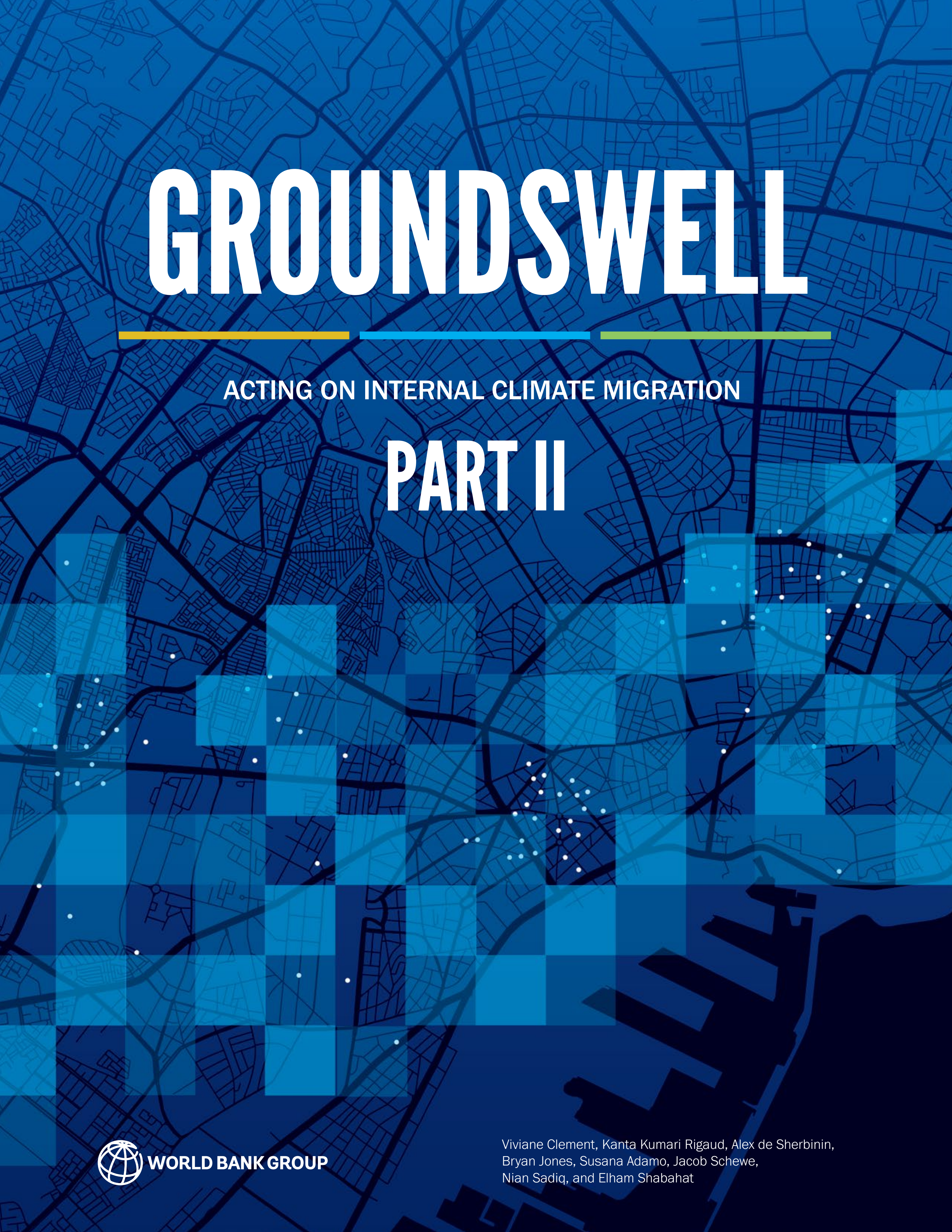

GROUNDSWELL

ACTING ON INTERNAL CLIMATE MIGRATION

PART II

WORLD BANK GROUP

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GROUNDSWELL

ACTING ON INTERNAL CLIMATE MIGRATION

PART II

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Glossary

Adaptation: Process of adjustment to actual or expected climate change and its effects. In human systems, adaptation seeks to moderate or avoid harm or 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.

Anthropogenic biome: Anthropogenic biomes describe the terrestrial biosphere in its contemporary, human-altered form using global ecosystem units defined by patterns of sustained direct human interactions, for example, rainfed croplands.

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.

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 tundra; see also anthropogenic biome).

Climate change: A change in the state of the climate that can be identified (for example, using statistical tests) 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-driven migration: In this report, refers to migration that can be attributed largely to the slow-onset impacts of climate change on livelihoods owing to shifts in water availability and crop productivity, or to factors such as sea-level rise or storm surge.

Climate in-migration hotspot: For the purposes of this study, climate in-migration hotspots are areas that will see increases in population in scenarios that take into account climate change impacts relative to a population projection that does not take climate change impacts into account. These increases can be attributed to in-migration, the "fast" demographic variable. Areas were considered to have increases in population when at least two of the three scenarios modelled had increases in population density in the highest 10th percentile of the distribution.

Climate out-migration hotspot: For the purposes of this study, climate out-migration hotspots are areas that will see decreases in population in scenarios that take into account climate change impacts relative to a population projection that does not take climate change impacts into account. These decreases can be attributed to out-migration, the "fast" demographic variable. Areas were considered to have decreases in population when at least two of the three scenarios modelled had decreases in population density in the highest 10th percentile of the distribution.

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.

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 10 kilometers of the coastline.

Coping capacity: The ability of people, organizations, and systems to face and manage adverse conditions in the short to medium term.

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

Demographic dividend: The potential for economic growth made possible from shifts in a population's age structure.

Displacement: Forced removal of people or people obliged to flee from their places of habitual residence.

Distress migration: Movements from the usual place of residence, undertaken when an individual and/or their family perceive that there are no options open to them to survive with dignity, except to migrate. This may be a result of a slow-onset climate change, rapid-onset events, other disasters, conflict events, or a succession/combination of such events, that result in the loss of assets and coping capacity.

Environmental mobility: Temporary or permanent mobility as a result of sudden or progressive changes in the environment that adversely affect living conditions, either within countries or across borders. In practice, mobility is usually multicausal, and direct linkages between environmental factors and mobility are often difficult to single out; however, evidence of those linkages is growing, and understanding of the complexities is improving.

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).

Forced migration: Migratory movement in which an element of coercion exists, including threats to life and livelihood, whether arising from natural or man-made causes (for example, movements of refugees and internally displaced persons as well as people displaced by natural or environmental disasters, chemical or nuclear disasters, famine, or development projects). Forced migration generally implies a lack of volition concerning the decision to move, though in reality motives may be mixed, and the decision to move may include some degree of personal agency or volition.

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

Gravity model: Model used to predict the degree of interaction between two places and the degree of influence a place has on the propensity of a population in other locations to move to it. It assumes that places that are larger or spatially proximate will exert more influence on the population of a location than places that are smaller and farther away.

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.

Human mobility: Movement of people, 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 (see also environmental mobility).

Immobility: Inability to move from a place of risk or not moving away from a place of risk due to choice.

Internal climate migrant (migration) (shorthand climate migrant): In this report, internal climate migrants are people who move—within countries—because of climate-driven migration (see above). The modeling work captures people who move in a country at spatial scales of over 14 kilometers and at decadal temporal scales. Shorter distance or shorter-term mobility (such as seasonal or cyclical migration) is not captured.

Internal migration (migrant): Internal migration is migration that occurs within national borders.

International or cross-border migration (migrant): Migration that occurs across national borders.

IPSL-CM5A-LR: Climate model developed by the Institut Pierre Simon Laplace Climate Modeling Center in France (see Appendix B).

Irregular migration: Movement of persons that takes place outside regular and formalized migration channels, such as movement outside the laws, regulations, or international agreements governing the entry into or exit from the state of origin, transit or destination.

Labor mobility: The geographical and occupational movement of workers.

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.

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).

Migration: Movement that requires a change in the place of usual residence and that is longer term. In demographic research and official statistics, it involves crossing a recognized political/administrative border.

Migration cycle: The three stages of the migration process—before, during, and after moving— which can be leveraged for adaptation i.e., adapting in place; enabling mobility; and preparing sending and receiving areas.

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.

Other internal migrant: In this report, the term other internal migrant is used in reference to migrants who move within countries largely for reasons other than climate change impacts.

Planned relocation: The movement of people, typically in groups or whole communities, as part of a process led by the state or other organization, to a predefined location, often away from areas of environmental risks.

Radiative forcing: Measurement of capacity of a gas or other forcing agent to affect the energy balance, thereby contributing to climate change.

Rainfed 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 RCP8.5 employed in this report imply futures in which radiative forcing of 2.6 and 8.5 watts per square meter, respectively, are achieved by the end of the century.

Resilience: Capacity of social, economic, and environmental systems to cope with a hazardous event, trend, or disturbance by responding or reorganizing in ways that maintain their essential function, identity, and structure while maintaining the capacity for adaptation, learning, and transformation.

Salinization: The accumulation of water-soluble salts in the soil that can lead to substantial negative impacts on plant productivity and water quality.

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.

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 categorized by the degree to which they represent challenges to mitigation (greenhouse gas emissions reductions) and societal adaptation to 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 livelihood: Livelihood that endures over time and is resilient to the impacts of various types of shocks including climatic and economic.

System dynamics model: A model which decomposes a complex social or behavioral system into its constituent components and then integrates them into a whole that can be easily visualized and simulated.

Trapped populations: People unable to move away from locations in which they are extremely vulnerable to environmental change.

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).

Wet bulb temperature: An indicator of dangerous heat-humidity combination defined as the temperature that an air parcel would reach through evaporative cooling once fully saturated. When the outside wet bulb temperature exceeds the body skin temperature, about 35 °C, evaporative cooling will be significantly less effective, and the body will likely accumulate heat.

Abbreviations

AOSIS	Alliance of Small Island States
AR5	Fifth Assessment Report by the Intergovernmental Panel on Climate Change
ASEAN	Association of Southeast Asian Nations
CIESIN	Center for International Earth Science Information Network of Columbia University
COP	Conference of Parties (of the UNFCCC)
ENSO	El Niño Southern Oscillation
FAO	Food and Agriculture Organization
FDRP	Framework for Resilient Development in the Pacific
GCM	global climate model
GDP	Gross domestic product
GHG	greenhouse gas
GRID	Green, Resilient, and Inclusive Development
HDI	human development index
ITCZ	Intertropical Convergence Zone
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
NAPA	National Adaptation Programme of Action
NCAR-CIDR	National Center for Atmospheric Research-CUNY Institute for Demographic Research
NDC	Nationally Determined Contribution
OECS	Organization of Eastern Caribbean States
PIK	Potsdam Institute for Climate Impact Research
RCP	Representative Concentration Pathway
SIDS	Small Island Developing States
SSP	Shared Socioeconomic Pathway
UN	United Nations
UN DESA	United Nations Department of Economic and Social Affairs
UNFCCC	United Nations Framework Convention on Climate Change
WMO	World Meteorological Organization

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GROUNDSWELL

By 2050—without concrete climate and development action—climate change could lead more than

216 MILLION PEOPLE

in 6 regions to migrate within their own countries

Hotspots of internal climate migration will intensify in rural, urban, and coastal systems

People will migrate due to slow-onset climate change impacts—those included in the model are:

- Water scarcity
- Lower crop productivity
- Sea level rise and storm surge

Some places may become less livable—factors examined include:

- Heat stress
- Extreme events
- Land loss

People in the Middle East and Small Island Developing States (SIDS) will also be affected by climate-driven migration

TAKING ACTION ON INTERNAL CLIMATE MIGRATION

The number of people forced to move because of climate change could be reduced by as much as 80 percent...

80%

IF WE ACT NOW TO:

CUT GLOBAL GREENHOUSE GASES

to reduce the climate pressures that drive climate migration

INTEGRATE CLIMATE MIGRATION

into far-sighted green, resilient and inclusive development planning

PLAN FOR EACH PHASE

of migration — before, during and after — to ensure positive adaptation and development outcomes

INVEST IN UNDERSTANDING THE DRIVERS

of climate migration through evidence-based research, models, and consultations, to inform policy response

Foreword

Juergen Voegele
Vice President for Sustainable Development, World Bank

Three years ago, the World Bank's first *Groundswell* report projected that, by 2050, climate change could lead 143 million people in three regions of the world (South Asia, Latin America and Sub-Saharan Africa) to migrate within their own countries. Since then, the world has been hit by the COVID-19 pandemic and a reversal of decades-long progress reducing poverty. At the same time, the impacts of climate change are increasingly visible. We have just lived through the warmest decade on record and are seeing extreme weather events around the world, with changes in the Earth's climate occurring in every region and across the whole climate system.

The new *Groundswell* report builds on the work of the first, modeling three additional regions, namely East Asia and the Pacific, North Africa, and Eastern Europe and Central Asia—to provide a global estimate of up to 216 million climate migrants by 2050 across all six regions. It's important to note that this projection is not cast in stone. If countries start now to reduce greenhouse gases, close development gaps, restore vital ecosystems, and help people adapt, internal climate migration could be reduced by up to 80 percent—to 44 million people by 2050.

