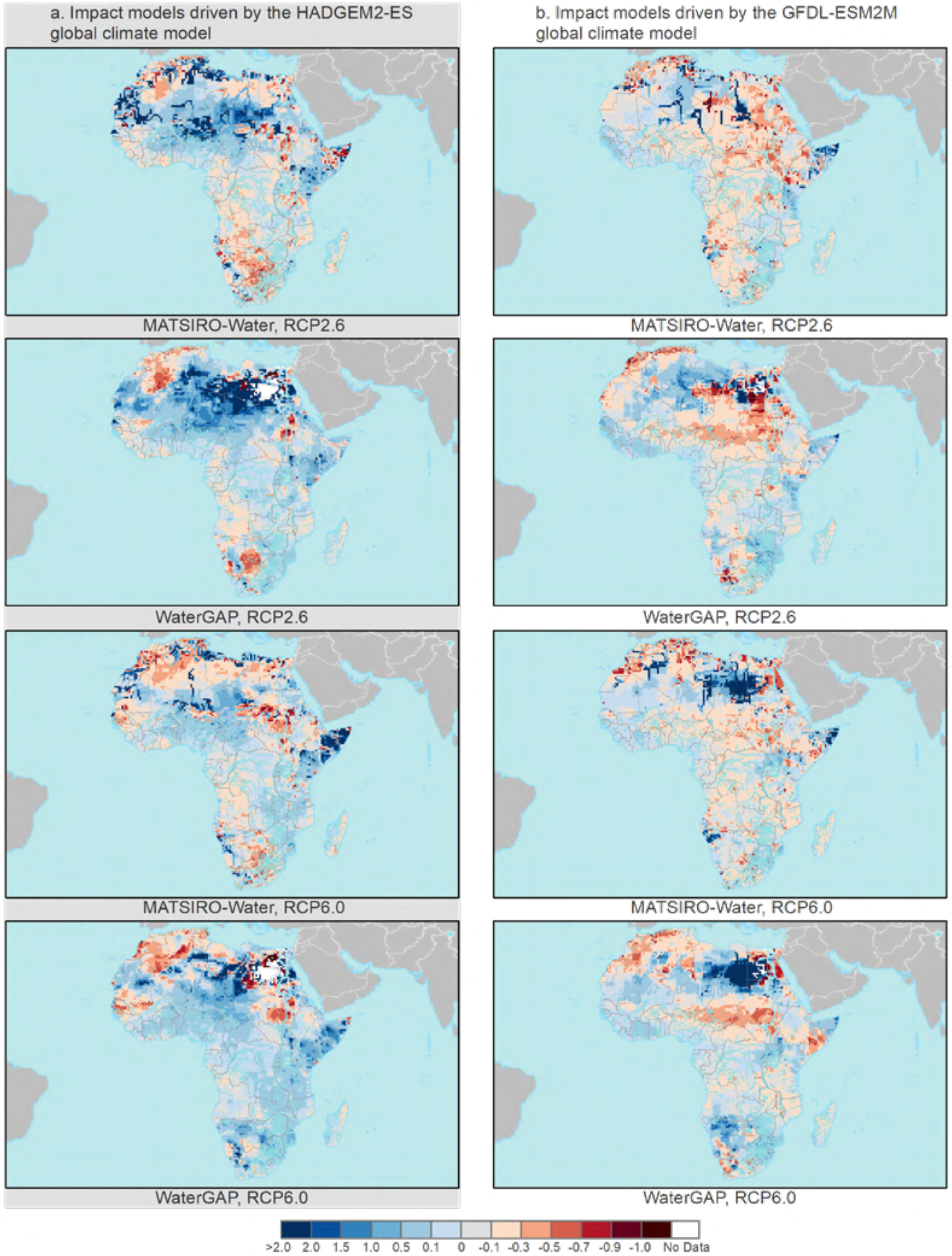
$$\text{Index} = (F_{avg} - B_{avg}) / D_{avg}$$

Where $F_{avg}$ is the 40-year average, and $D_{avg}$ is the baseline average. Note that this is a summary measure of the actual impacts in 5-year increments from 2010 to 2050, and the way that impacts evolve over the course of the four-year projection period has an impact on how the population distribution (and consequently migration) evolves.

The maps are presented in two columns, with impact models driven by the Hadley HADGEM2-ES climate model on the left, and impact models driven by Princeton's GFDL-ESM2M climate model on the right. The top four panels represent the RCP2.6 low emissions scenarios, and the four panels at the bottom represent the RCP6.0 high emissions scenarios. Within those four panels are the two impact models used for water (Matsiru and WaterGAP), crops (LPJmL-Crop and GEPIC), and NPP (LPJmL-NPP and ORCHIDEE), respectively. Note that NPP is only used in areas without crop production, and Mapset A4 shows the combination of crop and NPP impacts. Red areas on maps reflect declines in water availability, crop production and NPP, while blue-coloured areas represent increases in these same impacts.