Without these actions, the report predicts that "hotspots" of climate migration will emerge as soon as within the next decade and intensify by 2050, as people leave places that can no longer sustain them and go to areas that offer opportunity. For instance, people are increasingly moving to cities, and we find that climate-related challenges such as water scarcity, declining crop productivity, and sea-level rise play a role in this migration. Even places which could become hotspots of climate out-migration because of increased impacts will likely still support large numbers of people. Meanwhile, receiving areas are often ill-prepared to receive additional internal climate migrants and provide them with basic services or use their skills.

The trajectory of internal climate migration in the next half-century depends on our collective action on climate change and development in the next few years. What will it take to slow it? First and foremost, early action to reduce greenhouse gas emissions to reduce the climate pressures that drive internal climate migration. This must be a global effort and it must happen now.

At the same time, it will be important to recognize that not all migration can be prevented and that, if well managed, shifts in population distribution can become part of an effective adaptation strategy, allowing people to rise out of poverty and build resilient livelihoods. Countries can start planning today for orderly and well-managed internal climate migration. This report lays out how this can be supported, including by embedding climate migration in development planning and better understanding the factors that drive it in order to craft well-targeted policies. It will also entail planning for each phase of migration—before, during, and after moving—according to the different needs of communities and countries.

Development that is green, resilient, and inclusive can slow the pace of distress-driven internal climate migration. This report is a timely call for urgent action at the intersection of climate, migration, and development.

J. Vogle

Overview

Climate change is an increasingly potent driver of migration. This report, which builds on the 2018 *Groundswell* report, presents new regional analyses that reaffirm how climate-driven internal migration could escalate in the next three decades. Looking at slow-onset climate change impacts on water availability and crop productivity, plus sea-level rise, it highlights the urgency for action as livelihoods and human well-being are placed under increasing strain.

Internal climate migration is set to increase across regions and countries. Climate change impacts will hit the poorest and most vulnerable regions the hardest and threaten to reverse development gains. In some places, questions of habitability will arise. Exploring future scenarios and identifying patterns of potential "hotspots" for both in- and out-migration are key steps to better understand the nexus of climate, migration, and development.

The trajectory of internal climate migration in the next half-century depends on our collective action on climate and development in the next few years. The window to avert the conditions that lead to distress-driven internal climate migration is shrinking rapidly. Countries must come together and act decisively both to ensure that development is green, resilient, and inclusive, and to sharply reduce global emissions, consistent with the Paris Agreement.

It is also crucial to begin planning for orderly and well-managed internal climate migration where appropriate, so it can serve as an effective adaptation strategy with positive development outcomes. Action now at the intersection of climate, development, and migration is critical to safeguard the achievement of the Sustainable Development Goals over the next 10 years and ensure shared prosperity to mid-century and beyond.

THE GROUNDSWELL REPORT SERIES: BRIDGING THE GAP

There is an urgent need to better understand how escalating climate change impacts may affect internal migration patterns in the coming decades—to drive better informed and evidenced-based policy and planning. Governments and development partners can no longer assume that population distribution, development trends, and livelihoods in rural and urban systems will remain unchanged in the face of climate change.

The first *Groundswell* report, published in 2018, used a robust and novel modeling approach to help understand the scale, trajectory, and spatial patterns of future climate migration within countries, with a focus on three regions: Sub-Saharan Africa, South Asia, and Latin America. Specifically, it examined how slow-onset climate change impacts on water availability and crop productivity, and sea-level rise augmented by storm surge, could affect future internal migration, modeling three plausible scenarios. The report, which included subregional analyses and country case studies, aimed to inform policy dialogue and foster proactive solutions.

This second *Groundswell* report builds on that work, applying the same approach to three new regions: the Middle East and North Africa, East Asia and the Pacific, and Eastern Europe and Central Asia. Qualitative analyses of climate-related mobility in countries of the Mashreq and in Small Island Developing States (SIDS) are also provided.

The two reports' combined findings provide, for the first time, a global picture of the potential scale of internal climate migration across the six World Bank regions, allowing for a better understanding of how projected climate change impacts, population dynamics, and development contexts shape mobility trends. They also highlight the far-sighted planning needed to meet this challenge and ensure positive and sustainable development outcomes.

Both *Groundswell* reports use the same modeling approach, which allows for direct comparison of results and for aggregation to derive the global figure for internal climate migration. They take a scenario-based approach and implement a modified form of a gravity model to isolate the projected portion of future changes in spatial population distribution that can be attributed to slow-onset climate factors up to 2050. The Spotlight discusses the key innovations and scope of the modeling approach.

Spotlight: Key Features of the *Groundswell* Modeling Approach

Modeling at scale: The gravity model used in the report illuminates the relative importance of push factors (environmental or economic factors at origin that influence the decision to migrate) versus pull factors (similar factors at destination that influence the decision to migrate) over larger geographic areas. Modeling the attractiveness of locations in terms of economic or demographic characteristics, expressed as an agglomeration effect and influenced by environmental conditions, fits with existing theory. While the model does not focus on individual reasons for migration, it provides compelling information on patterns and trends to inform policy dialogue and action. To enable comparisons across countries and regions, select global datasets and scenario pathways, including spatially and temporally consistent sectoral impact datasets, were used as model inputs.

Calibration, simulation, and visualization: The model was calibrated in two periods, 1990–2000 and 2000–2010, using historical climate change impacts and population distribution data to demonstrate that populations are already sensitive to climate change impacts and assess how this sensitivity could affect population distribution in the coming decades. The projection simulations were then done in decadal steps from 2020 to 2050. Applied at the level of 14-kilometer grid cells and aggregated upward to national and regional levels, the datasets allow for the visualization of hotspots of climate in- and out-migration. The full methodology, sources of uncertainty, and possibilities for expanding the scope of the work are laid out in Appendices B and C of this report.

Spotlight: Key Features of the *Groundswell* Modeling Approach (cont.)

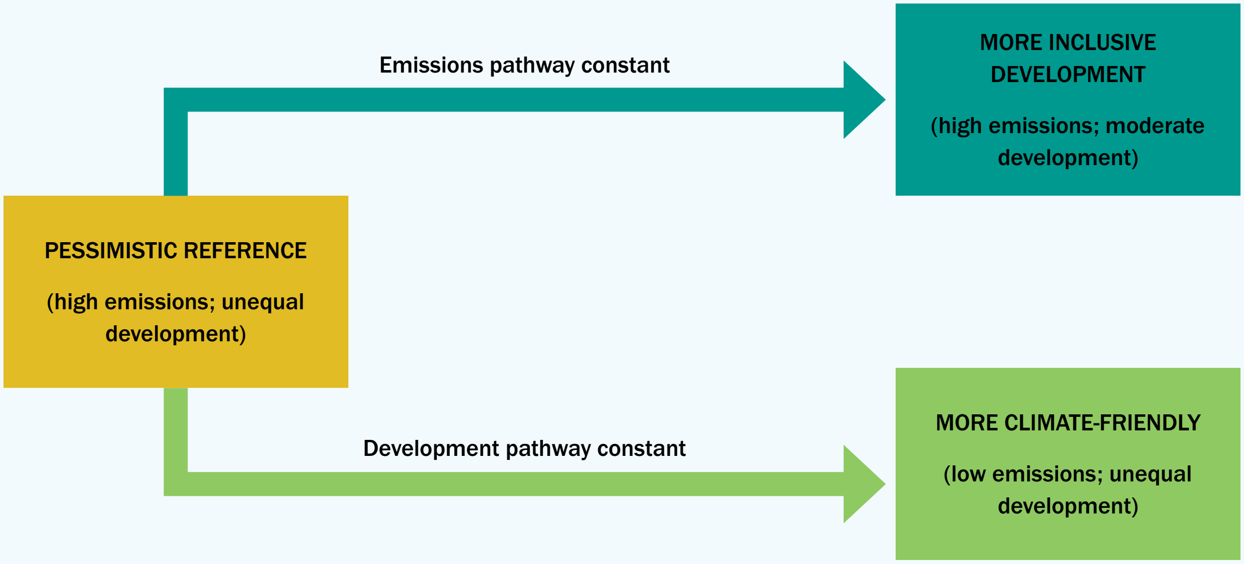
Slow-onset climate change impacts: Rather than using simple future projections for precipitation and temperature, the model uses the Inter-Sectoral Impact Model Inter-comparison Project (ISIMIP) global crop and water simulations. These represent a database of state-of-the-art model simulations of biophysical climate change impacts that are directly relevant to livelihoods and development outcomes. They offer a framework for consistently projecting the impacts of climate change across affected sectors and spatial scales. Additionally, sea-level rise, augmented by storm surge, is included as a spatial mask, reflecting expected loss of habitability in areas likely to be inundated.

A scenario-based approach: Future migration dynamics will be driven by several factors with varying degrees of uncertainty, from changes to local climate conditions to evolving political changes, social norms, or technologies. To manage this uncertainty, the report uses a scenario-based approach, which helps to explore potential futures and plan for different possible outcomes. Three internal climate migration scenarios are developed—pessimistic reference, more inclusive development, and more climate-friendly—with different combinations of development (Shared Socioeconomic Pathways) and emissions (Representative Concentration Pathways) trajectories, based on modeled inputs (see Figure 1). The range of internal climate migration within and across scenarios provide insights on how both climate- and development-related factors could affect internal climate migration over the coming decades.

Regional and country applications: Beyond the upward aggregation of internal climate migration in the regions of focus, deeper analysis is undertaken for selected subregions and individual countries. These provide valuable context for plausible internal climate migration patterns under contrasting demographic and economic profiles, vulnerability to climate risk, and past migration trends, to inform policy and planning.

Scope of the modeling approach: The modeling focuses on *internal* climate migration as the great majority of migrants do not cross borders, but rather move within their own countries, and a better understanding of this form of mobility is needed and warranted. Other forms of mobility including cross-border migration, displacement, and planned relocation, as well as immobility, are therefore not included. The modeling also focuses on *long-term* migration or shifts in population and does not reflect shorter-term, seasonal, or cyclical migrations. Moreover, it focuses mainly on the effect of *slow-onset* climate change impacts on livelihoods, through shifts in water availability and crop productivity, as well as sea-level rise augmented by storm surge. The model therefore does not reflect rapid-onset climate change impacts, such as short-term climate variations and extreme weather events, except where successive shocks accumulate over multiple years. Different forms of mobility and climate change impacts are all important for development policy and planning, and are discussed as appropriate in the report.

Figure 1: Projecting internal climate migration in three scenarios



Note:
1. The scenarios are based on combinations of two Shared Socioeconomic Pathways—SSP2 (moderate development) and SSP4 (unequal development)—and two Reprecentative Concentraion PAthways –RCP 2.6 (low emissions) and RCP 8.5 (high emissions).
2. Estimates of climate migrants are derived by comparing these plausible climate migration (RCP-SSP) scenarios with development only (SSP) or the "no climate impact" scenarios.

KEY FINDINGS

1. Internal climate migration is set to accelerate to 2050 across six regions, hitting the poorest and most vulnerable the hardest and threatening development gains.

The combined results of the two *Groundswell* reports show that by 2050, as many as 216 million people could be internal climate migrants across the six World Bank regions (at the high end of the pessimistic reference scenario), as shown in Figure 2. This represents almost 3 percent of these regions' total projected population.[1] Sub-Saharan Africa could see as many as 85.7 million internal climate migrants (4.2 percent of the total population); East Asia and the Pacific, 48.4 million (2.5 percent of the total population); South Asia, 40.5 million (1.8 percent of the total population); North Africa, 19.3 million (9.0 percent of the total population); Latin America, 17.1 million (2.6 percent of the total population); and Eastern Europe and Central Asia, 5.1 million (2.3 percent of the total population).

The scale of internal climate migration will be largest in the poorest and most climate-vulnerable regions, an indication that underlying gaps in the ability of livelihood, social, and economic systems to cope with climate change could undermine development gains. Of the six regions examined in the two reports, Sub-Saharan Africa is projected to have the largest number of internal climate migrants. The region is highly vulnerable to climate change impacts, especially in already fragile drylands and along exposed coastlines. Agriculture, which is almost all rainfed in the region, also accounts for a large share of employment. North Africa is projected to have the largest share of internal climate migrants relative to total population. This is due to a great extent to severe water scarcity, as well as the impacts of sea-level rise on densely populated coastal areas and in the Nile Delta. Within regions, there are particularly vulnerable countries that drive up the overall numbers. For example, as shown in the first *Groundswell* report, Bangladesh, with up to 19.9 million internal climate migrants by 2050, has almost half the projected internal climate migrants for the entire South Asia region.

It is important to note that the estimates presented in this report are likely to be conservative for several reasons. The analysis focuses on migration driven by slow-onset climate change impacts acting through water availability, crop productivity, and sea-level rise augmented by storm surge. It also only estimates climate migration within countries and does not consider other forms of mobility. Moreover, although the two reports combined model all six World Bank regions, they do not cover most high-income countries, including in Europe and North America. The estimates also exclude the Middle East and Small Island Developing States (SIDS), which could not be modeled using the established methodology.