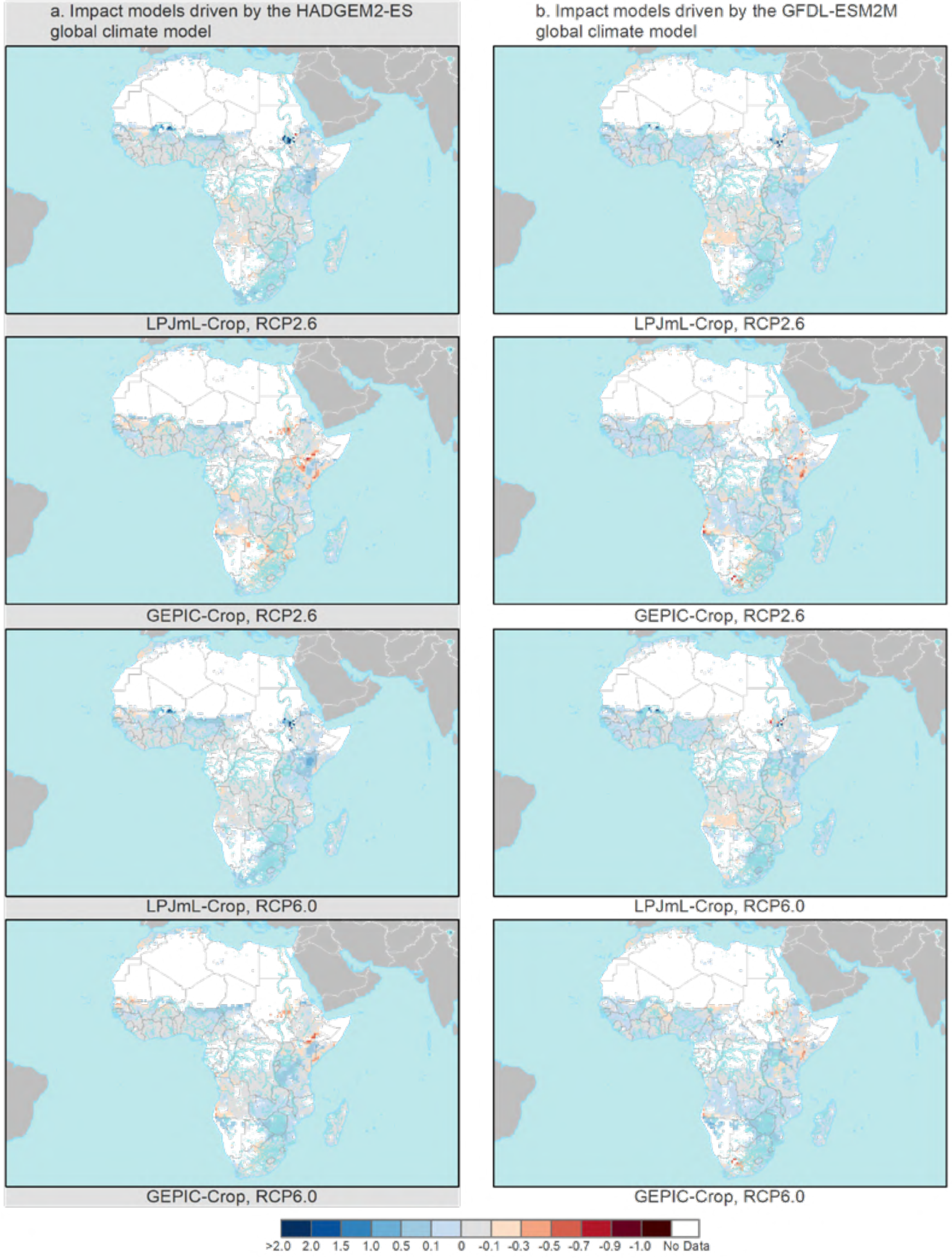
Mapset A1

**Average index values for water availability, 2010 to 2050**



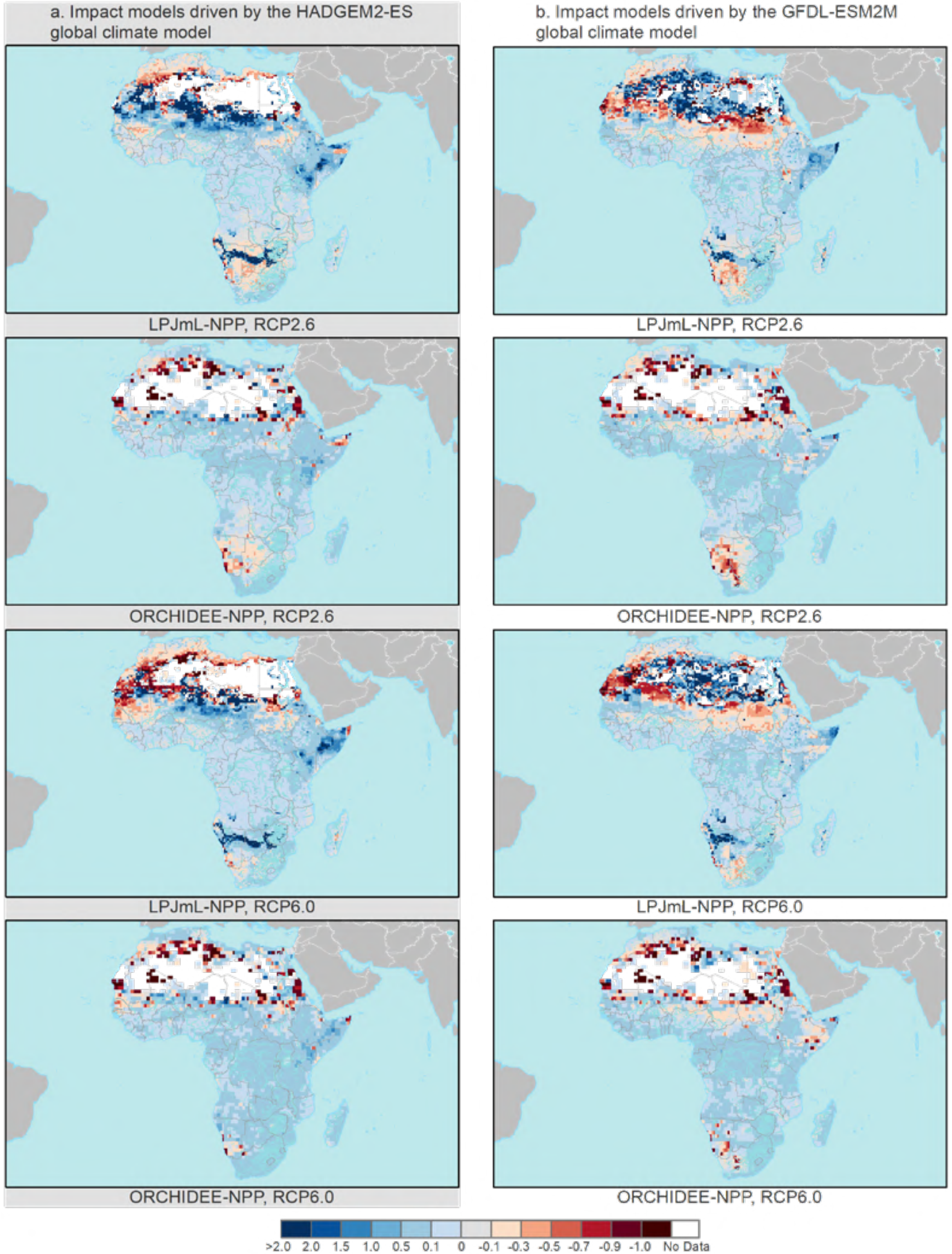
Mapset A2

**Average index values for crop yields, 2010 to 2050**



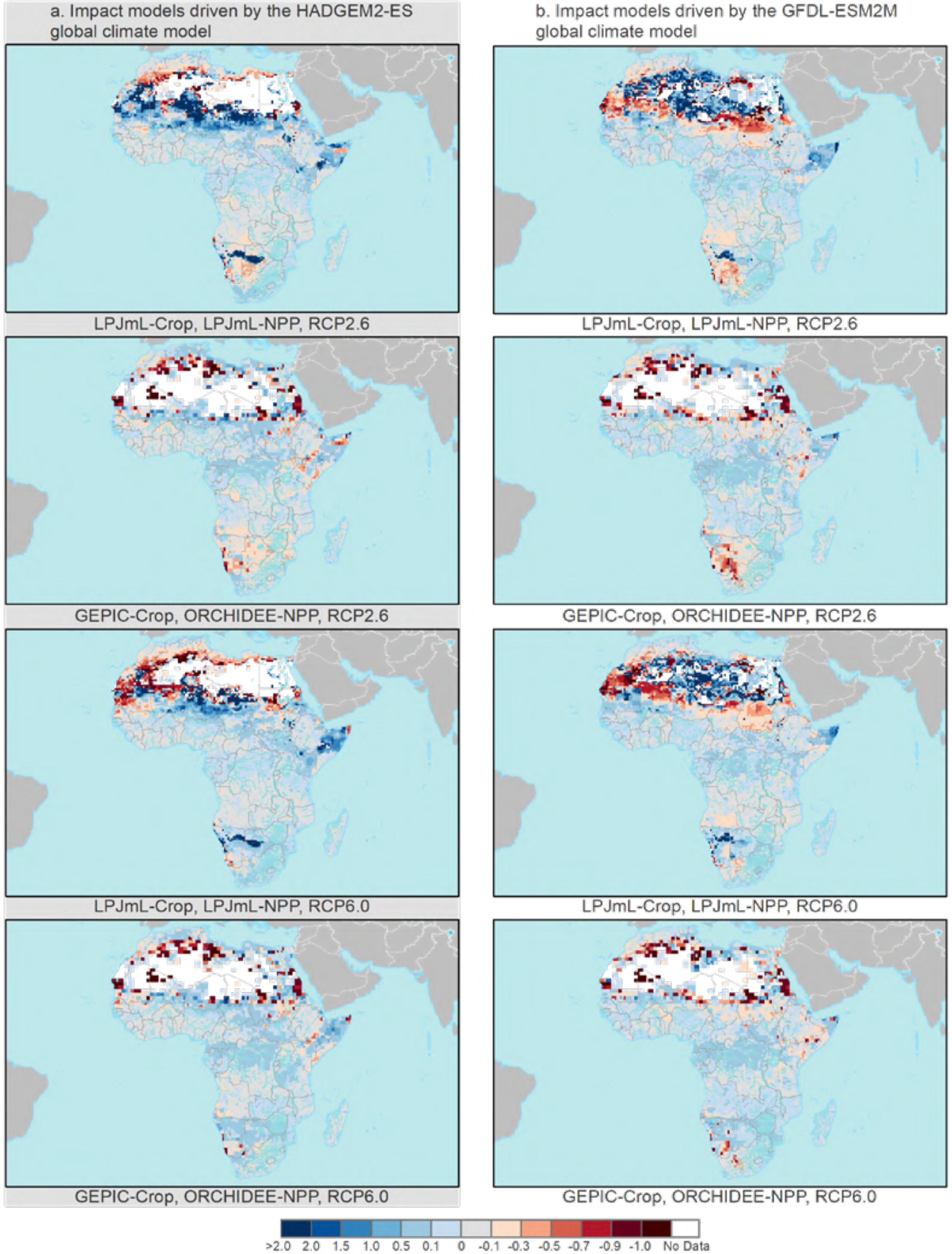
Mapset A3

**Average index values for NPP, 2010 to 2050**



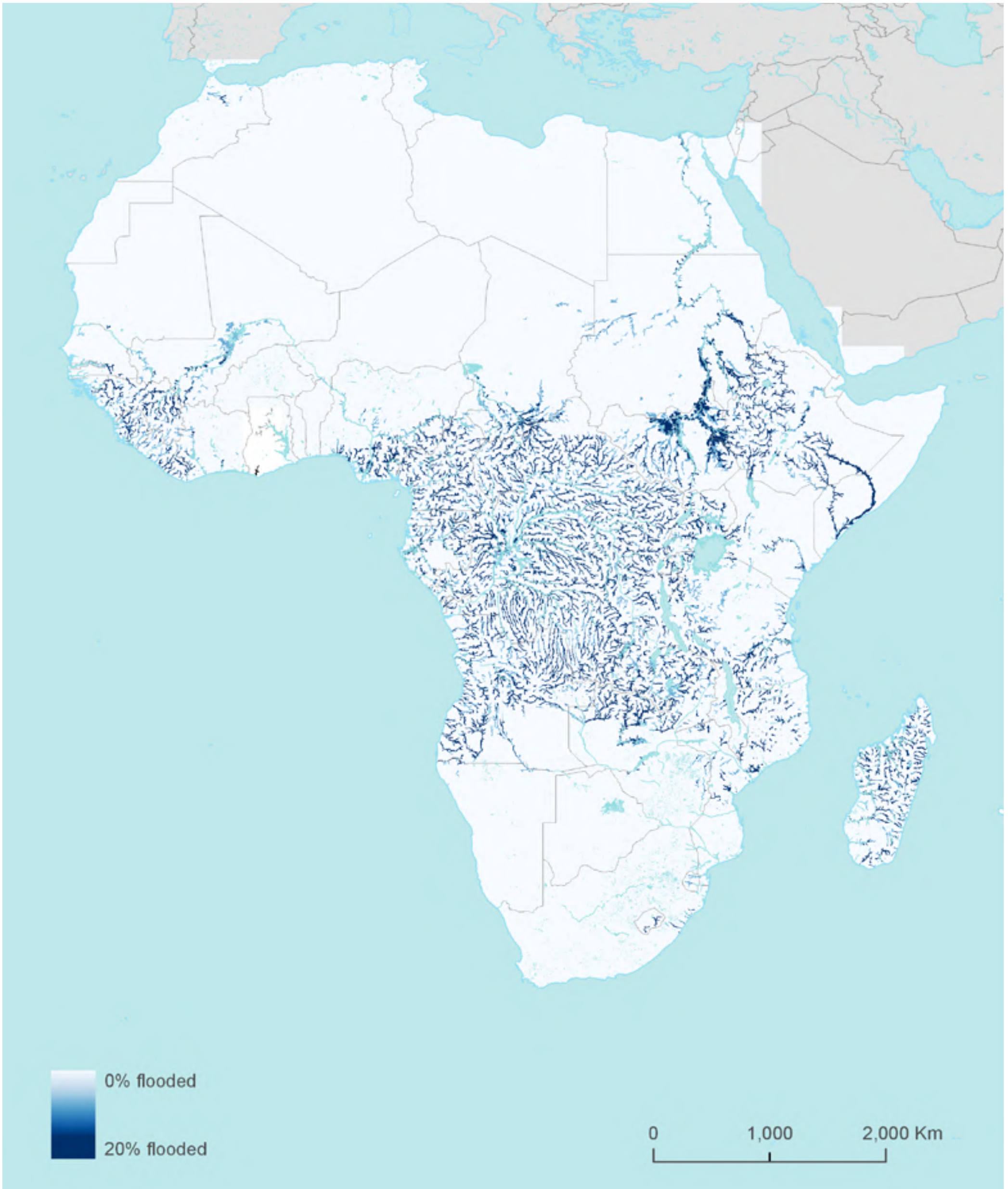
Mapset A4

**Average index values for crops gap-filled with NPP, 2010 to 2050**



Map A5

**Flood risk projections under RCP6.0 to 2050**




Map: CIESIN, Columbia University, December 2021. Data source: Potsdam Institute for Climate Impacts Research, Ensemble of ISIMIP Flood Depth Projections using the H08, LPjML, MPI-HM, Orchidee, PCR-GlobWb, and WaterGAP2 models under RCP 6.0.

## A.2.5
# Cross-border mobility modelling methods

To complement the modelling of internal migration flows, we project future transboundary migration flows throughout the African continent over the period extending from 2015 to 2050 at intervals of five years. These projections are intended to shed light on future migration trends at the international level within a South-South context. While less salient in media discussion than flows from and to Europe, transnational migration flows are ubiquitous throughout the continent. In fact, some of the regions display significant movements of people across borders, foremost in West Africa.

To project future bilateral migration, we calibrate our models based on observed (historical) data on bilateral migration flows, crop yields, water availability, and population and GDPs over the period 1995 to 2010. Our calibration framework uses Bayesian hierarchical linear regression with three sets of random intercepts: origin, destination, and migration corridors[n]. Using the parameters estimated in the calibration stage, we then project future bilateral migration flows based on crop yields and river discharge projections from the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP), as well as population and GDP figures from the Shared Socioeconomic Pathways (SSP). We project bilateral flows under both RCP 2.6 and 6.0 climate scenarios, as well as under a *counterfactual* scenario, which holds water availability and crop yields constant at their historical average (1990 to 2010). Our projections cover 46 African countries, all located on the mainland[o].

In the following, we describe the calibration and projections models, as well as provide an overview of the results from the calibration process.

### A.2.5.1
## Calibration model

As a starting point, we built on the migration model developed by Jones (2020)[215], which models historical transboundary migration flows as a function of environmental conditions, economic opportunities, political violence, migrant and population at origin[p]. We base our modelling approach on this simple migration model, but refine this basic setup by using a Bayesian hierarchical log-linear model to more accurately predict migration flows in Africa[216,217].

To calibrate our model, we use historical migration figures provided by Abel and Cohen (2019)[218] on the basis of UN migration stock data[3] and computed using *stock difference, reverse negative* approaches[q]. Because we aim to model how climate shocks affect transboundary migration through its effect on economic and social systems, we subtract the number of refugees. To do so, we use adjusted estimates of the number of refugees by Marbach[219,220] based on UNHCR refugee counts[221]. The variable is included in our model as dependent variable after taking logs[r].

Following the literature our modelling framework assumes a gravity model of migration. Specifically, the model posits first that intra-continent migration in Africa is a function of capacity (ability to overcome financial costs of migration), proxied by GDP per capita at origin, and economic attractiveness of a given destination, measured by the ratio between GDP per capita at origin and destination. In other words, capacity is an indicator of households' access to economic resources required to overcome the financial costs associated with international migration. International migration typically requires more resources than internal migration[222]. Thus, in comparatively richer countries, a larger share of the population should have the means to overcome the costs of migration. While migration costs should be particularly high for long-distance migration, such as to Europe, it likely also matters, albeit on a smaller scale, for transboundary migration within Africa and to neighbouring countries.

n A migration corridor connects a specific origin country to a specific destination country.

o Due to a lack of projection data, Madagascar, as well as small-islands states, such as Cape Verde or the Comoros are not included.

p Jones (2020) also includes corruption as a determinant of migration. However, due to data shortage, we do not include this variable here.

q We privilege stock differences approaches due to concern about error propagations in demographic account approaches used primarily by demographers.

r We add unity prior the log transformation to avoid taking the log of zero.

For its part, the desire to migrate should be proportional with the economic gap between origin and destination countries. The wider this gap, the stronger the attractiveness of the destination. The interaction of these two variables gives rise to the well-known hump function, whereby out-migration is strongest in countries occupying a middle position in the distribution of economic wealth[223]. People in particularly poor countries may have a strong desire to leave, but may lack the means to do so, while people in rich countries have access to the necessary financial resources but may have little desire to leave. While the existence of this hypothesised hump function has been historically documented primarily for migration from poor to rich countries, it could also influence migration patterns observed in Africa.