These projections should impart a sense of urgency for early action. Climate change could shift social, economic, and livelihood circumstances in ways that may force people to migrate in distress. This could place significant pressures on both sending and receiving areas, if left unplanned. Countries that have made important development gains may see their progress threatened, and some could face existential challenges related to habitability. Compounding shocks, including conflicts, situations of fragility, and health and economic crises, also impact decisions to move, while simultaneously reducing the capacity to cope, adapt, and rebound. Conversely, if well managed, internal climate migration and associated shifts in population distribution can become part of an effective adaptation strategy, allowing people to rise out of poverty, build resilient livelihoods, and improve their living conditions.

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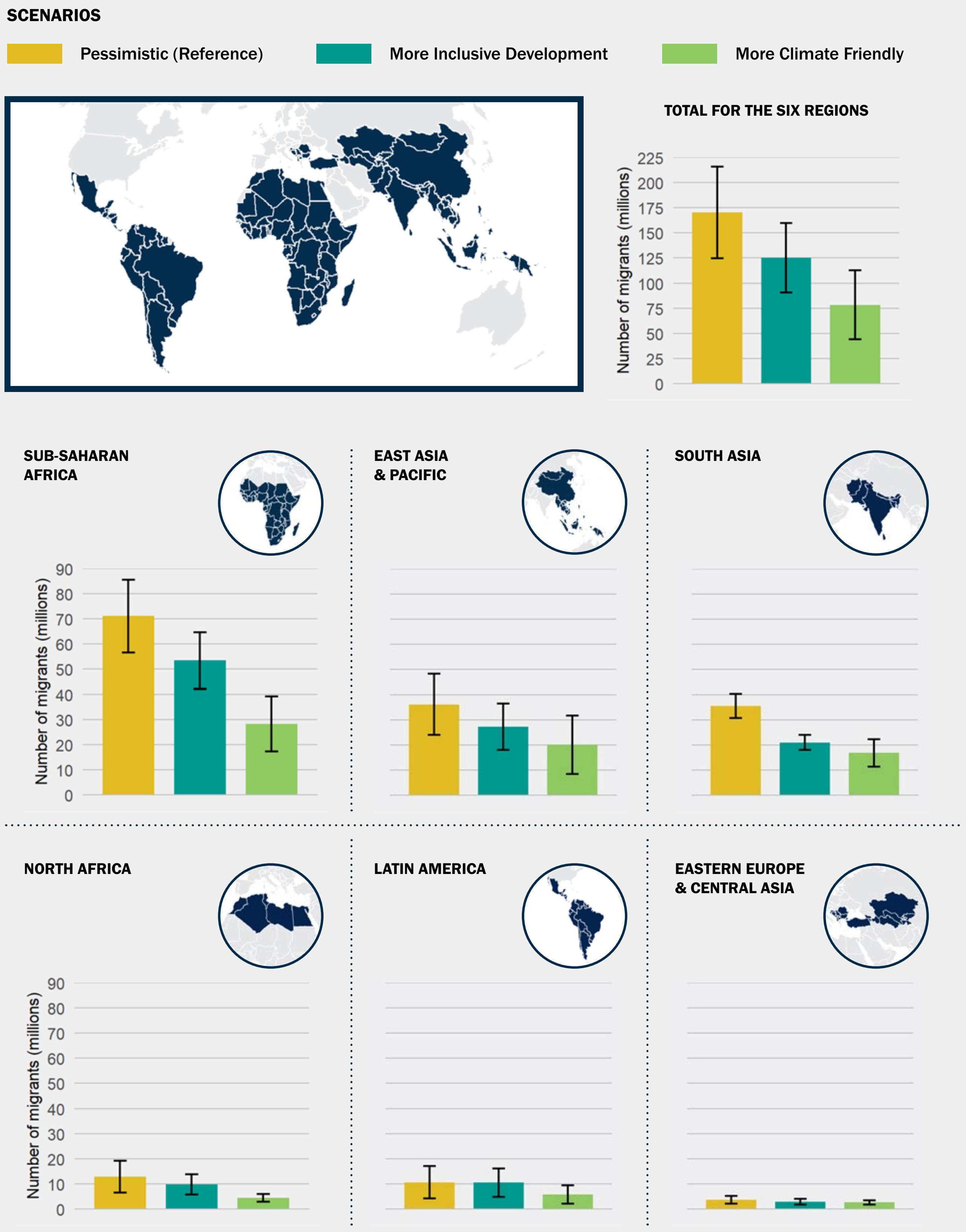
[1] The report includes modeling for a total of 106 countries across the six World Bank regions.

Figure 2: Projected number of internal climate migrants across six regions, in three scenarios, by 2050



2. Hotspots of internal climate in- and out-migration emerge as early as 2030 and grow and intensify by 2050, highlighting the need to integrate plausible migration scenarios in spatial development.

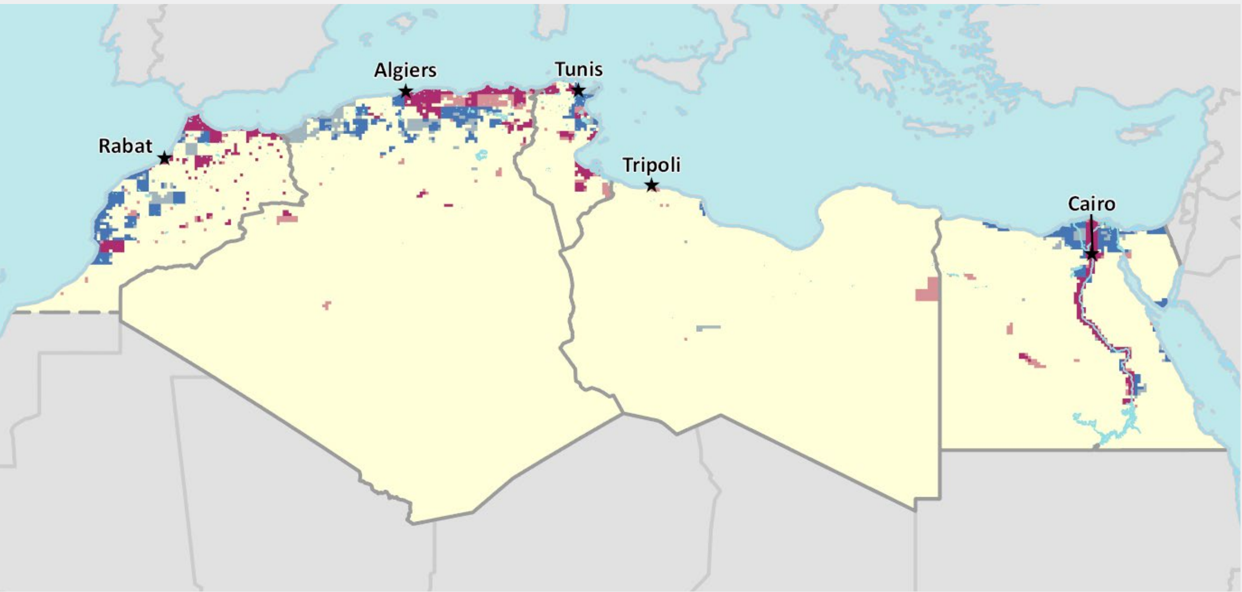
The model results show clear spatial patterns of internal climate in- and out-migration within each country and region—including hotspots that emerge as early as 2030 and are considerably more pronounced by 2050. Climate change impacts are already unfolding and are set to alter the attractiveness of livelihood and resource conditions in rural, coastal, and urban systems across regions. As a result, many countries could see shifts in population distribution, on top of already complex mobility dynamics. Development planning needs to be proactive in preparing in-migration hotspots for inflows of migrants, to ensure they are prepared to fully integrate them, while out-migration hotspots need to plan for options to adapt in place and build resilience for the populations who remain.

In North Africa, the model results show changes in water availability as a main driver of internal climate migration. They push people out of coastal and inland areas where water is becoming scarcer, slowing population growth in climate out-migration hotspots along the northeastern coast of Tunisia, the northwestern coast of Algeria, western and southern Morocco, and the already water-stressed central Atlas foothills (see Figure 3). In Egypt, the eastern and western portions of the Nile Delta, including Alexandria, could become out-migration hotspots due to both declining water availability and sea-level rise. Several places with better water availability, meanwhile, are projected to become climate in-migration hotspots, including important urban centers such as Cairo, Algiers, Tunis, Tripoli, the Casablanca-Rabat corridor, and Tangiers.

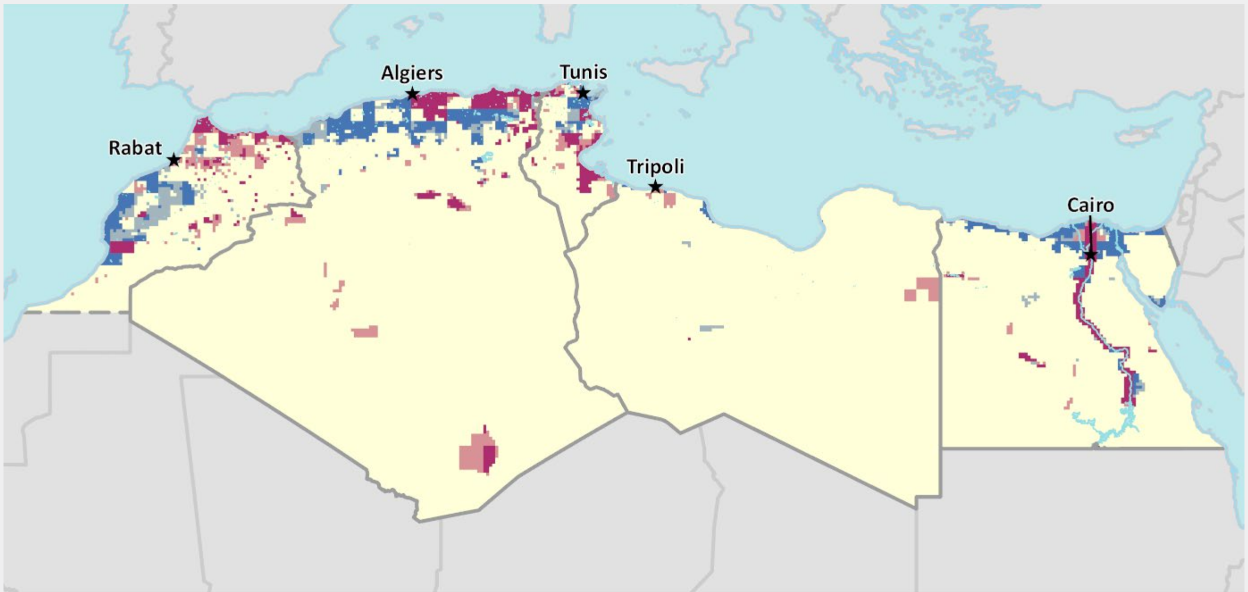
Photo Credit: World Bank

Figure 3: Areas projected to have high climate in-migration and out-migration in North Africa, 2030 and 2050

a. 2030



b. 2050



IN-MIGRATION

- 🟥 High certainty in high levels of climate in-migration
- 🟥 Moderate certainty in high levels of climate in-migration

OUT-MIGRATION

- 🟦 High certainty in high levels of climate out-migration
- 🟦 Moderate certainty in high levels of climate out-migration

Note: High certainty reflects agreement across all three scenarios modeled, and moderate certainty reflects agreement across two scenarios.

In the Lower Mekong subregion, sea-level rise, augmented by storm surge, is projected to create climate out-migration hotspots in some densely populated, low-lying coastal regions—such as the Mekong Delta in Vietnam. Sea-level rise and related impacts there pose threats to key livelihoods, including rice production, aquaculture, and fisheries. Climate in-migration hotspots are projected to emerge in areas where the population is already growing, such as the Red River Delta and the coastal central region of Vietnam. Both may see more favorable water availability and crop productivity conditions, but they are also very vulnerable to increasingly frequent and severe tropical storms. Out-migration hotspots in agricultural areas of central Thailand and Myanmar coincide with areas expected to see declines in both water availability and crop productivity, while in-migration hotspots to the southeast of Phnom Penh in Cambodia along the Mekong River and southern Myanmar are expected to see increases in both factors.

In Central Asia, both water availability and crop productivity increases are projected to create climate in-migration hotspots in already densely populated and economically productive areas, such as the Ferghana Valley, and also drive migrants into new areas of potential livelihood opportunities, such as northern Kazakhstan. These projections do not take into account impacts from glacial melt, which could decrease water flows in the subregion's major rivers in the long run, potentially leading migrants to be attracted elsewhere. In the Kyrgyz Republic, reduced water availability is expected to create climate out-migration hotspots in important agricultural and pastoral areas in the northern, central, and southwestern regions, which are already seeing rural-urban migration, particularly from mountainous areas.

In many places, internal climate migration will amplify patterns of mobility that are already unfolding. The regional and country-level analyses in this report highlight the importance of tailoring approaches to the different needs, risks, and opportunities identified in emerging hotspots of climate in- and out-migration. Notably, many out-migration hotspots are economic and population growth centers that will continue to support large numbers of people despite increasing climate change impacts. This includes the Mekong Delta in Vietnam, where those who remain will face significant social, economic, and environmental risks, including from severe floods. Many in-migration hotspots also face escalating risks from both rapid-onset and slow-onset climate change impacts, even if water availability and crop productivity become more favorable. In Morocco, for example, the Tingitana Peninsula and eastern coast are expected to attract growing numbers of migrants due to better water availability, but they face sea-level rise and storm surge risks. Some oasis settlements, including Tamanrasset in southern Algeria, could see in-migration due to relative increases in crop productivity and water availability, but these are very arid areas that may have limited capacity to accommodate additional agricultural activity.

In some places, severe climate change impacts threaten habitability. In the Mashreq countries, for instance, the number of days with temperatures that exceed thresholds of human tolerance is projected to increase in several major and growing urban areas, including Amman, Aden, and Baghdad, as well as in coastal regions including southern Yemen, countries on the eastern Mediterranean, the southern coast of Iran, and the southernmost part of Iraq. Heat stress could also affect the continuity of agricultural livelihoods. Such environmental thresholds could increasingly act as push factors for migration. In many SIDS, meanwhile, sea-level rise is shrinking the available land area, while exposure to extreme weather events and the deterioration of key ecosystems and livelihood systems are raising questions about long-term habitability.

3. Early action both to cut global greenhouse gas emissions and to ensure inclusive and resilient development is essential, and can reduce the scale of internal climate migration by as much as 60–80 percent.

Global action to reduce greenhouse gas emissions could dramatically slow the rise in internal climate migration. In the more climate-friendly scenario in this report, the number of internal climate migrants would be as much as 80 percent lower by 2050 across the six regions (44 million people at the low end of the more climate-friendly scenario, compared with 216 million at the high end of the pessimistic reference scenario). The differences are particularly stark in regions with large populations in climate vulnerable areas and climate-sensitive livelihoods: Sub-Saharan Africa, East Asia and the Pacific, South Asia, and North Africa.

In the other two regions, the difference between the pessimistic reference and more-climate friendly scenarios are smaller. Latin America for instance, hosts middle-income countries with diversified economies and highly urban populations, many of which have already experienced their demographic transitions. Stronger economies can mean greater adaptive capacity and financial resources to support the most vulnerable areas and groups. In Eastern Europe and Central Asia, countries are generally less dependent on agriculture, and mobility is more heavily influenced by historical and other non-environmental factors. Still, reducing global emissions is critical to mitigating climate change impacts on vulnerable areas and livelihoods, particularly where these coincide with pockets of poverty.

Inclusive and resilient development trajectories are also central to reducing the scale of internal climate migration. In the more inclusive development scenario, this scale is reduced by up to 60 percent (91 million people at the low end of the more inclusive development scenario, compared with 216 million at the high end of the pessimistic reference scenario). This reduction is particularly evident in regions that host low- and middle-income countries, especially those with rapid demographic growth and large numbers of young people, such as Sub-Saharan Africa, South Asia, and North Africa.

The future scale, trend, and spatial patterns of internal climate migration will depend on our level of collective climate and development action now in this pivotal decade.

Photo Credit: World Bank

POLICY RECOMMENDATIONS

The first *Groundswell* report identified key policy recommendations to address the underlying drivers of internal climate migration and prepare for expected migration flows. The findings presented in this second report emphasize the importance and urgency of these actions—particularly in this pivotal decade.

1. Cut global greenhouse gases now to reduce the climate pressures that drive internal climate migration.

Managing the scale of internal climate migration will require immediate collective action to get on lower global greenhouse gas emission trajectories with differentiated strategies across regions and countries. Five years after the Paris Agreement, the world is still headed for at least 3°C of warming by 2100. Ambitious action to curb global emissions is critical to reducing the burden of climate change impacts on key resources, livelihood systems, and urban centers that may drive people to migrate in distress.

In the lead-up to COP26 in Glasgow, countries are updating and enhancing their commitments under the Paris Agreement. This is a critical opportunity to ratchet up ambition to put the world on track for net-zero emissions by mid-century and have a chance at limiting global warming to 1.5°C. Adhering to the Paris Agreement, and staying close to the more climate-friendly scenario used in this report, would help substantially reduce internal climate migration. Urgent and aggressive action on inclusive, resilient, and sustainable development alongside global action on emissions reductions will also be needed.

2. Embed internal climate migration in far-sighted green, resilient, and inclusive development planning.

The modeling results show how much the scale of internal climate migration can be reduced by pursuing more inclusive and resilient development pathways. Integrating internal climate migration in development planning is critical to address the poverty factors that make people particularly vulnerable to climate change impacts, such as a lack of viable livelihood options and lower quality assets. This is particularly important as the most vulnerable groups tend to have the fewest opportunities to adapt locally or move away from risk—and when moving they tend to do so in adverse circumstances. Systematic planning at the nexus of climate, development, and migration can help broaden the opportunities for people to adapt where they live, or else enable them to move under better circumstances.

Far-sighted development planning can also enable countries to pursue green, resilient, and inclusive economic transformations. Notably, accounting for internal climate migration alongside broader demographic patterns can help fuel momentum towards the next generation of skills and jobs in both sending and receiving areas. Good management of demographic transitions is vital in this regard and will need to be accompanied by continuing investments to enable working-age populations to find opportunities in productive and climate-resilient labor markets, with good access to health care, education, and public services. Investment in human capital can increase adaptive capacity to cope with climate change impacts, particularly empowering youth, who face high unemployment rates in certain regions, as well as women. Supporting safer, more informed, and more economically beneficial migration for women—which requires addressing gender disparities and, in some cases, shifts in social norms—can help ensure that women can realize their full potential.

Climate-smart urban and rural transitions can also provide important win-win opportunities to drive economic transitions. Primary and secondary cities can be promoted as hubs of innovation and knowledge transfer, accelerators of the digital transformation, and centers of green technology and resilient infrastructure in key sectors, including energy, water, and transport. Cities have opportunities to leverage rural-urban migration and broader urbanization trends in many regions, capitalize on agglomeration effects, and develop economies of scale. In rural areas, nature-based solutions emphasizing the protection of ecosystem services can benefit agricultural productivity, provide buffers against floods and droughts, and enhance management of landscapes, forests, and watersheds on which livelihoods depend. More broadly, flexible social protection systems with robust and rapid delivery can significantly increase resilience to climate change and other shocks, particularly for the most vulnerable.

Development policies will also need to address compounding shocks that can increase underlying vulnerabilities and the likelihood of movement under distress. Climate change impacts can act as both a threat multiplier in the onset of other shocks, and as an amplifier in the fallout of such shocks. Fragility and conflict situations can be exacerbated by climate change, natural disasters, and natural resource degradation, putting additional stress on economic, social, and political systems. Extreme weather events can also hinder humanitarian responses to crises—as seen with the COVID-19 pandemic—or heighten the vulnerability of people returning to at-risk areas due to lockdowns in other places. Climate change, current situations of fragility and conflict, and the global pandemic make a clear case for the need to adopt migrant-inclusive risk management approaches and enhance emergency preparedness and response.

Internal climate migration should also be placed at the intersection of humanitarian, development, and peace partnerships, working with national and local stakeholders for end-to-end solutions. Global and regional dialogue and processes are starting to recognize climate change and migration in multilateral agreements and frameworks, while national governments are taking action to embed these issues in national development policies, strategies, and territorial planning. Greater cooperation, information sharing, and action needs to be pursued between the development, humanitarian, security, and disaster risk reduction communities to support countries in taking holistic action across the mobility continuum. Strong regional institutions are essential to address the multi-dimensionality of challenges. Locally led approaches working with civil society and community actors are critical to generate inclusive, participatory, and empowering solutions.

Photo Credit: World Bank

3. Plan for each phase of migration, so that internal climate migration as an adaptation strategy can result in positive development outcomes.

Planning for internal climate migration means accounting for all phases of migration—before, during, and after moving. Before migration, adapt-in-place solutions can help communities stay in place where local adaptation options are viable and sensible. During migration, policies and investments can enable mobility for people who need to move away from unavoidable climate risks. After migration, planning can ensure that both sending and receiving areas are well equipped to meet the needs and aspirations of their populations.

Policy makers will need to understand and account for differences in vulnerabilities across landscapes to provide a stronger basis for adaptive practices that would enable people to stay in viable livelihood systems. Integrated management of landscapes and natural resources, combined with resilient agri-food systems, will be central to ensuring livelihood sustainability and food security, particularly in densely populated localities or in productive areas that may already be stretched. Diversified livelihoods that are not tied to climate-sensitive sectors need to be available as options to adapt in place. Building adaptive capacity also means putting in place effective land administration systems that provide security of tenure, reduce informal tenure, and recognize customary land practices, as well as help manage appropriate land uses. Careful attention to the carrying capacity and reach of social, service delivery, economic, and livelihood systems is also key for spatial planning.

For people who need to move away from unavoidable climate risks, policy makers will need to enable mobility by creating supportive environments for planned and orderly migration into areas of low risk and high opportunity. Inclusion and sensitivity to migrants' needs will be crucial. In many regions, internal climate migration will have to be managed as an important part of a broader set of adaptation options and in the context of existing patterns of mobility. Targeted interventions can be deployed in the short and medium term to support migrants. For instance, informed decision-making can be facilitated for migrants through better access to financial resources and social services, increased financial literacy, secured legal status, and pre-departure training, skills, and orientation. Investments can also make social protection portable and scalable by easing registration and communication in receiving areas, particularly major urban centers; improving access to benefits through mobile money and digital identification systems; and allowing for social welfare systems to be adaptable to changing needs. Policy can also maximize the potential of financial and social remittances to bolster adaptation investments and income-generating activities and encourage knowledge transfer through diasporas and social networks.

In places where options to adapt in place have reached their limits, inclusive decision-making processes can help ensure that planned relocation and managed retreat enable movement in a safe and dignified manner. Planned relocation is a complex and multidimensional process to be adopted as a last resort and only when needed. It should involve the participation of affected people, and to be developed in a way that is specific to national and local contexts. Many SIDS, for example, have already taken proactive leadership roles on integrating mobility in the context of climate change in national policy frameworks to anchor the ability of inhabitants to remain where viable, while ensuring continued opportunities to migrate for those who choose to do so.

Policy makers will also need to ensure that both sending and receiving areas are adequately prepared to ensure the resilience of those who remain and to integrate additional flows of people. Many of the climate in-migration hotspots identified in the regions covered by this report are major urban areas, such as Algiers, the Casablanca-Rabat corridor, Tangiers, and Tunis in North Africa; Osh and Jalal-Abad in the Kyrgyz Republic; and Hanoi in Vietnam. These cities will need to provide advanced public service provision, affordable housing programs, and employment opportunities for increasing numbers of people. Fostering integration and social cohesion can also help ensure that destination areas leverage the opportunities that migrants bring to fill labor and demographic gaps, diversify human capital, and bring new skills and knowledge.

National and city planning systems will need to account for important changes to existing settlement patterns. These will need to go hand in hand with climate-resilient infrastructure investments and improved connectivity networks, especially as cities continue to grow and draw migrants from rural areas. Even cities projected to be out-migration hotspots and thus see potentially slower population growth, such as Alexandria and Ho Chi Minh City, will still continue to support large numbers of people who may face escalating climate risks. Urban planning and land use management will need to be inclusive and address the needs of the most vulnerable, who often live in areas with inadequate services, including informal settlements, sometimes on marginal land exposed to floods and other hazards. Vulnerable people, including those that are lower-skilled, poorer, and older, may also be unable to move away from areas of high risk. Involuntary immobility in the context of climate change should therefore be equally considered in development planning.

4. Continue to invest in improving understanding of internal climate migration to inform well-targeted policies.

More investments are needed in research at scale, including new, more granular data sources and differentiated climate change impacts, to better contextualize and understand internal climate migration at the regional and country level. The novel and transparent modeling presented in the *Groundswell* reports is a starting point, but decision-makers will need more spatially detailed projections to identify the most appropriate strategies in each location.

Such "deep dives" are already being undertaken by the World Bank in West Africa and the Lake Victoria Basin. They corroborated the *Groundswell* findings for those regions, while also using an updated methodology. Enhancements include shorter time steps, higher spatial resolution, and more climate change impact parameters—all of which provide a more granular analysis of the scale, trends, and spatial patterns of internal climate migration at the country level.

State-of-the-art models on the current and future trends of internal climate migration continue to be crucial to inform early action. Updated models using an array of climate change impacts and other biophysical, socioeconomic, and political indicators factors can help better inform decision-making at appropriate scales. These should also account for the inherent uncertainties in the way climate change impacts will play out in given locales that will affect the magnitude and pattern of climate change-induced movements. Important strides have been also made in new research to extend regional and national-scale modeling, and to gain further insights into how climate stressors impact individual decisions to move. The need to create a shared understanding of the scale, trajectory and spatial dimensions of internal climate migration remains critical to support development policy and planning.

A RENEWED CALL TO ACTION

The *Groundswell* report series reaffirms that internal climate migrants will continue to be the human face of climate change. The potency for climate change to drive migration is set to increase to mid-century and beyond if no action is taken. The call for solutions on internal climate migration cannot be subscribed to the very communities who would have to move in response to the increasing intensity and frequency of climate change impacts. Early and far-sighted global, regional, and national action is imperative to address the urgent challenges at the nexus of climate, migration, and development and foster momentum toward inclusive, sustainable, and resilient economic transitions for all.