Besides, migrants often depend on access to kin and co-national networks to learn about income opportunities at destination locations, secure travels and find work upon arrival at destination[224]. Thus, our model also includes a measure of the stock of migrants at destination at the beginning of each time period. We also include a control for the presence of political violence to adjust the calibration process to the residual presence of people in the data forced to move because of armed conflict, which may not have been entirely corrected by the removal of refugee data from the migrant tables[225]. Finally, we include a population-weighted measure of distance between origin and destination. Since Ravenstein[226], it has been known that the intensity of migration flows is inversely proportional to the distance between origin and destination.

To calibrate the parameters controlling the effects of future climate variability on migration, we include two indexes measuring water availability (e.g. reverse discharge) and crop yields at the country level. These indexes are computed in the same way as for the modelling of internal migration flows, except that the indexes represent variability at the country level, instead of the cell-level. To do so, we first average water availability and crop yields values at a 0°30” resolution to the country level. Data on crop yields is provided by the Inter-Sectoral Impact Model Intercomparison Project 2A (ISIMIP2A) GEPIC simulations based on historical climate data, respectively the WaterGAP2 simulations for river discharge (our indicator of water availability)[s].

Finally, we add three sets of random intercepts for the country of origin, country of destination, and directed migration corridor between origin and destination countries. These random intercepts are intended to account for unobserved factors that condition these flows. Notably, these are expected to account for linguistic ties, historical legacies (e.g. colonies), specific immigration policies. The addition of these random intercepts is expected to increase the reliability of our projections. We also add times dummies for each time period in our calibration data to correct for unexpected systemic shock.

In formal terms, we thus seek to estimate the following log-linearised gravity equation with Bayesian hierarchical linear regression.

$$
\begin{aligned}
ln, Migration_{i,j,t} \sim & \quad \mathcal{N}\left(\mu_{i,j,t} + \phi_i + \gamma_j + \theta_{i\to j}, \sigma\right) \\
\mu_{i,j,t} = & \quad \alpha + \beta_1 \times cropyields_{i,t} + \beta_2 \times wateravailability_{i,t} + \\
& \quad \beta_3 \times lnpopulation_{i,t} + \beta_4 \times lnGDPpc_{i,t} + \beta_5 lnGDPRatio_{i,j,t} + \\
& \quad \beta_6 \times lnmigstock_{i,j,t} + \beta_7 \times lnconflict_{i,t} + \beta_8 \times lndistance_{i,j} + u_t \\
\phi_i \sim & \quad \mathcal{N}\left(0, \tau_{orig}\right) \\
\gamma_i \sim & \quad \mathcal{N}\left(0, \tau_{dest}\right) \\
\theta_{i\to j} \sim & \quad \mathcal{N}\left(0, \tau_{orig\to dest}\right)
\end{aligned}
$$

We use weakly informative prior for the population fixed effects[t]. For the random intercept priors and standard deviation parameter of the linear regression, we use a half-student-t distribution with a 3 degree of freedoms and 2.5 scale parameters[u]. The parameters of the models are estimated using the R brms package[227], based on the Stan Modeling Language[228]. The parameters are estimated using *Markov Chains Monte Carlo* with four chains of 4,000 iterations each (incl. 2,000 warmup iterations, for a total of 8,000 post-warm up draws). In total, the regression frame includes 8,190 observations. The unit of analysis is the country of origin — country of destination — time period at five-year interval.

s In addition, we ran an alternative sets of calibration models using the LPJmL data for crop yields and water availability. For reasons, we discuss below we ended not using this set of calibrated parameters to project future migration.

t $\beta_k \sim t\left(0, \frac{s_y}{s_x}\right); \alpha \sim t\left(0, s_y\right)$. Instead of using a normal distribution for the priors of the population fixed effects, we use a student-t distribution.

u For additional information, see here ↗ (rstanarm models) and here ↗ (brms models).

Table A5 provides an overview of the data and sources for the calibration model. Most of the original data included in the calibration model is measured annually (except for the variables modelling historical crop yields and water availability). We, thus, average these data over a five year period.

Table A5 **Data sources: Calibration**

| Type | Variable | Source | Note |
|---|---|---|---|
| Calibration | Migration | (Abel and Cohen 2019) | |
| Calibration | Refugee | (UNHCR 2022; Marbach 2018a) | |
| Calibration | Crop yields index | GEPIC ISIMIP2b | $\frac{crop_t - \overline{crop}}{\overline{crop}}$ |
| Calibration | Water availability index | WaterGAP2 ISIMIP2b | $\frac{water_t - \overline{water}}{\overline{water}}$ |
| Calibration | Population | World Population Prospects (United Nations 2022) | |
| Calibration | GDP per capita at origin | Penn World Table 7.0 (Heston, Summers, and Aten 2011) | |
| Calibration | GDP per capita ratio | Penn World Table 7.0 (Heston, Summers, and Aten 2011) | $\frac{GDP_{dest}}{GDP_{orig}}$ |
| Calibration | Migrant stock | 2020 UN International Migration Stock (United Nations 2020) | |
| Calibration | Conflict intensity | UCDP GED 20.1 (Sundberg and Melander 2013) | N. fatalities (all forms of political violence in the dataset) |

### A.2.5.2
## Projection model

Future bilateral migration flows in sub-Saharan Africa are projected based on the entire estimated set of parameters from the calibration process in order to account for stochastic uncertainty. We proceeded iteratively by projecting future transboundary migration within Africa by intervals of five years[v]. The advantage of using the full range of estimated parameters, rather than the mean or median value, is that we are able to precisely estimate the conditional uncertainty of the projected migration flows.

Data on demographic and economic projections (GDP per capita at origin, and GDP per capita ratio between origin and destination) came from the SSP scenarios (using the IIASA projections)[104·229–231·w]. Because the SSP demographic scenarios are based on assumption about future migration, we use a modified set of projections assuming no future migration[x]. Both demographic and economic scenarios are rescaled so that they match their observed values for 2010 to avoid and break in the data, susceptible to artificially influence projections.

Crop yields and water availability projections are provided from ISIMIP2b GEPIC simulations for crop yields and WaterGAP2 simulations for water availability (based on the Coupled Model Intercomparison Project 5 (CMIP5) GFDL-ESM2M climate simulations from the Princeton *Geophysical Fluid Dynamics Laboratory*)[y]. We use two sets of crop yields and water availability projections for Representative Concentration Pathways (RCP) 2.6 and 6.0.

Migration stocks at destination are initialised using the 2010 estimates of migration stock at destination from the United Nations[3]. Finally, we set the conflict intensity to its African-wide average between 1990 and 2010[z]. In addition, we set the time dummies values to 2005.

Proceeding iteratively at time steps of five years, SSP 'no migration' populations projection and migrant stocks are updated based on projected migration flows to reflect the population change induced by migration. In doing so, we assumed that migration stocks at destination are only affected by migration. In other words, we assume that migrants maintain ties with origin countries, irrespective of when they first arrived in destination countries (recently or many decades ago) and that natural migrant population growth and decay (as a result of birth or death) is essentially zero.

As mentioned, we obtain three distinct sets of projections for RCP 2.6, RCP 6.0 and a *counterfactual* scenario holding constant crop yields and water availability values at their historical average (1990 to 2010). The *counterfactual* scenario allows to examine the incremental impact of projected environmental change on bilateral migration within Africa. To prevent the compounding impact of outlier parameter estimates on projected bilateral migration flows, we rotate the parameters estimates at each time steps using sampling without replacement (the rotation is the same for each scenario considered). While the calibration model is estimated on a log scale, we project the number of migrants on a level scale, by taking the exponents and rounding to the nearest integer.

v Parameters are included in the projection framework irrespective of whether the credibility interval of the estimates overlap zero. For reasons of feasibility and speed, we randomly drew 1,000 sets of parameters out of the set of 8,000 draws. We use the same set of draws for each projection.

w Because of missing data, we add GDP projections for Angola from the OECD SSP projections[232].

x These data are graciously provided to us by Samir KC and Hélène Benveniste.

y We also used alternative projections using the LPJmL ISIMIP2b projections for crop yields and water availability and the HadGEM2-ESM2M CMIP5 climate projections. Because these projections could not replicate the recent drying trends over Eastern Africa, we ended up privileging crop yields and water availability projections based on the CMIP5 GFDL and ISIMIP2b GEPIC / WaterGAP2, as we discuss in the note below.

z Alternatively, we could have simply used each country average value over the same period or set the conflict intensity to zero. We ended up using the country average as the alternatives were not ideal. Conflict areas tend to shift spatially over time, while assuming zero violence was similarly unrealistic. We are considering using a decay function in future applications.

Table A6 provides an overview of the sources of data for the projections stage. Crop yields and water availability projections are provided from ISIMIP2b data (GFDL). We chose the GEPIC projections for the crop yields and the WaterGAP2 projections for water availability. For demographic and economic projections, we used the SSP scenarios. As before, only the SSP1 and SSP3 were considered. SSP1 can be described as an optimistic scenario with developing countries experiencing high economic growth, and a sharply decreasing rate of demographic growth. By contrast, the SSP3 is a more pessimistic scenario, in which developing countries experience slow economic growth and high demographic growth.

Table A6 **Data sources: Projection**

| Type | Variable | Source | Note |
|---|---|---|---|
| Projection | Crop yields index | GFDL GEPIC ISIMIP2b RCP 2.6, 6.0 | $\frac{crop_t - \overline{crop}}{\overline{crop}}$ |
| Projection | Water availability index | GFDL WaterGAP2 ISIMIP2b RCP 2.6, 6.0 | $\frac{water_t - \overline{water}}{\overline{water}}$ |
| Projection | Population | SSP IIASA 1, 3;[104, 229] | under 'no migration' assumption |
| Projection | GDP per capita at origin | SSP IIASA 1, 3;[104, 229] | |
| Projection | GDP per capita ratio | SSP IIASA 1, 3;[104, 229] | $\frac{GDP_{dest}}{GDP_{orig}}$ |
| Projection | Migrant stock | 2020 UN International Migration Stock[3] | |
| Projection | Conflict intensity | UCDP GED 20.1[198] | N. fatalities (all forms of political violence in the dataset) |

### A.2.5.3
## Note on model choice

In the report, we present the results of cross-border mobility flows projections based on the GFDL-ESM2M CMIP5 climate model and ISIMIP2b GEPIC and WaterGAP2 climate impact models for crop yields, respectively river discharge. In addition, we have also projected bilateral cross-border mobility flows using alternatively the ISIMIP2b LPJmL climate impact models for crop yields and river discharge in conjunction with the GFDL-ESM2M CMIP5 climate model, as well as replicated the two sets of ISIMIP2b climate impact models for crop yields and river discharge (GEPIC/WaterGAP2 and LPJmL) with the HadGEM2-ES CMIP5 climate model. We selected the GFDL-ESM2M CMIP5 climate model because it appears to better replicate the recent observed drying trends over Eastern Africa compared to the HadGEM2-ES based ISIMIP2b climate impact models, which project that water discharge will significantly increase in the region in the future. We note, however, that climate scientists are currently unable to establish whether the projected increases in rainfall over East Africa reflect fundamental bias in existing climate models, or whether the current drying trend in the region is simply due to short-term climate variability (on the 'Eastern Africa Paradox'[233, 234]).

Furthermore, we selected the ISIMIP2b GEPIC/WaterGAP2 for projections of the climate impact on mobility because the calibration of the model based on ISIMIP2A GEPIC/WaterGAP2 observational data on crop yields and river discharge reports a statistical association between crop yields and bilateral mobility flows in Africa, while crop yields and river discharge were not statistically associated bilateral cross-border mobility using the LPJmL ISIMIP2A data for calibration. That said, assessments of the predictive skills of each model suggest that the choice of climate impact model does not result in a substantial increase in the predictive skills of the model using historical data as a benchmark.

We wish to caution readers that replicating mobility projection using either HadGEM2-ES CMIP5 climate model as a basis for the ISIMIP2b climate impact models for crop yields/river discharge or the LPJmL ISMIP2b in conjunction with the HadGEM2-ES CMIP5 climate model indicates that it is possible that aggregate bilateral cross-border mobility within Africa may not be substantially influenced by projected warming over the continent. Taken together, these four sets of projections (two CMIP5 climate models and two ISIMIP2b climate impact models) suggest that expected global warming will either have no effects on bilateral cross-border mobility within Africa or will result in an increase in the size of these flows under the RCP 6.0 scenario.

### A.2.5.4
## Calibration results

Table A7 presents the results of the calibration model together with 95 percent Bayesian credible intervals[a]. The findings indicate that only crop yields correlate — positively — with international migration. By contrast, water availability — proxied by river discharge, does not correlate with historical migration patterns. In substantive terms, these findings indicate that an increase in crop yields at origin due to more favourable climate conditions predicts larger flows of migrants over the period 1990 to 2010. By the same token, reduced crop yields at origin results in lower levels of migration. These findings are consistent with a narrative stressing the costs of international migration, in the face of persistent desire to migrate. In effect, the results indicate that higher crop yields translate into higher income for rural households, and thus enable more households to send migrants abroad in search of labour opportunities elsewhere.

In addition, we find that the level of economic development at origin positively correlates with out-migration. Broadly, they can be interpreted as evidence that international migration in Africa requires resources to overcome financial costs faced by those hoping to migrate. We note that these findings are consistent with the results for crop yields. On the other hand, we find little evidence that the magnitude of the wealth gap between origin and destination correlate with migration in Africa.

[a] In total, the model involved estimating 2,178 parameters, including 12 population fixed effects, one standard deviation parameter, three random intercepts standard deviation parameters, and 2,162 random separate intercepts.

While this finding stands in marked contrast with others[223], it likely reflects the smaller wealth gaps existing between African countries, as opposed to the existing wealth gap with Europe.

The calibrated model also suggests that the size of the diaspora at destination is a predictor of in-migration, while conflict correlates with out-migration. This latter result indicates that UNHCR refugee data does not capture entirely migration resulting from conflict in Africa. Finally, increasingly large distance predicts smaller migration flows[b].

We evaluated the convergence of the model. All the parameters had $\hat{R}$<1.01 for the reported parameters with lowest Bulk Effective Sample Size (Bulk-ESS) and Tail Effective Sample Size (Tail-ESS) of at least 2,500. $\hat{R}$ values indirectly measure the degree to which MCMC chains have mixed and are stationary by evaluating the the scale at which the resulting parameter distribution may be reduced if the model would have run longer (i.e. for more iteration). As MCMC proceeds iteratively, draws are naturally auto-correlated, Bulk-ESS and Tail-ESS measures the number of draws, which can be effectively considered independent[217]. In effect, it is a measure of efficiency of the sampling process.

Table A7 **Results of the calibration model**

| | GDFL | GEPIC / WaterGAP2 |
|---|---|---|
| Crop yields | 0.69 | [0.31;1.08] |
| Water availability | -0.07 | [-0.36;0.22] |
| Population, In | 0.01 | [-0.08;0.10] |
| GDP pc ratio, In | 0.07 | [-0.03;0.18] |
| GDP pc origin, In | 0.24 | [0.10;0.38] |
| Conflict intensity, In | 0.03 | [0.02;0.05] |
| Migrant stock, In | 0.39 | [0.38;0.41] |
| Distance, In | -0.55 | [-0.64;-0.46] |
| $\tau_{orig}$ | 0.45 | [0.37;0.55] |
| $\tau_{dest}$ | 0.39 | [0.31;0.49] |
| $\tau_{orig \to dest}$ | 0.76 | [0.72;0.81] |
| $\sigma$ | 1.70 | [1.67;1.73] |

Mean param. estimate and 90 percent credible interval in square brackets.

[b] The lack of conclusive findings with regards to the population parameter could reflect the short temporal frame of the data.

### A.2.5.5
## Posterior predictive performance

To evaluate the posterior predictive ability of the model, we use *Leave-one-out cross-validation* (looic)[235,236]. We compared the results with a similar log-linear model, which excluded the random intercept. They suggest that adding random intercepts marginally improves the posterior predictive ability of our model[c].

Nevertheless, the performance of the models should not be overstated. Posterior predictive checks on the calibration data suggest that both models miss significant features of the data and are unable to replicate key features of the calibration data for migration, such as the mean or the maximum[d].

### A.2.5.6
## Limitations

While useful to project future migration conditional on the chosen scenario, the current implementation of the calibration model has some significant shortcomings, which future researchers may seek to remedy. In the ensuing text, we discuss three of these limitations, as they relate to calibration.

First, the current specification assumes that the effects of a decrease in crop yields or water availability on migration is similar in each country in the sample. The problem with such an approach is that the literature has shown that the magnitude of these effects depends on the level of development and exposure (e.g. agriculturally reliant countries are more vulnerable to climate shocks)[47,237–240]. Modelling these heterogeneities would increase the performance of the calibration model, and thus possibly the accuracy of projections of migration flows in the future. This could be done by modifying the model, such that the effects of these variables would vary by country of origin (i.e. using a 'random slope' Bayesian model).

Second, the current treatment of the effects of political violence, a major driver of cross-border migration, in the ACMI is naive, fixing future armed conflict to historical average over the entire African continent (1990 to 2010). A better approach would involve adding a decay function, which would see violence in the near future be very close its current value in any country and then gradually converge to its mean value across the African continent by 2050.

Third, the current model assumes a simple (log) linear function between the dependent (migration) and independent variables (crop yields, water available, economic factors, and other covariates). While practical and easy to estimate, such a specification is unable to model both the excess number of zero count of migration in the calibration data (i.e. migration flows from Morocco to Mozambique are typically very low in any given year, if not zero), nor the large dispersion in the calibration data. While harder to estimate, the use of count distribution (e.g. poisson log-normal or a negative binomial) would allow to better capture these features of the calibration data.

c Comparing the looic value suggests that the use of a hierarchical model increases the predictive ability by about 3.4 percent. To compute the looic statistics for the Bayesian hierarchical linear model, we used moment_match = TRUE of the Loo packages in *R*, because of a bad pareto *K* values (*K>0.7*) and had to refit the model once.

d Initially, we attempted to model migration as a count variable, instead of log transformed variable, with a negative binomial, but the projections evidenced significant issues with such an approach.

A.3

# Case studies & field research

The field research aimed to support greater knowledge and understanding of the link between the effects of climate-related events on individual and household decisions to move, ensuring the inclusion of the human face of climate mobility in the report and agenda for action.

The aim of the field work was to explore responses to climate-related events for those who stay and for those who aspire to move, and to consider successful integration in destinations for both migrant and host communities. The research was designed to address the following core research questions:

1. Where are choices relating to mobility (or immobility) situated among other strategies to cope with and adapt to climate variability and extremes?
2. What is driving migration/displacement from areas in Africa affected by climate change?
3. How do climate variability and extremes interplay with other factors in people's decision to move?
4. To what extent are climate variability or extremes a driving factor in this movement?
5. How is movement from places affected by climate variability or climate extremes characterised?
6. Having moved, how have the individual's/household's circumstances (perception of their situation and needs) and aspirations changed (i.e., has migration proved a positive adaptation strategy)?

The relationship between the effects of climate change, environmental drivers of mobility, and the actual decision and act of migration is complex. We often see the direct link between a sudden-onset disaster like a storm, or flooding, and immediate, short-term (and often short-distance) displacement. However, the link between repeated experiences of sudden-onset disasters, or of slow-onset disasters, and a more considered decision to move — which may still be perceived as forced — is less clear. Similarly, it is not always easy to establish the effects of climate change on populations who are not able to move, or who are already mobile, and changes in their patterns of mobility, which can culminate in 'displacement in place'[241]. The dynamic shifts in mobility patterns across Africa, and the increasingly visible effects of climate change, mean it is crucial to focus on the links between the two phenomena to better comprehend how they relate.

To capture the role of migration as a response to climate-related events (or, conversely, the role of climate-related events as drivers of migration), the design for this research is grounded in two disciplines: it takes inspiration from literature on resilience and adaptation to better understand how people are responding (adapting) to the effects of climate change, and applies this understanding to the ability/aspiration model of migration decision-making.

Carling introduced the ability/aspiration model, to help describe the conditions under which people decide to migrate: aspiration is a preference to migrate, and ability is the set of factors determining the capacity to migrate[25,242]. Both concepts are determined by external factors as well as individual characteristics, and differences in the degree of 'aspiration' and 'ability' lead to different outcomes and modes of migration[243]. Using this framework, as well as work by Schewel on the outcomes of the model, and on the capability to stay[40,63], and de Haas on the aspirations-capabilities framework[25], MMC developed a conceptual model to include the role of climate-related impacts on decision-making around mobility.

There are four potential migration outcomes, according to the aspiration/capability framework: staying in place, either voluntarily or involuntarily, and moving, either voluntarily or not. However, this is of necessity an oversimplification. Voluntary migration and forced displacement are points on a spectrum.

Additionally, the research explores the kind of movement that occurs from areas impacted by environmental stressors. What kind of journeys do people undertake? Is there a link between the degree of capability and aspiration, and the kind of mobility? And once in migration, how successful do people perceive their migration to have been, and what are their aspirations now?

The overall target population is people in locations in Africa that are being affected by climate variability and extremes, and where displacement/migration is occurring and assumed to be caused in part by the effects of climate change. MMC therefore selected seven locations that fit these criteria and represented exploratory diversity in terms of: geographic location across the continent; type of climate-related event; population density; livelihoods. It was also decided that data collection would take place in a secure site. The final sites were selected after consultations with experts: Cahama (Cunene, Angola), Nchalo (Chikwawa, Malawi), Ajegunle (Lagos, Nigeria), Praia Nova (Beira, Mozambique), Tatki (Podor, Senegal), Nadunget (Moroto, Uganda), Al Max (Alexandria, Egypt).

Each site was the subject of a context analysis, reviewing the existing situation with regard to the variables included in the analytical framework, as well as the current political, economic, socio-demographic, and cultural dynamics. This context analysis informed the development of the data collection tools, assisted the definition of the final zone for data collection, and provided a foundation for the analysis. The particular zones were selected based on the context analysis and with the help of local informants on site.

MMC took a mixed methods approach. A closed-question (quantitative) survey was administered across six locations, with a minimum of 100 respondents in each location. The survey covered the participants' profile and household; satisfaction with living conditions; experience of mobility; aspirations around mobility (and drivers); perception and impact of climate-related events; use of coping/adaptation strategies; any links between climate impacts and movement; expectations for the future. Respondents were sampled through random walks within a designated area; only one person participated per household. This quantitative aspect enables the study to reach a relatively large number of people and allows for some degree of comparison across cases.

Three focus group discussions were held in every location. The aim was to reach people whose voices may be less represented in the survey: women-only and youth focus groups took place in each location, but the composition of the third group varied (for details, see the individual case studies). Participants were selected from among survey respondents, or via referrals. This qualitative data allowed for a more nuanced understanding of the local context.

The researchers then held 10 in-depth discussions. Participants were selected based on the survey results regarding people's thinking about mobility to ensure interviews took place with people representing the dominant attitudes. Where possible, two people were interviewed from each household: e.g., a man and a woman, or someone who wants to stay and someone who wants to leave. Where a household member (or an entire household) had left, the interviews were conducted by phone. Sampling was purposive, and often through referral among survey participants. These interviews probed the topics covered in the survey, but also explored the migration outcomes further.

The survey questionnaire, and the focus group and interview guides, benefitted from external review by experts in adaptation and resilience, and climate and mobility.