Chapter 1

An Evolving Global Landscape for Climate Change as a Driver of Migration

The global policy landscape and dialogue around climate change and mobility continues to evolve, and there have been important developments since the first *Groundswell* report was published (Rigaud et al. 2018). This chapter provides an update on the global landscape, with important context for new modeling results presented in Chapters 2 and 3 on internal climate migration in the Middle East and North Africa, East Asia and the Pacific, and Eastern and Europe and Central Asia with subregional and country-level case studies. It also provides context for the qualitative analyses in Chapters 4 and 5 on environmental and climate-related mobility in the countries of the Mashreq and in Small Island Developing States (SIDS). The chapter includes a discussion of recent compounding shocks, including the COVID-19 pandemic, fragility and conflict situations, and their implications for mobility. The latter part of this chapter lays out the objective of the report and its structure.

1.1 CLIMATE CHANGE, MOBILITY, AND DEVELOPMENT: A GROWING NEXUS

Climate change poses unprecedented and growing threats to sustainable development. Globally, the years 2016, 2019 and 2020 have been the warmest on record, and 2011–2020, the warmest decade ever (WMO 2021a; Copernicus 2021; Hausfather 2021). Rising global temperatures have contributed to more frequent and severe extreme weather events around the world, including heat waves, droughts, heavy precipitation, floods, and severe storms, along with continued sea-level rise, ocean warming and acidification, and glacial loss (WMO 2021b).

Human activities are already estimated to have caused about 1.0°C of global warming above pre-industrial levels, with a likely range of 0.8°C to 1.2°C and significant regional variations (IPCC 2018). Not only is the world not on track to keep warming “well below” 2°C, as countries committed to under the Paris Agreement—it is still headed towards at least 3°C of warming by 2100 (UNEP 2020; World Bank 2014). The latest climate science has made it clear that limiting warming to 1.5°C would substantially reduce climate-related risks for natural and human systems relative to a 2°C world, though these would still be greater than they are today (IPCC 2018). At current emission rates, global warming could likely reach 1.5°C between 2030 and 2052, and as early as 2030.

This has urgent implications for sustainable development and poverty reduction. There is ample evidence that people living near or below the poverty line are particularly vulnerable to climate change impacts, losing more and less able to cope with shocks and adapt (Hallegatte et al. 2016). This is due to several factors, including lower-quality assets (such as housing stock), greater dependence on livelihoods in climate-sensitive sectors, greater vulnerability to rising food prices during disaster-related supply shocks, and inadequate public services that leave them more susceptible to climate-related diseases such as diarrhea and malaria (Hallegatte et al. 2016; World Bank 2020a). Disasters resulting from extreme events can reverse decades of development progress, while more gradual climate change impacts—from shifts in precipitation patterns to sea-level rise—are already affecting livelihoods and straining the natural systems on which these depend (IPCC 2018). Such shifts have effects across the development spectrum: on health, livelihoods, food security, water supply, and overall human security. Across regions, poverty disproportionately affects rural, young, and undereducated people (World Bank 2020a). Four-fifths of those living on less than US$1.90 per day in 2018 were in rural areas, while children and youth (ages 15–24) together accounted for two-thirds of the global poor. Women, especially those aged 25–34, are also overrepresented among the poor.

In this context, mobility in all its forms continues to have important development implications. The latest UN estimates put the number of international migrants worldwide at 281 million in 2020, or 3.6 percent of the global population (IOM 2019). Both the absolute number and relative share of international migrants are on the rise. Notably, the great majority of migrants do not cross borders, but rather move within their own countries. Internal migration, mainly in search of employment, and often from rural to urban areas, is widespread in many regions.

As outlined in the first *Groundswell* report, climate change impacts are already shifting patterns of mobility, and those effects are expected to grow over time (Rigaud et al. 2018). The Internal Displacement Monitoring Centre (IDMC) estimates that 40.5 million new displacements took place in 2020, of which 30.7 million were triggered by disasters (IDMC 2021).[2] The overwhelming majority, 30 million, were the result of weather-related hazards such as storms (14.6 million) and floods (14 million). Most new displacements in 2020 were recorded in East Asia and the Pacific (12.1 million) and in South Asia (9.2 million), where tropical cyclones, monsoon rains, and floods hit highly exposed areas that are home to millions of people. While these figures relate to sudden-onset events that are not the focus of this report, they illustrate the increasing role of extreme weather-related events in mobility and in shaping underlying vulnerabilities. Evidence of the impact of disasters on mobility are mixed, with some evidence of shorter-term internal migration effects (Berlemann and Steinhardt 2017; Mbaye and Zimmermann 2015). Not all internally displaced persons return home soon after disasters however (IDMC 2021), and the scale and complex nature of protracted displacement triggered by disasters and climate change impacts constitutes a major knowledge gap.

Slow-onset climate change impacts—including changes in temperature and precipitation patterns, as well as sea-level rise—are also increasingly driving mobility. Recent meta-analyses and studies examining the effects of climate change on migration have found that factors such as variability and anomalies in rainfall, extreme precipitation; temperature changes and extremes; and droughts can increase migration (Hoffmann et al. 2020; Šedová, Čizmaziová, and Cook 2021). They particularly affect internal migration in agriculture-dependent countries (Hoffmann et al. 2020). Indeed, empirical studies looking at countries in South Asia, Africa, and South America have found that rising temperatures in agriculture-dependent areas can be a factor leading to out-migration (Berlemann and Steinhardt 2017). Research in Indonesia has found that increases in temperature and variations in rainfall are likely to have a greater effect on permanent out-migration than disasters (Bohra-Mishra, Oppenheimer, and Hsiang 2014). Other studies have found that longer-term rather than shorter-term variations in temperature may alter expectations of future conditions and influence out-migration (Mullins and Bharadwaj 2021). Environmental conditions can also interact with one another, and they act as both push and pull factors, influencing where people go (Hoffmann et al. 2020).

Recent research suggests that climate change impacts on natural resources and livelihood systems can induce different types of migration than economic shocks. For instance, periods of rainfall deficit have been found to be significant predictors of internal migration (Zaveri et al. 2021). Water shocks also tend to induce migration for those that are lower-skilled. Migrants often arrive in cities that are ill prepared to receive them, provide them with basic services, or use their skills. Many of these cities increasingly face their own water shortages, which can also slow economic growth and reverse critical development progress.

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[2] The IDMC also estimates that overall, there were 55 million people living in displacement at the end of 2020, with 48 million as a result of conflict and violence, and 7 million as a result of disasters including weather-related (IDMC 2021).

In sum, more vulnerable people are induced to move by climate change and other environmental impacts—they are often poorer, less educated, and less able to recover economically in their new homes (Hornbeck 2020). This is highly relevant for policy because as climate change affects agricultural productivity, with broader impacts on food systems and rural livelihoods, out-migration could become an increasingly common coping strategy. One in nine people worldwide is food-insecure—more than 820 million altogether—and food insecurity has consistently increased since 2014 (FAO 2019). COVID-19 has exacerbated the problem, as have conflicts, insecurity, and economic impacts in many countries (Charlton 2020).

Climate change impacts and gender dynamics can together influence migration as an adaptive strategy (Erman et al. 2021). Severe droughts in Ethiopia, for example, increased men's labor migration over a 10-year period, but decreased women's marriage-related moves (Gray and Mueller 2012a). In Bangladesh, meanwhile, both flooding and crop failure increased migration by women who have less secure access to land (Gray and Mueller 2012b). Migration from rural to urban areas has led to shifts in traditional gender roles and, in some contexts, to more empowerment and opportunities for women in their communities and households (Rigaud et al. 2018). At the same time, migrants, especially women, can be at risk of exploitation, including sexual exploitation, human trafficking, and violations of their rights. Climate risks can also make it more difficult for women to migrate, due to structural issues (Khan 2018). Gendered access to resources and equality can be determining factors in the decision to migrate, while gendered norms in receiving communities can lead to unfavorable outcomes for women (Lama, Hamza, and Wester 2021).[3]

Along with distress-driven movement, involuntary immobility in the context of climate change needs to be considered, on equal footing, in development planning. While the causes of immobility—voluntary or involuntary—are multifaceted and interconnected, it is often the most vulnerable who are unable to move away from exposure to natural hazards, poverty, food insecurity, or conflict exacerbated by climate change (Zickgraf 2021). Recent research finds, for example, that the likelihood of becoming trapped has been found to be particularly high for women and in low-income countries (Šedová, Čizmaziová, and Cook 2021). Other research has found that in places where there is extreme poverty, and migration is costly, water deficits are more likely to trap people than induce them to migrate (Zaveri et al. 2021). It is the poorest who often lack the means to migrate, even when doing so might improve their livelihoods and prospects, and they have few options to adapt in place. How national and local policies combine with individual socioeconomic, demographic, and psychological factors to affect whether people can and do move should be further examined (see, e.g., Ayeb-Karlsson, Kniveton, and Cannon 2020; Zickgraf 2019).

1.2 COMPOUNDING SHOCKS AND THE INCREASING COMPLEXITY OF MOBILITY

Compounding shocks, such as the COVID-19 pandemic, fragility and conflict situations, and the locust outbreak in East Africa, highlight the increasingly complex and interconnected drivers of mobility. Together with climate change impacts, these shocks are reversing hard-won gains in poverty reduction and shared prosperity (World Bank 2020a). After nearly a quarter-century of steady global declines in extreme poverty, the pandemic is estimated to have pushed 88–115 million people back into extreme poverty in 2020, with the total rising to as many as 150 million by 2021, depending on the severity of the economic contraction. Extreme poverty is likely to persist at those higher levels in 2021, particularly in fragile and conflict situations and in Sub-Saharan Africa, due to compounding shocks (World Bank Group 2020b).

The ways in which COVID-19, conflict, and climate change act as risk multipliers highlight the urgency to address underlying drivers of mobility in a holistic and anticipatory manner. Many of the world's poorest people live in fragile and conflict-affected countries, including some middle-income economies, and they are already facing severe climate change impacts (Corral et al. 2020; World Bank 2020b). Combined with the pandemic, those factors can be powerful drivers of migration and displacement (United Nations 2020). A prime example is the locust outbreak that has hit several Intergovernmental Authority on

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[3] For a review of the literature on gendered impacts of migration patterns and impacts on vulnerable groups, see Rigaud et al. (2018), Chapter 2.

Development (IGAD) countries, including Ethiopia, Kenya, Somalia, and Uganda, which has been linked to climate change and has put millions of people at risk of starvation (Kray and Shetty 2020).

The pandemic has affected established mobility patterns— including seasonal, rural-urban, and international migration—that play an important role in poverty alleviation (Guadagno 2020a; Smith and Wesselbaum 2020; Wright and Tänzler 2020), as discussed further in Box 1.1. In some cases, reverse migration from urban to rural areas can increase people's vulnerability, particularly in locations where livelihoods are already at risk due to climate change impacts and environmental degradation (UNHCR 2020). For instance, in Tuvalu, people voluntary moved to rural islands in large numbers, with some islands experiencing a 35 percent increase in average population, while the capital, Funafuti, lost a quarter of its residents (Kitara et al. 2020). Population increases on outer islands may increase strains on local resource systems, which are already under pressure from coastal erosion and saltwater intrusion, changing rainfall patterns, and altered land and marine ecosystems. Tuvalu's agricultural lands and densely populated coastal areas, including housing and infrastructure, are also vulnerable to extreme weather events. More generally, large inflows of returning migrants can pose important challenges for rural communities with limited access to food and supplies; this can contribute to deepening and widening rural poverty (Sanchez-Paramo 2020).

In places that are highly vulnerable to climate change impacts, the pandemic has sometimes constrained humanitarian responses to extreme weather and disasters. Measures to contain the spread of COVID-19 can affect emergency evacuations, as shelters hosting large groups of people could act as spreading grounds for the virus (Guadagno 2020b; Paoletti and Vinke 2020; UNHCR and Potsdam Institute for Climate Impact Research 2020). People may be unable to leave at-risk areas due to pandemic-related mobility restrictions. For example, evacuation plans in response to Cyclone Amphan, which affected Eastern India and Bangladesh in May 2020, and Cyclone Harold, which affected the Solomon Islands, Vanuatu, Fiji, and Tonga in April 2020, were complicated by the need to follow strict precautions to prevent the spread of COVID-19.

The COVID-19 pandemic also risks worsening the precarious conditions in which millions of internally displaced persons and migrants already live, exacerbating food insecurity, and disrupting social networks (World Bank 2020a). The poor and socially marginalized may see their already limited financial reserves shrink further, constraining their ability to overcome the combined effects of COVID-19 and climate change (Milner et al. 2021). These concerns are particularly daunting for locked-down communities that are also exposed to overlapping climate-related environmental risks such as flooding, fires, hurricanes, and extreme heat events.

In fragile situations, climate change, natural hazards, and environmental degradation can further strain economic, social, and political systems (World Bank Group 2020b). Where institutions and governments are unable to manage the stress or absorb the shocks of a changing climate, the risks to the stability of states and societies may increase. In addition, competition over ever-scarcer resources can exacerbate tensions and situations of fragility (UN DESA 2020; World Bank Group 2020b). The intersection of climate change, geographic isolation, and fragility is particularly pronounced in the Pacific, for example, where half of the 12 World Bank Group member states—Kiribati, the Marshall Islands, the Federated States of Micronesia, Papua New Guinea, the Solomon Islands, and Tuvalu—are classified as fragile. These countries are particularly vulnerable due to small size, weak infrastructure and capacity, limited economic opportunities, and frequent natural hazards.