The Senegal case study, consisting of qualitative data, was conducted slightly differently, through focus groups and in-depth interviews with participants from households in Tatki and the encampments. Five focus group discussions were held (one with young people, one with women, one with men, and two mixed groups). Ten key informant interviews were conducted with civic and religious leaders, and 20 in-depth interviews with people from pastoralist households — although not always with the household members who moved — to explore mobility, climate related events and their impacts, and the link between the two (9 women, 11 men, aged 19–70). The household survey used in the six other cases for this project was not conducted in this setting because the questionnaire was designed for a sedentary population, and therefore the questions were not applicable.

Limitations and potential bias include:

- Sites were selected because of evidence of climate impacts: often, this evidence is strongest among marginalised communities, which have a stronger dependence on natural resources. While efforts were made to reach areas with different socioeconomic profiles and livelihoods, there were few opportunities to observe the impacts of climate events and mobility among more wealthy populations, where the findings may have been different.

- Efforts have been made to cover a broad range of locations, but obviously each is unique, therefore findings may not be applicable to all locations that experience similar climate-related events and processes and mobility.

- The scale of data collection was limited: it was decided to focus on a very small site in each location, and interview numbers were limited, meaning findings are not fully representative.

- Research is time-bound. Data collection is one-off, a snapshot of the situation and people's aspirations and behaviour at a particular point in time, and we cannot know whether and how (rapidly) circumstances and decision-making change.

- Asking questions about intentions and aspirations is difficult — while extreme opinion may be easier to capture, people whose views lie in the middle are harder to define and validate. For people who see no option for moving, the aspiration may no longer be accepted or recognised. In addition, cross-cultural comparison must consider differences in perception of these questions.

- In the interest of reaching people who have moved across as broad a geographic area as possible, the data collection from people who have moved was conducted by telephone. This carries the inherent bias that participants must have access to a phone. Additionally, there may be a self-selection bias in that those who agree to be interviewed have a success story to tell.

- Travel restrictions: oversight was primarily virtual, and training was done via videoconference due to Covid-19. Some quality assurance measures were only possible to carry out remotely, which incurred a longer time delay between data collection and full quality control than usual.

A.4

# The ACMI consultations

Between December 2021 and August 2022, the ACMI conducted a rigorous consultations process to review the findings of the climate mobility modelling and field research and discuss their implications for policy and action with a diversity of African stakeholders and international partners.

The consultations process was structured in two phases. The analysis phase of the consultations examined the results of the ACMI field research and modelling scenarios through the lens of five key geographies:

1. Coastal & Delta Areas
2. Urban Areas
3. Rural Areas
4. Pastoral Areas
5. Borderlands

Each geographic workstream held a series of three virtual workshops (for a total of fifteen), co-led and moderated by institutions with expertise in that geography. The analysis phase concluded with a discussion on policy implications and possible directions for action in each geography. It involved some 500 participations from leading experts and practitioners from 125 organisations. Represented were research institutions, academia, sub-regional and international organisations, national and local governments, civil society, and the private sector.

The policy phase of the consultations saw the engagement of specific constituencies through the lens of four policy ecosystems:

1. Sustainable resource governance for green growth
2. People-centred climate action
3. Prevention and protection
4. Cooperation for a continent on the move

The ACMI convened five dedicated workshops:

1. with African youth
2. with African city representatives
3. with the Union of Economic and Social Councils and Similar Institutions of Africa
4. with international partners
5. with experts and stakeholders of the 'Prevention and Protection' ecosystem

Through the process of consultations and stakeholder engagement, the ACMI has begun building a continent-wide Community of Practice, including dedicated forums for Youth, Women, Knowledge, Partnerships, and Cities. By supporting these key constituencies in the continent, the ACMI seeks to create an eco-system of change agents that can drive knowledge generation, advocacy, and the implementation of the Agenda for Action beyond the UN Climate Summit (COP27) in Sharm El-Sheikh. In July 2022, the ACMI organised a virtual Stakeholders Forum as a key milestone in the process leading up to COP27. The Forum brought together the ACMI's partners, stakeholders, and representatives of the key constituencies in the Community of Practice. Over three half-days of deliberation, the Summit discussed the insights garnered through the ACMI research and consultations and facilitated an exchange on:

1. Key priorities for action for different groups of stakeholders and how those can be advanced through the ACMI.
2. Key policy recommendations and messages to be included in the Africa Climate Mobility Report.
3. A common narrative and concrete initiatives to be presented at COP 27.

The outcomes of the Summit have informed the drafting and finalisation of the *African Shifts* report and Agenda for Action, as well as various flagship programmes announced at COP27, where the Global Centre for Climate Mobility hosted a dedicated Climate Mobility Pavilion.

# 537 Entities participating in the ACMI consultations

0 — 3ilms

4CMaroc

A — ACEPEC

Act On Sahel

Action For Youth Development Uganda

Addis Ababa University

adelphi

ADEPT

ADES

AFFORD

Africa Green Ladies

Africa Improved Foods Rwanda Ltd

Africa No Filter

Africa Policy Research Institute (APRI)

Africa Policy Research Private Institute

African Climate Foundation

African Development Bank

African Intellectual Resource Organization – AIRO

African Migration and Development Policy Centre (AMADPOC)

African Migration Observatory

African Network of Young Leaders for Peace and Sustainable Development

African Network of Young Researchers

African Refugee and Migrants Aid (ARMA)

African Regional Center for Space Science and Technology in French

African Risk Capacity of AU

African Technology Policy Studies Network

African Union

African Union Border Programme

African Youth Advocates

African Youth in Livestock, Fisheries and Aquaculture Incubation Network

African Youth Peer Review Committee

Agricultural Expertise Center

AGRO BIBI

Albertine Rift Conservation Society (ARCOS)

Alexandria Research Center for Climate Adaptation

Alliance for a Green Revolution in Africa (AGRA)

Alliance for Food Sovereignty in Africa (AFSA)

American Friends Service Committee

American Society of Adaptation Professionals

Amnesty International

Angel Support Foundation

AOBC

APCO Worldwide

Arab Health and Development Corporation (AHDO)

Arab Network for Environment and Development (RAED)

ARC – Institute for Soil, Climate and Water

Arua City

ASA – Afrique Secours et Assistance, Côte d'Ivoire

ASSIH

Association d'Aide à l'Education de l'Enfant Handicapé (AAEEH)

Association de Défense des Droits des Aide-menagères et Domestiques (ADDAD-Mali)

Association des Femmes de l'Afrique de l'Ouest (AFAO)

Association des Professionnels en Gestion et Conservation de la Biodiversité APro-GCB

Association for Indigenous Women and Peoples of Chad (AFPAT)

Association Les Amis du Bassin du Congo

Association OBJECTIF JEUNESSE 20

Association of Caribbean States

Association Sénégalaise des Amis de la Nature (ASAN)

Awdal Youth Volunteers

B — Bahir Dar University

Baruch College

BJ Consulting Farms

BMZ

BOC (Les Bénévoles Des Océans du Cameroun)

Build Peace and Development
Bureau de l'Environnement et les Changements Climatiques, Senegal
Burundi, Ministry of Environment, Agriculture and Livestock

**C —** C40 Cities
Cairo International Center for Conflict Resolution, Peacekeeping and Peacebuilding
Caritas Internationalis
Caritas Nigeria
Catholic Youth Network for Environmental Sustainability in Africa
Center for Child Protection and Womens Empowerment
Center for Development Support Initiatives
Center for Global Development
Center for International Earth Science Information Network (CIESIN)
Center for Mediterranean Integration – UNOPS
Centre de recherche 'Point Sud'
Centre for Nonviolence and Gender Advocacy in Nigeria
Centre Régional AGRHYMET/CILSS
CERED
CES RDC
CESE Maroc
CESOC-Niger
CGIAR
Chatham House Common Futures Conversations Initiative
Chemba DC
CIAD Burundi
CICRA Justicia Ambiental
Cities Alliance
City of Alexandria
City of eThekwini
City of Freetown
City of Milan
Civil Society Advocacy Network on Climate Change and the Environment Sierra Leone (CAN-SL)
Civilian Protection National Agency, Togo
Clean & Save
Clean Africa
Climate Analytics Lome Office
Climate Care Africa
Climate Change and Social Research Centre
Climate Education Congo
Climate Live
Climate Refugees
Climate, Migration & Displacement Platform
CNEDD, Niger
Columbia University
Columbia University Graduate School of Architecture, Planning and Preservation
COMESA
Commission Environnement et Cadre de vie, Côte d'Ivoire
Community Emergency Response Initiative (CERI)
COMYAP
Congo Innovation Academy
Conseil National de l'Environnement pour un Développement Durable (CNEDD), Niger
Conselho Municipal da Beira
CoRMSA
Corporate Assist Advisory
County Government of Trans Nzoia
CREWS Secretariat
Crisis Group
Curious Minds Ghana

**D —** DANI Africa
Danish Refugee Council
Danone
Delmore 'Buddy' Daye Learning Institute
Deltares
Department of Environmental Affairs, South Africa
Department of Forestry, Fisheries and the Environment, South Africa
Department of Forestry, Malawi
Department of Peace Operations

Department of Political and Peacebuilding Affairs
Development Frontier International
Dexterity Management Consultancy Services
DIAL-IRD University Paris Dauphine
DiMTEC
Direction Nationale de l'Assainissement et du Cadre de Vie
Disability Right and Inclusion Matters (DRIM-SL)
Dokuz Eylül üniversity

E — East African Community-GIZ Cluster
EARTHDAY.ORG
East African Centre for Forced Migration & Displacement
East African Grain Council (EAGC)
Eastern and Southern African Pastoralists Network
ECOWAS
ECOWAS Youth Council
Edar Seed Foundation
Education for All Coalition
Edulink WestAfrica
Egerton University Kenya
EIE-GROUP'S
El NARJOL ADVISING SARL
El Warda
Eletric Mobility Cape Verde
Embassy of Sweden in Addis Abeba
En Group
Enable the disable action (EDA)
ENDA PRONAT
Energy Commission of Nigeria
Engie Energy Access
Entersports24TV
Environment Protection Agency, Sierra Leone
Environmental Protection Agency, Ghana
ESEC
Établissement Biodiversité Vie
EU Delegation to the United Nations
European Commission
European Council on Foreign Relations

F — Faculdade de Letras e Ciências Sociais – UEM
Faculté d'agronomie de Niamey
Faculté des sciences d'Agadir
Faculté des Sciences et Techniques Marrakech
FarmAsyst
Federal Foreign Office of Germany
Federal University of Agriculture, Abeokuta
Federal University of Technology Akure, Nigeria
Fédération ivoirienne des associations et clubs pour l'Unesco
FEMNET
Feynuus International
Food and Agriculture Organization (FAO)
Friedrich-Ebert-Stiftung (FES)
Friedrich-Ebert-Stiftung Flight and Migration Competence Center (FES-FMCC)
Friends of Lake Turkana

G — GAIA Africa
Gathering Youth Initiators of Changes
GAYO Ghana
Gender and Environmental Risk Reduction Initiative (GERI)
Gender Equality for Good Governance Sierra Leone
Georgetown University
GERI NGO
German Development Institute
Ghana Federation of Slum Dwellers
Ghana Meteorological Agency
Ghanaian Federation of Slum Dwellers
GICC
GIFSEP
GIMAC
GIZ
GLIHD Rwanda
Global Citizen
Global ECC Initiative
Global Refugee Youth Network
Globe Steward
Graphic Communications Group

Grassroots Development Initiatives Foundation-Kenya
Green Energy Mission
Green Growth Champion’s Network
Green Life Act
Greenpeace Africa
Greenrev

H — Hano Academy (TVET) NGO
Hargeisa Municipality
HIRED Consult
HSBC
Hugo Observatory

I — I4safe Migratio
Ibn Tofail University
ICAD Southern Africa
ICLEI Africa
ICMPD – International centre for Migration Policy Development
ICPAC
ICRC Dakar
Idealwoman
IEVD – Initiatives Eco-Vie Durable
IFRC
IGAD
IGAD CEWARN
IIHL
Inclusive Action for Peace and Development in Africa
Independent Diplomat
Infinite Hope For Vulnerable Africa
Innovations for Poverty Action
Innovea Development Foundation
INSAH-Institut du Sahel
Institut des Relations Internationales du Cameroun
Institut Supérieur Pédagogique de Bukavu
Institute for Economics and Peace
Institute for Security Studies
Institute for Water Research, Rhodes University
Intercommunity Development Social Organization (IDS)
Intergovernmental Authority on Development (IGAD)
Internal Displacement Monitoring Centre (IDMC)
International Committee of the Red Cross (ICRC)
International Crisis Group
International Food Policy Research Institute (IFPRI)
International Igbo Organization
International Institute for Environment and Development (IIED)
International Organization for Migration (IOM)
International Refugee Assistance Project
International Rescue Committee
International Water Management Institute (IWMI)
IOM GMDAC
IPAR/GERM UGB
IUCN

J — Jeunes Voix du Sahel, Tchad
Jewel Environmental Initiative
Jomo Kenyatta University of Agriculture and Technology

K — Kafubu Water and Sanitation Company Ltd
Kahrdo Organization
Kaldor Centre
Kenya Land Alliance
Kenya Methodist University
Kibabii University
Kikandwa Environmental Association
King Ceasor University, Bunga, Kampala
Kisii University Organization
Kounkuey Design Initiative
Kulima Kotsogola 2223
Kyambogo University

L — Lagos State
Lesotho Meteorological Services
Let's Green the Future
London School of Economics

M — Major Group for Children and Youth
Makere University
Marie Stopes International Organisation Nigeria (MSION)
Masinde Muliro University of Science and Technology
Master Class Maroc

Mayors Migration Council
Michael Okpara University of Agriculture
Migration Policy Institute
Million Trees International Organization
Ministère de Cadre de Vie et du Développement Durable, Benin
Ministère de l'Urbanisme, de l'Environnement, Djibouti
Ministère de l'Environnement et du Développement Durable, Central African Republic
Ministère de la transition énergétique et du développement durable, Morocco
Ministère du Cadre de vie et du Développement Durable, Bénin
Ministry of Environment, Agriculture and Livestock, Burundi
Ministry of Environment, Benin
Ministry of Environment, Côte d'Ivoire
Ministry of Environment, Protection of Nature and Sustainable Development, Cameroon
Ministry of Youth and Civic Education, Cameroon
Misereor
Mixed Migration Centre
Modèle Francophone des Nations Unies du Lycée Descartes de Rabat (DESMNU)
Monrovia
Mziti Group

**N —** Nala Feminist Collective
National Civil Society Network for Environment and Sustainable Development (NGO RENASCEDD)
National Climate Change Secretariat, Liberia
National Disaster Management Centre, South Africa
National Gender and Equality Commission, Kenya
National Human Rights Council of Morocco
National office for agricultural advisory, Morocco
National Renewable Energy Platform (NREP)
National University of Science and Technology
Nature Cares Resource Centre
Navitas Energy Resources
NDC Action Project – UNEP
Netherlands Ministry of Foreign Affairs
NEWAVE
NGO Save Our Planet
Nigerian National Ocean Decade Stakeholders' Committee
Nordic Africa Institute
NOW Partners
NRC

**O —** Observatoire du Sahara et du Sahel (OSS)
OCHA
ODI
OFADEC – Office Africain pour le Développement et la Coopération
Office of the Assistant Secretary-General for Rule of Law and Security Institutions, Department of Peace Operations
Office of the AU Youth Envoy
Office of the Prime Minister, Uganda
OHCHR
ONG Biogenèse
Open Society Foundations
Orange
Organization for Community Engagement (OCE)

**P —** PACIDA
Partnership for African Social and Governance Research (PASGR)
PENHA Network
Permanent Mission of Botswana to the United Nations
Permanent Mission of Canada to the United Nations
Permanent Mission of Germany to the United Nations
Permanent Mission of Japan to the United Nations
Permanent Mission of Morocco to the United Nation
Permanent Mission of Sweden to the United Nation
Permanent Mission of Switzerland to the United Nations
Plan International
Platform on Disaster Displacement (PDD)
Polycom Development Project
Portland State University
Potsdam Institute for Climate Impact Research (PIK)
Powering Young Initiatives

Princeton University
Public Health and Environmental Promotion Organization of Zambia

**Q** — Quaker United Nations Office

**R** — Rainbow Youth Empowerment Village
Rainforest Alliance
Rainforest Defense Foundation
Raoul Wallenberg Institute of Human Rights and Humanitarian Law
Rassemblement des Jeunes Initiateurs du Changement, RJIC
REACH Initiative
Red Cross Red Crescent Climate Centre
Red Cross Uganda
REDESO
Regional Sustainable Energy Center of Excellence for Sub Saharan Africa
RELON-Kenya
Research Triangle Consortium (RTC)
Resilient 40 Africa
Resource Conflict Institute (RECONCILE)
Richcoat Paint
Rift Valley Institute Research
Riseup Movement
Robert Bosch Stiftung
RUFORUM Secretariat

**S** — SADC Secretariat
SAF-ADAPT
Safe Home
Safer Nairobi Initiative
Samrego
Samuel Hall
Saracen Marketing Group
Savannah Zambia
Save & Plant Trees!
SAYWIN
SDI
Seatrust Institute
Secrétariat permanent du Conseil national pour l'environnement et le développement durable (SP-CONEDD)
SEI Africa
Senegal
Shack Dwellers International
She leads
Sierra Leone Urban Research Center
Smart Youth Network Initiative
SNV
SOAS University of London
Society for International Development
Solutions Journalism Network
Somalia NGO Consortium
South Africa Institute of International Affairs (SAIIA)
South African Climate Action Network
South African Red Cross Society
Spaces for Change
Steward Bank
Stockholm Environment Institute
Strathmore Law School
Sudan Youth Organization on Climate Change
Sudd Institute
Sultan Moulay Sliman University
Sustain267
Sustainable Environment and Education Constancy
Sustainable Green Environment Initiative
SustaiNet Group
SWAC-OECD
SWISSAID

**T** — Technical University of Mombasa
Temple of Understanding
The Alliance of Bioversity and CIAT
The Clean Fight
The Gambia Red Cross Society
The Initiative for Climate Action and Development (ICAD)
The Jakaya Mrisho Kikwete Foundation

The Rainmaker Enterprise
The South African Red Cross Society
The Tony Elumelu Foundation
The Waste Museum
The World Bank
Translantic Development Limited
Tree Adoption Uganda
Triumph Uganda
Tumaini University Makumira

U — UAC/INE
UCESA
UCLG
UCLG Africa
UICN
UICN PAPACO
UN Environment Programme
UN Habitat Egypt
UN Office of the Special Adviser on Africa
UN OICT
UN Women
UNDP Asia Pacific
UNDP Borderlands
UNDP Egypt
UNDP Resilience
UNESCO
UNFCCC
UNFPA
UNFPA ESARO
UNICEF
UNICEF Green Yoma
UNIDO
Unissons-nous pour la Promotion des Batwa (UNIPROBA)
United Cities and Local Governments Africa
United Nations Assistance Mission in Somalia (UNSOM)
United Nations Development Programme (UNDP)
United Nations Economic Commission for Africa (UNECA)
United Nations High Commissioner for Refugees (UNHCR)
United Nations Human Settlement Programme (UN Habitat)
United Nations Office for West Africa and the Sahel (UNOWAS)
United Nations Regional Office for Central Africa (UNOCA)
United Nations University – EHS
United Nations University MERIT
United Nations University – INRA
Université Abdou Moumouni
Université Assane Seck de Ziguinchor
Université de Kisangani
Université de N'Djaména
Université de Yaoundé
Université des sciences juridique et politiques de Bamako
Université Félix Houphouët-Boigny
Université Gaston Bergé
Université Joseph Ki Zerbo
Université Libre de Maradi
Université Marien Ngouabi
Université Mohammed V
Université Norbert Zongo
Université Thomas Sankara
University Ibn Zohr
University of Abomey-Calavi
University of Buea, Cameroon
University of Cape Coast
University of Dar Es Salaam
University of East Anglia
University of Energy and Natural Resources Sunyani Ghana
University of Ghana
University of Groningen
University of Ibadan
University of Kinshasa
University of Nairobi
University of Namibia
University of New South Wales
University of Sciences & Technologies Houari Boumediene (USTHB)
University of South Africa

University of the Free State
University of the Western Cape
University of Uyo
University of Zimbabwe
UNOPS
UNU-GCM
Urban Tree Revival Initiative
USAID

V — VENRO
VIC-AFRICA
Vodacom Tanzania
Voyants Solutions Private Limited

W — WACA-Mauritania
Walker Institute at University of Reading
WASCAL
Water For Life Cameroon
Western Area Rural District Youth Council
Western Indian Ocean Marine Science Association (WIOMSA)
Wits School of Governance
Women Environmental Programme
Women for a Change Cameroon
Women Human Rights Defenders Hub (The Hub)
Women in Humanitarian Response in Nigeria Initiative
Women Leaders for Planetary Health
Women of Africa Zimbabwe
Women's Right To Education Programme
Wooro Global
World Alliance of Mobile Indigenous Peoples (WAMIP)
World Bank Knomad
World Merit
World Refugee & Migration Council
World Youth Publishers

Y — YAFTEMOPA (Youth Ambassadors For The Free Movement Of Persons in Africa)
Yale Program on Climate Change Communication
YMCA
Young Africans Policy Research Hub
Young Voices from the Sahel
Young Volunteer for the Environment
YOUNGO
Youth 4Climate
Youth Alliance and Initiative for Innovation and Environmental Development (YAIIED)
Youth for Climate Refugees
Youth for Sustainable Development (YSD)
Youth International Conclave
Youth of United Nations Tanzania
YouthGoGreen
YSAT

Z — Zambia Climate Change Network
Zambia Road Safety Trust
Zambia's NDA for GCF and AF
Zimbabwe People's Land Rights Movement
Zolberg Institute

# GLOSSARY

**2030 Agenda for Sustainable Development**
A UN resolution in September 2015 adopting a plan of action for people, planet and prosperity in a new global development framework anchored in 17 Sustainable Development Goals (SDGs).

**Adaptation**
Process of adjustment to actual or expected climate change and its effects. In human systems, adaptation seeks to moderate or avoid harm, or to exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate change and its effects.

**Adaptive capacity**
Ability of systems, institutions, humans, and other organisms to adjust to potential damage, take advantage of opportunities, and respond to consequences of climate change impacts.

**Aridity**
The state of a long-term climatic feature characterised by low average precipitation or available water in a region.

**Attractiveness**
Desirability of a locale based on a number of factors including but not limited to economic opportunity, transportation infrastructure, proximity to family, the presence of social amenities, environment, and intangibles such as place attachment.

**Behavioural change**
In this report, behavioural change refers to alteration of human decisions and actions in ways that mitigate climate change and/or reduce negative consequences of climate change impacts.

**Biodiversity**
Variety of plant and animal life in the world or in a particular habitat or ecosystem.

**Biome**
Large naturally-occurring community of flora and fauna occupying a major habitat (for example, forest or savannah).

**Capacity building**
The practice of enhancing the strengths and attributes of, and resources available to, an individual, community, society or organisation to respond to change.

**Climate**
In a narrow sense, climate is usually defined as the average weather — or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities — over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization (WMO).

**Climate change**
A change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity.

**Climate finance**
There is no agreed definition of climate finance. The term climate finance is applied to the financial resources devoted to addressing climate change by all public and private actors from global to local scales, including international financial flows to developing countries to assist them in addressing climate change. Climate finance aims to reduce net greenhouse gas emissions and/or to enhance adaptation and increase resilience to the impacts of current and projected climate change. Finance can come from private and public sources, channelled by various intermediaries, and is delivered by a range of instruments, including grants, concessional and non-concessional debt, and internal budget reallocations.

**Climate information**
Information about the past, current or future state of the climate system that is relevant for mitigation, adaptation and risk management. It may be tailored or ‘co-produced’ for specific contexts, taking into account users’ needs and values.

**Climate literacy**
Climate literacy encompasses being aware of climate change, its anthropogenic causes and implications.