In the countries of the Mashreq subregion, climate change is exacerbating existing water scarcity, slowing or reversing gains in water security. The social and economic impacts of those stresses, combined with political instability, could escalate fragility (World Bank 2018a). Cautions should be exercised, however, in invoking casual relationships between water (notably drought), conflict, and forced displacement, given the context-specific and complex nature of the water and displacement relationship (Borgomeo et al. 2021). There is a need to address the multiple dimensions of fragility, including climate change and other near- and longer-term risks, and strengthen sources of resilience (World Bank Group 2020b). Peace and stability are inextricably linked with resilient livelihoods, sustainable natural resource management, and food security.

Box 1.1: How the COVID-19 pandemic has amplified risks and vulnerabilities of migrants

The COVID-19 pandemic has affected migrants in several ways. In many countries, migrants have provided essential frontline services in the pandemic response and are central to longer-term recovery and development (Guadagno 2020a). However, migrant populations tend to be left out of national pandemic preparedness and response planning. While governments have included vulnerable populations in their response plans on paper, in practice, citizenship and residency status have been found to be essential in accessing aid (Ogude and Chekero 2020). At the same time, migrants have been particularly vulnerable to job losses caused by lockdown measures and the slowing of economies, as they are likelier to work in industries strongly affected by COVID-19, such as manufacturing and hospitality, as well in as the informal sector (Nguyen et al. 2020; Wright and Tänzler 2020).

In urban areas, migrants, informal workers, and those working in the sectors most affected by lockdowns and mobility restrictions are often not covered by existing safety nets and relief measures (Nguyen et al. 2020; World Bank 2020a). In India, for instance, where the vast majority of the labor force is informal, lockdown measures particularly affected migrants, who lacked access to social protection measures (Sengupta and Jha 2020). In Senegal, migrants returning from Dhakar may have helped spread the virus, straining rural health systems (Le Nestour and Moscovitz 2020). In rural areas, mobility restrictions have affected farm and non-farm activities and access to markets, meaning that the rural poor are likely to face important income losses (World Bank 2020a).

Many of the world's refugees and internally displaced persons are in countries with limited health care capacity due to protracted crises (Guadagno 2020a). The pandemic is also likely to increase the social risks faced in receiving areas (Ogude and Chekero 2020).

COVID-19 is also affecting international migrants and their communities of origin. Although predicted to decline, remittance flows proved resilient during the COVID-19 crisis, with some regions seeing growth in remittance flows due to fiscal stimulus, a broad shift from informal to formal remittance channels, and migrants' desire to help their families (Ratha, Kim, and Plaza 2021). Remittance flows surpassed the sum of foreign direct investment and official development assistance. However, there were declines in remittance flows in Europe and Central Asia, East Asia and the Pacific and Sub-Saharan Africa.

It is also critical to shift from reactive to proactive approaches to the compounding risks that drive mobility and displacement. Interconnected crises will require considerable institutional flexibility and rapid responses as communities need governance structures that are adaptive, inclusive, and forward-thinking to build resilient systems (Davies et al. 2020). The policies, frameworks, and measures that determine whether people can move, how, and their distribution and access to resources and opportunities are critical in this regard (Guadagno 2020a). Restrictions on movement and constraints on migrants' rights can keep people trapped in fragile areas or drive them into locations that are vulnerable to climate change, health impacts, or fragility, and where they may lacking access to employment, housing, or services. Ensuring that the most vulnerable and disempowered are properly protected from compounding shocks requires the early establishment of agreements, protections, and policies that will minimize social inequality when crises strikes (Manzanedo and Manning 2020). Concurrently, long-term preventive measures are needed that better correspond to the structural nature of migration, climate change, and other shocks and avoid recreating underlying risk conditions that lead to crises and disasters (Guadagno 2020b; Hut et al. 2020).

1.3 A GROWING INTEGRATION OF MOBILITY AND CLIMATE CHANGE IN POLICY FRAMEWORKS

Global processes on migration are aligning in how they address mobility in the context of climate change and should continue to build on this momentum. There is a growing call at the highest levels of the global dialogue for a multifaceted, coordinated, and inclusive approach to these issues. Table 1.1 provides a summary of international frameworks that address mobility in the context of climate change.

In global climate negotiations, mobility has been addressed by the United Nations Framework Convention on Climate Change (UNFCCC) Task Force on Displacement, which prepared a report for the Executive Committee of the Warsaw International Mechanism for Loss and Damage. The task force's recommendations for integrated approaches to avert, minimize, and address climate-related displacement (UNFCCC 2018b; 2018c) were presented to the Parties for their consideration at COP24 in Katowice.

The UN Secretary-General has appointed a Special Rapporteur on the human rights of internally displaced persons, who in 2020 submitted a report focused on internal displacement in the context of slow-onset climate change impacts (United Nations 2020). It recognizes mobility linked to climate change impacts over the coming years and decades—and its plausible scale—as a growing concern, making reference to the findings of the first *Groundswell* report (Rigaud et al. 2018). The report approaches these issues from a human rights perspective, but also makes a case for a holistic, coordinated approach to the complexities of mobility. It highlights the need to bring together a wide range of stakeholders to consider climate action, disaster risk reduction, development, and human rights protection, with the involvement of peace actors in settings where climate change impacts interact with armed conflict.

The Global Compact for Safe, Orderly, and Regular Migration[4] and the Global Compact on Refugees[5] call for a deeper understanding of climate change as a driver of migration. They include specific commitments to address the drivers of environmental mobility and develop policies to better protect those involved in or affected by these movements (Martin et al. 2018). In particular, the Global Compact for Migration recognizes the need to strengthen joint analysis and sharing of information to better map, understand, predict, and address migrations, including those driven by both sudden-onset and slow-onset natural hazards and climate change impacts. It also calls for developing adaptation and resilience strategies, taking into account the potential implications on migration. Long-standing multistakeholder processes on migration, including the International Organization for Migration and the Platform on Disaster Displacement, are increasingly focused on the role of climate change in mobility as well.[6]

The links between climate change and migration are also being addressed in the context of international legal frameworks. The UN Human Rights Committee recently recognized in the case of *Teitiota v. New Zealand* that in the future, under international human rights law, the effects of climate change in receiving states may expose individuals to a violation of their rights (UNHRC 2020; OHCHR 2020). This, in turn, could trigger the non-refoulement obligations of sending states, which guarantee that no one should be returned to a country where they would face torture, inhuman treatment, or other irreparable harm.[7] Thus, movement due to climate change could be protected under human rights law-based nonrefoulement, especially for those who may be exposed to cumulative violations of human rights as a result of climate-related displacement (McAdam 2012).

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[4] See summary (with link to full text) on the UN website: https://refugeesmigrants.un.org/migration-compact.

[5] See summary (with link to full text) on the UNHCR website: https://www.unhcr.org/en-us/the-global-compact-on-refugees.html.

[6] For example, the IOM has a Migration, Environment and Climate Change Division: https://www.iom.int/migration-and-climate-change, and the Platform on Disaster Displacement hosts an Environmental Migration Portal: https://environmentalmigration.iom.int/platform-disaster-displacement.

[7] For a brief summary from the OHCHR of the principle non-refoulement and its implications, see https://www.ohchr.org/Documents/Issues/Migration/GlobalCompactMigration/ThePrincipleNon-RefoulementUnderInternationalHumanRightsLaw.pdf.

Table 1.1: International frameworks that address mobility in the context of climate change

United Nations Framework Convention on Climate Change – Cancun Adaptation Framework	The framework formally incorporates mobility in the context of climate change in the 2010 Cancun Adaptation Framework, calling on countries for "measures to enhance understanding, coordination and cooperation with regard to climate induced displacement, migration, and planned relocation," while "taking into account their common but differentiated responsibilities" (UNFCCC 2010, 4).
Sendai Framework for Disaster Risk Reduction	Focused on disaster displacement, the Sendai Framework outlines "targets and priorities for action to prevent and reduce disaster risks, including through governance, investment in disaster reduction for resilience, and disaster preparedness, recovery, rehabilitation, and reconstruction" (United Nations 2015). The Sendai Framework articulates the need to include migrants in disaster risk reduction and management in three places (see Guadagno 2016 for in-depth analysis): Paragraph 7: governments should engage with relevant stakeholders, including […] migrants […] in the design and implementation of policies, plans and standards. Paragraph 27(h): empower local authorities, as appropriate, through regulatory and financial means to work and coordinate with […] migrants in disaster risk management at local level. Paragraph 36(a)(vi): Migrants contribute to the resilience of communities and societies and their knowledge, skills and capacities can be useful in the design and implementation of disaster risk reduction.
Paris Agreement	The Preamble of the Paris Agreement states that the "Parties should, when taking action to address climate change, respect, promote and consider their respective obligations on […] migrants" (UNFCCC 2015)
UNFCCC Task Force on Displacement	The Warsaw International Mechanism for Loss and Damage focuses on preparing for and addressing loss and damage from both sudden- and slow-onset climate change impacts, including effects on mobility. The UNFCCC Task Force on Displacement, established under the Warsaw Mechanism, is specifically mandated to address climate-related displacement through supporting "efforts, including finance, technology and capacity building of parties and other actors, including with and for communities and local actors, to avert, minimize and address displacement related to the adverse impacts of climate change, at all levels, including community, national, regional and international levels" (see Task Force report: UNFCCC 2018b).
UNFCCC 24th Conference of Parties Decision	The COP24 Decision, informed by a report from the UNFCCC Task Force on Displacement, invites UNFCCC parties "[to] facilitate orderly, safe, regular and responsible migration and mobility [. . .] in the context of climate change, by considering the needs of migrants and displaced persons, communities of origin, transit and destination, and by enhancing opportunities for regular migration pathways, including through labor mobility" (UNFCCC 2018a, 44).
Global Compact for Safe, Orderly, and Regular Migration	Recognizes the need to strengthen joint analysis and sharing of information to better map, understand, predict, and address migration movements, such as those that may result from sudden-onset and slow-onset natural disasters and the adverse effects of climate change, as well as develop adaptation and resilience strategies, taking into account the potential implications on migration.
Global Compact on Refugees	Provides specific commitments to address the drivers of environmental mobility and develop policies aimed at ensuring greater protection for those affected by these movements.

In parallel, a number of regional frameworks in the Pacific, Africa, and Latin America and the Caribbean are also addressing mobility in the context of climate change. The Framework for Pacific Regionalism,[8] the Framework for Resilient Development in the Pacific (FDRP)[9] and the SAMOA Pathway offer an overarching approach to building resilience to climate change and managing disaster risks, including addressing displacement (Wewerinke-Singh and Van Geelen 2018). The FDRP in particular calls for Pacific countries to address mobility in national policies and actions, to protect people and communities vulnerable to climate- and disaster-related displacement and migration, including through relocation and labor migration policies. The United Nations Pacific Strategy,[10] meanwhile, prioritizes addressing the links between migration and climate change, protecting migrants' rights, and facilitating safe, well-managed migration.

The African Union, meanwhile, has taken several steps to protect migrants and displaced people. Its Kampala Convention[11] commits signatories to protecting and assisting "persons who have been internally displaced due to natural or human made disasters, including climate change." In February 2020, the seven Member States of the Intergovernmental Authority on Development endorsed a Free Movement Protocol,[12] which provides broad protections for those affected by climate change impacts and disasters, allowing citizens of IGAD countries to cross borders "in anticipation of, during or in the aftermath of disaster," and to stay as long as returning home "is not possible or reasonable" (Wood 2020).

In Latin America, the 2014 Brazil Declaration and Plan of Action recognizes the "challenges posed by climate change and natural disasters, as well as by the displacement of persons across borders that these phenomena may cause in the region."[13] In the highly climate-vulnerable Caribbean, meanwhile, free movement agreements embedded in economic integration schemes in the Caribbean Community (CARICOM) and the Organization of Eastern Caribbean States (OECS) have laid the foundations for greater mobility, particularly within the OECS Economic Union, which grants full free movement to all OECS nationals of Protocol Member States (see discussions in Francis 2019; Aragón and Mawby 2019). In the 2017 hurricane season, the

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8. The Framework for Pacific Regionalism was endorsed in July 2014 by Pacific Islands Forum Leaders. The full text is available at https://www.forumsec.org/wp-content/uploads/2017/09/Framework-for-Pacific-Regionalism.pdf.
9. The full name of the FDRP is Framework for Resilient Development in the Pacific: An Integrated Approach to Address Climate Change and Disaster Risk Management (FRDP) 2017–2030. The full text is available at http://tep-a.org/wp-content/uploads/2017/05/FRDP_2016_finalResilient_Dev_pacific.pdf.
10. The United Nations Pacific Strategy (UNPS) 2018–2022 is available at https://unsdg.un.org/resources/united-nations-pacific-strategy-2018-2022.
11. The African Union Convention for the Protection and Assistance of Internally Displaced Persons in Africa was adopted in Kampala in October 2009. The full text is available at https://au.int/en/treaties/african-union-convention-protection-and-assistance-internally-displaced-persons-africa.
12. A communiqué on the adoption of the Protocol is available at https://igad.int/attachments/article/2373/Communique%20on%20Endorsement%20of%20the%20Protocol%20of%20Free%20Movement%20of%20Persons.pdf. For a summary of the provisions, see Wood (2020).
13. The full text of the Brazil Declaration and Plan of Action, adopted in December 2014, is available at https://www.unhcr.org/en-us/brazil-declaration.html.

economic integration schemes granted displaced Caribbean nationals protection benefits after catastrophic hurricanes, including a right of entry in other islands and easing access to foreign labor markets through a mutual recognition of skills scheme and/or a waiver of work permit requirements.

These are all steps in the right direction, but there is a need for more comprehensive and cohesive international legal frameworks to address mobility in the context of climate change. For instance, refugee status is currently not afforded to those moving mainly for environmental reasons, including climate change impacts—even as international institutions increasingly recognize the links between climate change and mobility (Behrman and Kent 2018). The term "climate refugee," is not generally endorsed or recognized, with greater accuracy and preference given to the term "persons displaced in the context of disasters and climate change."[14] However, as acknowledged in recent legal guidance (UNHCR 2020), international refugee law protection could apply to people moving due to secondary impacts of climate change that are considered grounds for refugee status, such as armed conflict, under the 1951 Refugee Convention criteria on "nexus dynamics" (see also Bodansky, Brunnée, and Rajamani 2017; Weerasinghe 2018). As noted above, people displaced by climate change could also gain protection through human rights-based non-refoulement.

Better understanding and recognition of the links between climate change and mobility can inform national policy frameworks to address underlying drivers and help both sending and receiving areas to prepare. Governments are beginning to address these linkages in development and spatial planning, using newly available information and adapting international and regional frameworks to their national contexts. This involves both actions to mitigate and/or adapt to climate risks, and medium- to long-term policies to transform livelihoods, landscapes, and socioeconomic systems to build more widely shared prosperity. Effective approaches need to be tailored to each country's climate vulnerabilities, development trajectory, demographics, and mobility dynamics.

Vanuatu, for example, is highly vulnerable to climate change and other natural hazards.[15] It faces a set of climate risks common across the Pacific Islands, including sea-level rise, worsening cyclones, ocean warming and acidification, droughts, and extreme precipitation—along with non-climate hazards such as earthquakes, tsunamis, and volcanic eruptions. In 2018, Vanuatu adopted a National Policy on Climate Change and Disaster-Induced Displacement, one of the first of its kind (Republic of Vanuatu 2018). It includes measures to integrate mobility into development planning, as well as actions on return and reintegration, local integration, and planned relocation (see Chapter 5 for a more detailed discussion). Already in 2007, Vanuatu's National Adaptation Programme of Action (NAPA) explicitly referred to the relocation of Lateu, a very low-lying village facing coastal erosion and flooding, to a more inland area on Tegua, an island in the northern part of the country (Republic of Vanuatu 2007). The country's Nationally Determined Contribution (NDC), meanwhile, prioritizes climate vulnerability and multi-sector impact assessments, integrated climate change adaptation and disaster risk reduction, community-based adaptation, and ecosystem-based approaches (Republic of Vanuatu 2021).

In the first *Groundswell* report, Bangladesh was projected to account for a third of internal climate migrants in South Asia by 2050 in the pessimistic reference scenario, due to its growing population and high vulnerability to climate change. Model results showed that in all scenarios, urban and coastal areas could see dampened growth as climate out-migration hotspots, as sea-level rise, augmented by storm surges, would make them less livable (Rigaud et al. 2018). *Bangladesh's Perspective Plan 2021–2041* factors in climate change as a driver of future migration and shifting population centers, while also recognizing migration as a potential adaptation option for people living in the most vulnerable areas (Government of Bangladesh 2020). It also acknowledges the need for both incremental and transformational approaches to build resilience to climate change in key sectors, especially agriculture. The *Bangladesh Delta Plan 2100,* adopted in September 2018, lays out a comprehensive strategy for managing risks in delta regions, including those from climate change (Government of Bangladesh 2018). Bangladesh has also adopted a strategy to develop secondary cities and towns and make them hubs of innovation, providing new economic, education, and employment opportunities (see Box 1.2).

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[14] See the UNHCR web page on climate change and disaster displacement: https://www.unhcr.org/en-us/climate-change-and-disasters.html (accessed April 16, 2021).

[15] For an overview of Vanuatu's climate context, with historical data, seze the World Bank Climate Change Knowledge Portal: https://climateknowledgeportal.worldbank.org/country/vanuatu.

Box 1.2: Bangladesh's growth pole strategy

Internal migration is common in Bangladesh—driven by both economic and environmental factors, and mainly toward urban areas. Major cities such as Dhaka already face challenges in absorbing influxes of migrants (Alam et al. 2018). Rural-urban migration is increasing the concentration of poor people in urban areas and putting a strain on urban and social services.

In this context, some have suggested incentivizing migrants towards secondary cities (Alam et al. 2018). The idea is that the government could identify climate-resilient and migrant-friendly cities closer to stressed regions that could act as new alternative economic hubs able to provide key services, such as education, housing, health care, and sanitation.

The Bangladesh *Perspective Plan 2021–2041* lays out such a "growth pole" strategy to deconcentrate growth in certain urban centers while promoting others as technological innovation hubs, akin to Bangalore in India and Silicon Valley in the United States (Government of Bangladesh 2020). In particular, the Plan identifies Cox's Bazaar and the coastline as having growth potential for technological innovation in the marine industry, aquaculture, and wind energy.

For example, the International Center for Climate Adaptation and Development, with funding support from PROKAS-British Council, is working to promote Mongla as a migrant-friendly town, with initiatives to provide quality education, health care, and housing for migrants (Qader, Anwar, and Fuad 2020). Mongla is a growing port town in the Southwest coastal region and a destination for internal migrants. Through urban planning that integrates climate-resilient infrastructure, coupled with economic opportunities and public services, the project aims to make Mongla an attractive alternative to Dhaka. Given the serious climate change impacts faced by Bangladesh, however, it will be important to ensure that the development of growth poles is consistently informed by climate and disaster risk considerations.

The *Perspective Plan 2021–2041* also envisions developing rural growth centers through an initiative called "My Village, My Town". It aims to improve infrastructure and amenities in rural areas and thus slow migration to cities (Government of Bangladesh 2020). The initiative includes plans for climate-resilient road networks, providing adequate water supply, developing community spaces, and rural infrastructure development to bridge the rural-urban divide.

Countries are increasingly addressing climate-related mobility as they delineate their national climate priorities. An analysis of the first round of NDCs found that references to migration appeared in a fifth of them—33 of the first 162 submissions (IOM 2016). Of these, 46 percent were in Africa, 33 percent in the Asia-Pacific region and Oceania, and 21 percent in Latin America. References to mobility focused on three main dimensions: (i) managing the effects of climate change on security and the need to address and prevent displacement; (ii) using migration as a possible adaptation strategy through policy measures such as planned relocation; and (iii) leveraging remittances and transfers from migrants and diasporas to contribute to climate action. As countries continue to update their second round of NDCs, climate change and mobility, loss and damage, and the need for adaptation strategies to address these issues are likely to emerge more strongly. SIDS in particular have taken a proactive leadership role in integrating mobility in the context of climate change in their NDCs and national frameworks.

At the World Bank, the development implications of mobility in the context of climate change are increasingly informing institutional dialogue and targeted investments informed in part by the findings of the first *Groundswell* report (see Box 1.3). Continued efforts to better understand climate change as a driver of mobility can help ensure that the World Bank complements global efforts on migration by generating knowledge for policy making. This was identified as a key area of further engagement in a recent briefing to the World Bank Board on leveraging economic migration for development (World Bank 2019c).

Box 1.3: Overview of World Bank action at the climate-migration-development nexus

The IDA20 dialogue recognizes the importance of climate change as a driver of migration (World Bank 2021), citing increased drought and desertification, rising sea levels, repeated crop failures, and more frequent and extreme weather events as likely to increase both internal and international migration, particularly in fragile, conflict and violence-affected countries. It recognizes the recent compounding effects of the COVID-19 and climate crises on increased food insecurity and migration in IDA countries.

The World Bank Group Climate Change Action Plan 2021–2025 recognizes that climate change increases the risks of internal displacement, migration, and instability (World Bank Group 2021b). It also aims to advance the climate change aspects of the World Bank Group's Green, Resilient, and Inclusive Development (GRID) approach (World Bank Group 2021a), which has been adopted to promote economic progress through a recovery path that is inclusive and consistent with environmental and social sustainability, recognizing that the challenges of poverty, inequality, and sustainability are interrelated.

The World Bank Group Strategy on Fragility, Conflict and Violence 2020–2025 also refers to climate change as a driver of fragility and a threat multiplier, highlighting that both in the immediate and long-term, climate change can aggravate already fragile situations and increase vulnerabilities, exacerbate grievances, and deepen pre-existing fragility (World Bank Group 2020b).

The World Bank also expanded The Global Knowledge Partnership on Migration and Development (KNOMAD) as well to support the preparation of World Bank operations addressing migration, including those driven by environmental causes.

World Bank support to address mobility in the context of climate change also includes programmatic and targeted operations and investments across regions with a few examples outlined below:

- The *Sahel Adaptive Social Protection Program* aims to help poor and vulnerable households become more resilient to the effects of climate change. It enables new and existing social protection systems to act before extreme climate events become disasters (World Bank 2020b).

- The *Regional Sahel Pastoralism Support Project* supports transboundary migration as an adaptation strategy for pastoralists who are threatened by drought and conflict. It uses a range of interventions, including migration corridors, shared water points, surveillance for major diseases and other veterinary services, more robust early warning systems, and enhanced crises response (World Bank 2020b).

- The *Lebanon Municipal Services Emergency Project* aimed to ease the load on municipal services, areas, and communities hosting Syrian refugees and provide a cost-effective, clean-energy water supply. It provided a cost-effective, clean-energy water supply by installing solar PV pumping systems. This resulted in quick-win municipal services with built-in flexibility, while actively engaging municipal governments, host communities, and refugees (World Bank 2018b).

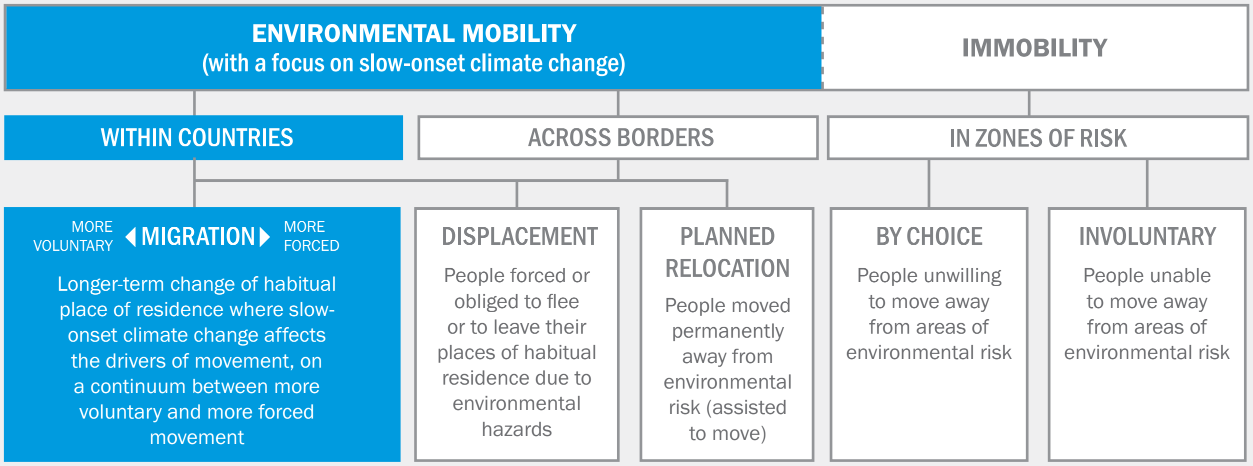
- The *Oases Ecosystems and Livelihoods Project* in Tunisia aims to improve sustainable natural resources management and promote livelihoods diversification in selected oases. Oasis farmers especially youth are moving away due to a loss of livelihoods induced by degraded ecosystems exacerbated by climate change impacts, loss of soil fertility, poor land management, and unsustainable tourism development. The project focuses on piloting participatory approaches for sustainable and efficient water and land management at the local level, diversifying economic opportunities, supporting income-generating activities, and creating jobs especially for women and youth (World Bank 2019b).

- The *CASA Community Support Project for Tajikistan* seeks to engage communities in the development of social and economic infrastructure in order to enhance services, livelihoods and inclusion in villages near the near the CASA1000 Transmission Line. The project is empowering youth to be effective ambassadors for climate change and energy efficiency, while informing communities on livelihood improvements. In the context of Tajikistan, with mobility and migration as an adaptation strategy, the project seeks to increase the resilience of communities to climate change through citizen engagement (World Bank 2019a).