**Climate mobility hotspot**
For the purposes of this study, climate mobility hotspots are areas that will see significant differences in population across multiple scenarios that take into account climate change impacts relative to population projections that do not take climate change impacts into account. Areas with multiple scenarios showing high positive differences are likely to be climate mobility destination areas, and those with negative differences are likely to be climate mobility source areas. To qualify as a high confidence hotspot 3 or 4 out of 4 scenarios need to show population differences in the top 5th percentile of the distribution of differences, both at high (positive) and low (negative) ends. Medium confidence hotspots are those in which 2 out of 4 scenarios meet this criteria.

**Climate model**
A qualitative or quantitative representation of the climate system based on the physical, chemical and biological properties of its components, their interactions and feedback processes and accounting for some of its known properties.

**Climate prediction**
A climate prediction or climate forecast is the result of an attempt to produce (starting from a particular state of the climate system) an estimate of the actual evolution of the climate in the future, for example, at seasonal, interannual or decadal time scales. Because the future evolution of the climate system may be highly sensitive to initial conditions, such predictions are usually probabilistic in nature.

**Climate projection**
Simulated response of the climate system to a scenario of future emissions or concentrations of greenhouse gases (GHGs) and aerosols and changes in land use, generally derived using climate models. Climate projections depend on an emission/concentration/radiative forcing scenario, which is in turn based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realised.

**Climate risk**
Potential for consequences from climate variability and change where something of value is at stake and the outcome is uncertain. Often represented as the probability that a hazardous event or trend occurs multiplied by the expected impact. Risk results from the interaction of vulnerability, exposure, and hazard, as well as responses to climate change failing to achieve their goals.

**Climate services**
Climate services involve the provision of climate information in such a way as to assist decision-making. The service includes appropriate engagement from users and providers, is based on scientifically credible information and expertise, has an effective access mechanism and responds to user needs.

**Climate variability**
Deviations of some climate variables from a given mean state (including the occurrence of extremes, etc.) at all spatial and temporal scales beyond that of individual weather events. Variability may be intrinsic, due to fluctuations of processes internal to the climate system (internal variability), or extrinsic, due to variations in natural or anthropogenic external forcing (forced variability).

**Climate-resilient development**
In line with the IPCC, climate resilient development refers to the process of implementing greenhouse gas mitigation and adaptation measures to support sustainable development for all.

**Coastal erosion**
Erosion of coastal landforms that results from wave action, exacerbated by storm surge and sea-level rise.

**Coastal zone**
In this report, the coastal zone is land area within 50 kilometres of the coastline.

**Coping**
The use of available skills, resources and opportunities to address, manage and overcome adverse conditions, with the aim of achieving basic functioning of people, institutions, organisations and systems in the short to medium term.

**Coping capacity**
The ability of people, institutions, organisations and systems, using

available skills, values, beliefs, resources and opportunities, to address, manage and overcome adverse conditions in the short to medium term.

**Coupled Model Intercomparison Project (CMIP)**

A climate modelling activity from the World Climate Research Programme (WCRP) which coordinates and archives climate model simulations based on shared model inputs by modelling groups from around the world. The CMIP3 multi-model data set includes projections using Special Report on Emissions Scenarios (SRES) scenarios. The CMIP5 data set (used in this report) includes projections using the Representative Concentration Pathways (RCP).

**Crop productivity**

The crop sector model outputs in this report represent crop yield in tons per hectare on an annual time step.

**Cultural impacts**

Impacts on material and ecological aspects of culture and the lived experience of culture, including dimensions such as identity, community cohesion and belonging, sense of place, worldview, values, perceptions and tradition. Cultural impacts are closely related to ecological impacts, especially for iconic and representational dimensions of species and landscapes. Culture and cultural practices frame the importance and value of the impacts of change, shape the feasibility and acceptability of adaptation options, and provide the skills and practices that enable adaptation.

**Disaster**

A 'serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts'.

**Disaster management**

Social processes for designing, implementing and evaluating strategies, policies and measures that promote and improve disaster preparedness, response and recovery practices at different organisational and societal levels.

**Disaster risk**

The likelihood over a specified time period of severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery.

**Displacement**

The movement of persons who have been forced or obliged to flee or to leave their homes or places of habitual residence, in particular as a result of or in order to avoid the effects of armed conflict, situations of generalised violence, violations of human rights or natural or human-made disasters.

**Early warning systems**

The set of technical and institutional capacities to forecast, predict and communicate timely and meaningful warning information to enable individuals, communities, managed ecosystems and organisations threatened by a hazard to prepare to act promptly and appropriately to reduce the possibility of harm or loss. Dependent upon context, EWS may draw upon scientific and/or indigenous knowledge, and other knowledge types.

**Ecosystem**

A functional unit consisting of living organisms, their non-living environment and the interactions within and between them.

**Ecosystem-based adaptation (EBA)**

The use of ecosystem management activities to increase the resilience and reduce the vulnerability of people and ecosystems to climate change.

**Emissions (Anthropogenic)**

Emissions of greenhouse gases (GHGs), precursors of GHGs and aerosols caused by human activities. These activities include the burning of fossil fuels, deforestation, land use and land-use changes, livestock production, fertilisation, waste management and industrial processes.

**Emissions (Fossil-fuel)**

Emissions of greenhouse gases (in particular, carbon dioxide), other trace gases and aerosols resulting from the combustion of fuels from fossil carbon deposits such as oil, gas and coal.

**Emission scenario**

A plausible representation of the future development of emissions of substances that are radiatively active (e.g., greenhouse gases (GHGs) or aerosols) based on a coherent and internally consistent set of assumptions about driving forces (such as demographic and socio-economic development, technological change, energy and land use) and their key relationships.

**Equality**

A principle that ascribes equal worth to all human beings, including equal opportunities, rights and obligations, irrespective of origins.

**Exposure**

The presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected.

**Extreme weather event**

Event that is rare at a particular place and time of year. Definitions of rare vary, but an extreme weather event would normally fall in the 10th or 90th percentile of a probability density function estimated from observations. The characteristics of extreme weather vary from place to place in an absolute sense. When a pattern of extreme weather persists for some time, such as a season, it may be classified as an extreme climate event, especially if it yields an average or total that is itself extreme (for example, drought or heavy rainfall over a season).

**Extreme sea level (ESL)**

The occurrence of an exceptionally low or high local sea surface height, arising from (a combination of) short-term phenomena (e.g., storm surges, tides and waves). Relative sea level changes affect extreme sea levels directly by shifting the mean water levels and indirectly by modulating the propagation of tides, waves and/or surges due to increased water depth. In addition, extreme sea levels can be influenced by changes in the frequency, tracks or strength of weather systems and storms, or due to anthropogenically induced changes such as the modification of coastlines or dredging. In turn, changes in any or all of the contributions to extreme sea levels may lead to long-term relative sea level changes. Alternate expressions for ESL may be used depending on the processes resolved.

**Facilitated migration**

Regular migration that has been encouraged or supported by State policies and practices or by the direct assistance of international organisations to make the act of migration and residence easier, more transparent and more convenient.

**Food security**

A situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. The four pillars of food security are availability, access, utilisation and stability.

**Forced migration**

A migratory movement which, although the drivers can be diverse, involves force, compulsion, or coercion.

**Fossil fuels**

Carbon-based fuels from fossil hydrocarbon deposits, including coal, oil and natural gas.

**Gender**

The socially constructed roles and relationships, personality traits, attitudes, behaviours, values, relative power and influence that society ascribes to males and females on a differential basis. Gender is relational and refers not simply to women or men, but to the relationship between them.

**GEPIC**

The GIS-based Environmental Policy Integrated Climate crop model (see Appendix B).

**Global warming**

Global warming refers to the increase in global surface temperature relative to a baseline reference period, averaging over a period sufficient to remove interannual variations (e.g., 20 or 30 years). A common choice for the baseline is 1850–1900 (the earliest period of reliable observations with sufficient geographic coverage), with more modern baselines used depending upon the application.

**Governance**

The structures, processes and actions through which private and public actors interact to address societal goals. This includes formal and informal institutions and the associated norms, rules, laws and procedures for deciding, managing, implementing and monitoring policies and measures at any geographic or political scale, from global to local.

**Governance capacity**

The ability of governance institutions, leaders and non-state and civil society to plan, coordinate, fund, implement, evaluate and adjust policies and measures over the short, medium and long term, adjusting for uncertainty, rapid change and wide-ranging impacts and multiple actors and demands.

**Gravity model**

Model used to predict the degree of influence one place has on another based on the size of the population and its distance, similar to the law of gravity where attraction (pull) is a function of mass and distance. It assumes that places that are larger or spatially proximate will likely attract more population from a given location than places that are smaller and farther away. Furthermore, place attractiveness can be altered through the inclusion of factors that attract or repel populations.

**Greenhouse gases (GHG)**

Gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of radiation emitted by the Earth's ocean and land surface, by the atmosphere itself and by clouds. This property causes the greenhouse effect. Water vapour (H2O), carbon dioxide (CO2), nitrous oxide (N2O), methane (CH4) and ozone (O3) are the primary GHGs in the Earth's atmosphere. Human-made GHGs include sulphur hexafluoride (SF6), hydrofluorocarbons (HFCs), chlorofluorocarbons (CFCs) and perfluorocarbons (PFCs); several of these are also O3-depleting (and are regulated under the Montreal Protocol).

**HadGEM2-ES**

Climate model developed by the Met Office Hadley Centre for Climate Change in the United Kingdom (see Appendix B).

**Hazard**

The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.

**Heat stress**

A range of conditions in, for example, terrestrial or aquatic organisms when the body absorbs excess heat during overexposure to high air or water temperatures or thermal radiation. In aquatic water-breathing animals, hypoxia and acidification can exacerbate vulnerability to heat.

**Heatwave**

A period of abnormally hot weather, often defined with reference to a relative temperature threshold, lasting from two days to months. Heatwaves and warm spells have various and, in some cases, overlapping definitions.

**High Road scenario**

ACMI climate scenario blending SSP1 with RCP6.0 where emissions remain high, and the planet heats by at least 2°C by mid-century; Africa adopts inclusive development, has low population growth, high urbanisation, medium GDP, and high education.

**Human mobility**

A generic term covering all the different forms of movements of persons, including temporary or long-term, short- or long-distance, internal or international, voluntary or forced, and seasonal or permanent, as well as planned relocation. Human mobility in the context of climate change is used to describe such movements for reasons related to climate change impacts.

**Human rights**

Rights that are inherent to all human beings, universal, inalienable and indivisible, typically expressed and guaranteed by law. They include the right to life, economic, social and cultural rights, and the right to development and self-determination.

**Human security**

A condition that is met when the vital core of human lives is protected, and when people have the freedom and capacity to live with dignity. In the context of climate change, the vital core of human lives includes the universal and culturally specific, material and non-material elements necessary for people to act on behalf of their interests and to live with dignity.

**Immobility**
Inability to move or choice not to move away from a place of risk.

**Impacts**
The consequences of realised risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather/climate events), exposure, and vulnerability. Impacts generally refer to effects on lives, livelihoods, health and well-being, ecosystems and species, economic, social and cultural assets, services (including ecosystem services) and infrastructure. Impacts may be referred to as consequences or outcomes, and can be adverse or beneficial.

**Indigenous knowledge**
The understandings, skills and philosophies developed by societies with long histories of interaction with their natural surroundings. For many indigenous peoples, IK informs decision-making about fundamental aspects of life, from day-to-day activities to longer-term actions. This knowledge is integral to cultural complexes, which also encompass language, systems of classification, resource-use practices, social interactions, values, ritual and spirituality. These distinctive ways of knowing are important facets of the world's cultural diversity.

**Inequality**
Uneven opportunities and social positions, and processes of discrimination within a group or society, based on gender, class, ethnicity, age and (dis)ability, often produced by uneven development. Income inequality refers to gaps between the highest and lowest income earners within a country and between countries.

**Informal settlement**
A term given to settlements or residential areas that, by at least one criterion, fall outside official rules and regulations. Most informal settlements have poor housing (with widespread use of temporary materials) and are developed on land that is occupied illegally with high levels of overcrowding. In most such settlements, provision for safe water, sanitation, drainage, paved roads and basic services is inadequate or lacking. The term 'slum' is often used for informal settlements, although it is misleading as many informal settlements develop into good-quality residential areas, especially where governments support such development.

**Internal migration or mobility**
The movement of people within a State involving the establishment of a new temporary or permanent residence.

**Internally displaced persons**
Persons or groups of persons who have been forced or obliged to flee or to leave their homes or places of habitual residence, in particular as a result of, or in order to avoid, the effects of armed conflict, situations of generalised violence, violations of human rights or natural or human-made disasters, and who have not crossed an internationally recognised state border.

**International migration**
The movement of persons away from their place of usual residence and across an international border to a country of which they are not nationals.

**IPSL-CM5A-LR**
Climate model developed by the Institute Pierre Simon Laplace Climate Modeling Center in France (see Appendix B).

**Land degradation**
The deterioration or decline of the biological or economic productive capacity of the land.

**Landscape approach**
A framework that advances multiple land uses and management to ensure equitable and sustainable use of land.

**Loss and Damage, and losses and damages**
Loss and Damage (capitalised letters) to refer to political debate under the United Nations Framework Convention on Climate Change (UNFCCC) following the establishment of the Warsaw Mechanism on Loss and Damage in 2013, which is to 'address loss and damage associated with impacts of climate change, including extreme events and slow onset events, in developing countries that are particularly vulnerable to the adverse effects of climate change.' Lowercase letters (losses and damages) have been taken to refer broadly to harm from (observed) impacts and (projected) risks and can be economic or non-economic.

**LPJmL**
A global water and crop model designed by the Potsdam Institute

for Climate Impact Research to simulate vegetation composition and distribution as well as stocks and land-atmosphere exchange flows of carbon and water, for both natural and agricultural ecosystems (see appendix B).

**Maladaptive actions (Maladaptation)**

Actions that may lead to increased risk of adverse climate-related outcomes, including via increased greenhouse gas (GHG) emissions, increased or shifted vulnerability to climate change, more inequitable outcomes, or diminished welfare, now or in the future. Most often, maladaptation is an unintended consequence.

**Migrant**

Any person who is moving or has moved across an international border or within a state away from his/her habitual place of residence, regardless of (1) the person's legal status, (2) whether the movement is voluntary or involuntary, (3) what the causes for the movement are and (4) what the length of the stay is.

**Migration**

The movement of persons away from their place of usual residence, either across an international border or within a State.

**Migration cycle**

Stages of the migration process encompassing departure from, and in some cases transit through one or more cities or States, settlement in a place or State of destination and return.

**Migration governance**

The combined frameworks of legal norms, laws and regulations, policies and traditions as well as organisational structures (subnational, national, regional and international) and the relevant processes that shape and regulate States' approaches with regard to migration in all its forms, addressing rights and responsibilities and promoting international cooperation.

**Mitigation (of climate change)**

Human intervention to reduce the sources or enhance the sinks of greenhouse gases.

**Nationally Determined Contributions**

The non-binding national plans by each country to reduce national greenhouse gas emissions and adapt to the impacts of climate change enshrined in the Paris Agreement.

**Planned relocation**

In the context of disasters or environmental degradation, including when due to the effects of climate change, a planned process in which persons or groups of persons move or are assisted to move away from their homes or place of temporary residence, are settled in a new location, and provided with the conditions for rebuilding their lives.

**Poverty**

A complex concept with several definitions stemming from different schools of thought. It can refer to material circumstances (such as need, pattern of deprivation or limited resources), economic conditions (such as standard of living, inequality or economic position) and/or social relationships (such as social class, dependency, exclusion, lack of basic security or lack of entitlement).

**Poverty trap**

Poverty trap is understood differently across disciplines. In the social sciences, the concept, primarily employed at the individual, household or community level, describes a situation in which escaping poverty becomes impossible due to unproductive or inflexible resources. A poverty trap can also be seen as a critical minimum asset threshold, below which families are unable to successfully educate their children, build up their productive assets and get out of poverty. Extreme poverty is itself a poverty trap since poor persons lack the means to participate meaningfully in society. In economics, the term poverty trap is often used at national scales, referring to a self-perpetuating condition where an economy, caught in a vicious cycle, suffers from persistent underdevelopment. Many proposed models of poverty traps are found in the literature.

**Projection**

A potential future evolution of a quantity or set of quantities, often computed with the aid of a model. Unlike predictions, projections are conditional on assumptions concerning, for example, future socio-economic and technological developments that may or may not be realised.

**Protection**

All activities aimed at obtaining full respect for the rights of the individual in accordance with the letter and the spirit of the relevant bodies of law (i.e. Human Rights law, International Humanitarian Law, Refugee law).

**Protracted displacement**
A situation in which refugees, internally displaced persons (IDPs) and/or other displaced persons have been unable to return to their habitual residence for three years or more, and where the process for finding durable solutions, such as repatriation, integration in host communities, settlement in third locations or other mobility opportunities, has stalled.

**Rain-fed agriculture**
Agricultural practice relying almost entirely on rainfall as its source of water.

**Rapid-onset event**
Event such as cyclones and floods which take place in days or weeks (in contrast to slow-onset climate change that occurs over long periods of time).

**Representative Concentration Pathway (RCP)**
Trajectory of greenhouse gas concentration resulting from human activity corresponding to a specific level of radiative forcing in 2100. The low greenhouse gas concentration RCP2.6 and the high greenhouse gas concentration RCP6.0 employed in this report imply futures in which radiative forcing of 2.6 and 6.0 watts per square meter, respectively, are achieved by the end of the century.

**Resilience**
Capacity of interconnected social, economic, and environmental systems to cope with a hazardous event, trend, or disturbance by responding or reorganising in ways that maintain their essential function, identity, and structure while maintaining the capacity for adaptation, learning, and transformation.

**Risk**
The potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change as well as human responses to climate change.

**Risk perception**
The subjective judgement that people make about the characteristics and severity of a risk.

**Rocky Road scenario**
ACMI climate scenario blending SSP3 with RCP6.0 emissions remain high, and the planet heats by at least 2°C by mid-century; Africa sees low development progress, with low levels of cooperation, high population growth, low urbanisation, low GDP, and low education.

**Scenario**
A plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g., rate of technological change, prices) and relationships. Note that scenarios are neither predictions nor forecasts, but are used to provide a view of the implications of developments and actions.

**Sea-level rise**
Increases in the height of the sea with respect to a specific point on land. Eustatic sea level rise is an increase in global average sea level brought about by an increase in the volume of the ocean as a result of the melting of land-based glaciers and ice sheets. Steric sea-level rise is an increase in the height of the sea induced by changes in water density as a result of the heating of the ocean. Density changes induced by temperature changes only are called thermosteric; density changes induced by salinity changes are called halosteric.

**Settlements**
Places of concentrated human habitation. Settlements can range from isolated rural villages to urban regions with significant global influence. They can include formally planned and informal or illegal habitation and related infrastructure.

**Shared Socioeconomic Pathway (SSP)**
Scenarios, or plausible future worlds, that underpin climate change research and permits the integrated analysis of future climate change impacts, vulnerabilities, adaptation, and mitigation. SSPs can be categorised by the degree to which they represent challenges to mitigation (greenhouse gas emissions reductions) and societal adaptation to climate change. This report uses SSP1 ‘sustainability’ and SSP3 ‘inequitable’ growth’.

**Social inclusion**
The process of improving the terms of participation in society,

particularly for people who are disadvantaged, through enhancing opportunities, access to resources and respect for rights.

**Social protection**

In the context of development aid and climate policy, social protection usually describes public and private initiatives that provide income or consumption transfers to the poor, protect the vulnerable against livelihood risks and enhance the social status and rights of the marginalised, with the overall objective of reducing the economic and social vulnerability of poor, vulnerable and marginalised groups. In other contexts, social protection may be used synonymously with social policy and can be described as all public and private initiatives that provide access to services, such as health, education or housing, or income and consumption transfers to people. Social protection policies protect the poor and vulnerable against livelihood risks and enhance the social status and rights of the marginalised, as well as prevent vulnerable people from falling into poverty.

**Socio-economic scenario**

A scenario that describes a possible future in terms of population, gross domestic product (GDP), and other socio-economic factors relevant to understanding the implications of climate change.

**Slow-onset climate change**

Changes in climate parameters — such as temperature, precipitation, and associated impacts, such as water availability and crop productivity changes — that occur over long periods of time (in contrast to rapid-onset events, such as cyclones and floods, which take place in days or weeks).

**Storm surge**

The rise in seawater level during a storm, measured according to the height of the water above the normal predicted astronomical tide.

**Sustainable Development Goals (SDGs)**

The 17 global goals for development for all countries established by the United Nations through a participatory process and elaborated in the 2030 Agenda for Sustainable Development, including ending poverty and hunger; ensuring health and well-being, education, gender equality, clean water and energy, and decent work; building and ensuring resilient and sustainable infrastructure, cities and consumption; reducing inequalities; protecting land and water ecosystems; promoting peace, justice and partnerships; and taking urgent action on climate change. See also Development pathways and Sustainable development.

**Sustainable livelihood**

Livelihood that endures over time and is resilient to the impacts of various types of shocks including climatic and economic.

**Sustainability**

Involves ensuring the persistence of natural and human systems, implying the continuous functioning of ecosystems, the conservation of high biodiversity, the recycling of natural resources and, in the human sector, successful application of justice and equity.

**Trapped populations**

People unable to move away from locations in which they are extremely vulnerable to environmental shocks and impacts.

**Tropical cyclone**

The general term for a strong, cyclonic-scale disturbance that originates over tropical oceans. Distinguished from weaker systems (often named tropical disturbances or depressions) by exceeding a threshold wind speed.

**United Nations Framework Convention on Climate Change (UNFCCC)**

The UNFCCC was adopted in May 1992 and opened for signature at the 1992 Earth Summit in Rio de Janeiro. It entered into force in March 1994 and as of May 2018 had 197 Parties (196 States and the European Union). The Convention's ultimate objective is the 'stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system'. The provisions of the Convention are pursued and implemented by two treaties: the Kyoto Protocol and the Paris Agreement.

**Urban**

The categorisation of areas as 'urban' by government statistical departments is generally based either on population size, population density, economic base, provision of services, or some combination of the above. Urban systems are networks and nodes of intensive interaction and exchange including capital, culture, and material objects. Urban areas exist on a continuum with rural areas and tend to exhibit higher levels of complexity, higher populations and population density, intensity of capital investment, and a preponderance of secondary (processing) and tertiary (service) sector industries. The extent and intensity of these features varies significantly within and between urban areas. Urban places and systems are open, with much movement and exchange between more rural areas as well as other urban regions.

**Urbanisation**

Urbanisation is a multi-dimensional process that involves at least three simultaneous changes: (1) land-use change: transformation of formerly rural settlements or natural land into urban settlements, (2) demographic change: a shift in the spatial distribution of a population from rural to urban areas and (3) infrastructure change: an increase in provision of infrastructure services including electricity, sanitation, etc. Urbanisation often includes changes in lifestyle, culture and behaviour, and thus alters the demographic, economic and social structure of both urban and rural areas.

**Vulnerability**

Propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

**Water availability**

The water sector model outputs in this report represent river discharge, measured in cubic meters per second in daily/monthly time increments.

**WaterGAP2**

The Water Global Assessment and Prognosis (WaterGAP) version 2 global water model developed by the University of Kassel in Germany (see Appendix B).

**Wellbeing**

A state of existence that fulfils various human needs, including material living conditions and quality of life, as well as the ability to pursue one's goals, to thrive and to feel satisfied with one's life. Ecosystem well-being refers to the ability of ecosystems to maintain their diversity and quality.

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# AFRICAN SHIFTS

## The Africa Climate Mobility Report: Addressing Climate-Forced Migration & Displacement

Global Centre for Climate Mobility

Africa Climate Mobility Initiative
Shaping the future of mobility

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