1.4 THE GROUNDSWELL APPROACH: UNDERSTANDING CLIMATE MIGRATION TO SUPPORT BETTER DEVELOPMENT OUTCOMES

As with the first *Groundswell*, this report contributes to a deeper understanding of climate change impacts as existing and increasingly potent future drivers of migration. It focuses on internal climate migration while also acknowledging the complexities of mobility in the context of climate change. It is intended as a catalyst for future work by the World Bank, national governments, development partners, and the international community. Figure 1.1, reproduced from the original *Groundswell* report, specifies the scope of this report. Box 1.4 defines key terminology that is used throughout the report.

Figure 1.1: Focus of this report and the broader landscape of mobility (and immobility) in the context of climate change



Source: Reproduced from Rigaud et al. (2018).

Box 1.4: Key terminology and scope of this report

Human mobility is an umbrella term used to describe all aspects of the movement of people, including involuntary internal and cross-border displacement of populations, voluntary internal and cross-border migration, and planned relocation (UNHCR et al. 2015).

When environmental factors, including climate change, affect mobility, this is referred to as **environmental mobility** (Foresight 2011), encompassing the categories of migration, displacement, and planned relocation. The term **human mobility in the context of climate change** is also used to describe such movements for climate-related reasons (Warner and Afifi 2014). In practice, mobility is usually multicausal, and direct linkages between environmental factors and mobility are often difficult to single out; however, evidence of those linkages is growing, and understanding of the complexities is improving (Hoffmann et al. 2020; Šedová, Čizmaziová, and Cook 2021).

This report focuses specifically on and uses the term ***internal climate migration*** (or the shorthand ***climate migration***) to reflect *longer-term* shifts in population distribution or more permanent migration occurring *within* countries that can be attributed largely to the *slow-onset* impacts of climate change on livelihoods, through shifts in water availability, crop productivity, and/or sea-level rise augmented by storm surge. The modeling work captures the potency of climate change impacts to drive shifts in population distribution within a country at spatial scales of around 14 kilometers at decadal temporal scales (see Appendices B and C for more details on the methodological approach).

As shown in Figure 1.1, environmental mobility is multifaceted, interacting with a wide range of other factors to influence a decision to move, and the degree to which this decision is voluntary (Rigaud et al. 2018, Chapter 2; UN DESA 2020). Differentiating between voluntary and forced movement in this context is often difficult due to the complexity of drivers of mobility (Kälin and Schrepfer 2012). Some will respond to growing climate change impacts by migrating, internally or across borders (see Box 1.5 for a discussion of cross-border migration and its linkages to climate change). Planned relocation, however, should be considered only as a measure of last resort (see Box 1.6).

Box 1.5: Cross-border migration and its linkages with climate change

The modeling results presented in this report do not explicitly include cross-border migration driven by climate change, except as a continuation of historical patterns of transboundary mobility. However, climate change could amplify or inhibit cross-border movements, depending on the contexts that propel individuals to decide to move.

As with internal climate migration, the links between climate change and cross-border migration are complex, as documented in a growing body of research. Some studies suggest that climate change may increase cross-border migration, especially as it plays out through impacts on natural resource-based livelihoods, while others suggest that it can also act as an inhibitor (Nawrotzki and Bakhtsiyarava 2017; Obokata, Veronis, and McLeman 2014). Results from two recent meta-analyses indicate that both rapid- and slow-onset climate change impacts can increase international migration, particularly from rural or agriculture-dependent areas to areas that are less dependent on agriculture (Hoffmann et al. 2020; Šedová, Čizmaziová, and Cook 2021). Newer research also confirms previous findings that cross-border environmental mobility is mainly short-distance and regional (Hoffmann et al. 2020).

These insights highlight the need to take a holistic approach to policy and planning that considers all forms of mobility in the context of climate change.

Box 1.6: Cross-cutting elements of planned relocation

Planned relocation is a complex and multidimensional process to be adopted as a last resort and only when other alternatives are not possible (UNHCR 2015). When needed, it should be carefully planned with the participation of affected people, depending on particular national and local contexts.

Cross-cutting elements that are applicable to planned relocation include (i) legal frameworks in place; (ii) needs and impacts evaluation; (iii) information, consultation and meaningful participation; (iv) availability of land; and (v) monitoring, evaluation and accountability (UNHCR and IOM 2017).

In SIDS, for example, it is important to fully embed the perspective of inhabitants and balance the imperative to move with existing deep ties to the land. Narratives around relocation as being inevitable may overlook issues such as local resilience and people's abilities and desires to make their own mobility decisions, whether due to climate change or other factors (Kelman 2018).

In contexts where migration may be unavoidable, plans for relocation should empower people to make their own decisions, while seeking outside assistance for specific processes such as land to move to or arrangements with neighboring nations to facilitate migration.

There is continuing interest in understanding the scale, trajectory, and spatial dimensions of mobility in the context of climate change, which is critical for integrated development planning. In some contexts, migration has been an inherent part of livelihood strategies and cultural norms. Moreover, migration is a common strategy for survival, coping, income diversification, risk management, and adaptation for people facing economic stress and adverse climate conditions. However, when people migrate unexpectedly and under distress, there is a heightened risk of adverse development outcomes (Melde, Laczko, and Gemenne 2017).

In contrast, safe, orderly, and regular migration can be an effective part of community strategies to adapt to climate change and mitigate risks (Martin et al. 2018; Rigaud 2018). The potential for migration as an adaptation strategy is increasingly recognized by international frameworks on climate change and migration, supported by emerging research (Martin et al. 2021). Migration can be a positive adaptation strategy from several perspectives: (i) for migrants themselves, when their needs and aspirations cannot be fulfilled where they live, and/or to improve their socioeconomic status in anticipation of or in response to climate change impacts; (ii) for communities of origin, through remittances that can bolster capital investments and income-generating activities, provide support after a natural disaster, or fund collective adaptation projects; and (iii) for receiving communities, by filling labor or demographic gaps, fostering economic growth and trade, diversifying social and cultural capital, and acting as a vehicle for transfers of knowledge and technologies (Gemenne and Blocher 2017). It is thus a priority to understand mobility in the context of climate change and address it in a systematic and proactive manner, to ensure that migration is a well-governed, positive part of adaptation and ensures good development outcomes.

1.5 STRUCTURE OF THE REPORT

Chapter 2 covers projections on the scale, trend, and spatial patterns of internal climate migration for the three new subregions of focus—North Africa, the Lower Mekong, and Central Asia. It also provides aggregated results for projections of internal climate migration in three scenarios in all regions covered by both *Groundswell* reports—East Asia and the Pacific, Eastern Europe and Central Asia, North Africa, Sub-Saharan Africa, South Asia, and Latin America—summarized in a global figure for internal climate migration across these six regions.

Chapter 3 illustrates and contextualizes the patterns described in Chapter 2 for the new subregions through three illustrative country examples: Morocco, Vietnam, and the Kyrgyz Republic. It relates the findings to each country's context and discusses the development implications of the research.

Chapter 4 provides a qualitative narrative of environmental and climate-induced mobility drivers, trends, and patterns in Mashreq countries. It pays particular attention to the vulnerability of Mashreq countries to water scarcity and extreme temperature, and how environmental thresholds in terms of water scarcity, land degradation, and heat stress could increasingly act as contributing factors to environmental and climate migration. It also discusses how climate change and natural resource degradation can act as threat multipliers, particularly in situations of fragility and conflict.

Chapter 5 provides a qualitative narrative of environmental and climate-induced mobility drivers, trends, and patterns in SIDS. It discusses the particular vulnerability of SIDS to climate change impacts on key sectors and on habitability. It also covers the proactive leadership roles taken on by many SIDS in integrating climate resilience and mobility in the context of climate change in advancing global and regional dialogues and within national policy frameworks.

Appendix A describes the results of the water availability and crop productivity models for the regions studied. Appendix B provides a refresher of the data and methods for the report's modeling approach. Appendix C provides additional details on model inputs, methodology, validation work, geospatial processing and data visualization methods, and future directions.

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Chapter 2

Climate Migration Projections: Subregions of Focus and the Global Picture

This chapter presents modeling results across three regions—the Middle East and North Africa, East Asia and the Pacific, and Eastern Europe and Central Asia. In line with the methodology used in this report, climate-induced shifts in population distribution are modeled at the country level, and the results are then aggregated at the broader regional levels.

The chapter starts by presenting a more in-depth analysis for the three focus subregions: North Africa, the Lower Mekong, and Central Asia, which have contrasting climatic, demographic, mobility, and development contexts. The modeling results show that in all three subregions, the number of internal climate migrants (described hereafter simply as climate migrants) is likely to increase by 2050. In each subregion, "hotspots" of climate in-migration and out-migration to 2050 are also identified, and there is also discussion of projected climate change impact trends beyond 2050 and the implications for climate migration. In Chapter 3, these findings are further deepened through illustrative case studies in Morocco, Vietnam, and the Kyrgyz Republic. Box 2.1 describes the metrics for climate migration presented in this chapter and Chapter 3.

Box 2.1: Climate migration scenarios modeled and key metrics

The modeling results presented here are based on three plausible scenarios—reflecting different combinations of future climate change impacts and development pathways. These scenarios are compared with alternative scenarios with the same development pathways, but no climate change impacts. In areas where the projected population is larger or smaller in the climate change impact scenarios than in the corresponding alternative scenarios, the difference was assumed to have been the result of in- or out-migration (or dampened population growth). It is important to note that those estimates reflect a plausible range of outcomes and should not be seen as precise forecasts. See Appendices B and C for a full description of the report's methodological approach.

The three climate migration scenarios are:*

- Pessimistic (the reference scenario for this report): high global greenhouse gas emissions combined with an unequal development pathway;
- More inclusive development: with equally high emissions, but a more equal development pathway; and
- More climate-friendly: with lower emissions, combined with an unequal development pathway.

Four key categories of results are presented for each subregion:

1. The total number of climate migrants in each scenario;
2. The number of climate migrants as a share of the total number of internal migrants;
3. Maps of hotspots of climate in- and out-migration—that is, places where population distribution trends are projected to be amplified or dampened by climate change impacts, across all three scenarios modeled; and
4. Net in- and out-migration in rural livelihood zones, coastal zones, and urban areas within subregions, under the different scenarios.

* The scenarios are based on combinations of two Shared Socioeconomic Pathways—SSP2 (moderate development) and SSP4 (unequal development)—and two Representative Concentration Pathways—RCP 2.6 (low emissions) and RCP 8.5 (high emissions).

In the final part of this chapter, climate migration projections are aggregated at the regional level and put in context with regional results from Sub-Saharan Africa, South Asia, and Latin America covered in the first *Groundswell* report, resulting in global projections of climate migration across the six World Bank regions.

2.1 CLIMATE MIGRATION PROJECTIONS FOR NORTH AFRICA

Key Findings

- **The analysis for North Africa shows climate migration increasing by 2050 in all three scenarios. In the pessimistic reference scenario, the projected number of climate migrants is 13.0 million, or 6.0 percent of the total population of the subregion. In the more inclusive development scenario, the projection is 9.9 million (4.2 percent of the total population), and in the more climate-friendly scenario, it is 4.5 million (2.1 percent of the total population).**

- **In the pessimistic reference scenario, by 2050, nearly half of all internal migrants could be climate migrants, and in the more inclusive development scenario, two-thirds. In the latter, climate migrants might even outnumber other internal migrants. In contrast, in the more climate-friendly scenario, climate migrants would represent about a quarter of all internal migrants by 2050.**

- **Climate out-migration hotspots by 2050 include several coastal areas, such as the Nile Delta (eastern and western portions, including Alexandria); the northeast coast of Tunisia, including Kelibia; coastal areas in the northwest of Algeria, including Oran; and smaller areas of the west and southwest coast of Morocco, including Agadir and Safi, due to declining water availability and the impacts of sea-level rise. Inland areas facing reduced water availability are also projected to become climate out-migration hotspots, such as the central Atlas foothills in Morocco, which are predominantly rainfed croplands. Climate change impacts would dampen projected population growth trends in these areas.**

- **Climate in-migration hotspots by 2050 are expected upstream along the Nile Valley and central Delta; the northwest and south coast of Tunisia, including the Gulf of Gabes; the eastern portion of the Algerian coast; and the northern coast of Morocco, amplifying projected population growth trends in these areas. These climate in-migration hotspots include densely settled large and mid-size urban areas such as Cairo, Algiers, Tunis, Tripoli, the Casablanca-Rabat corridor, and Tangiers. Hotspots coincide with areas projected to have increased crop productivity and water availability, including arid regions in southern Algeria (where the oasis and city of Tamanrasset are located).**

2.1.1 Subregional Context

Development and economic context

North Africa comprises Algeria, Egypt, Libya, Morocco, and Tunisia (Figure 2.1). In recent decades, the five countries have made strides in reducing poverty and income inequality, as well as on broader measures of development, such as educational attainment and child mortality. These gains have been achieved through expanded public spending, services, and employment. Countries have also relied on subsidies, especially for energy, to promote economic growth and broader access to resources (Abdellatif, Pagliani, and Hsu 2019). The North African countries are all classified as lower-middle income, except Libya, which is upper-middle income.[16] The COVID-19 pandemic led to economic contractions in 2020, except in Egypt, but the subregion is expected to recover in 2021 and 2022 (AfDB 2021).

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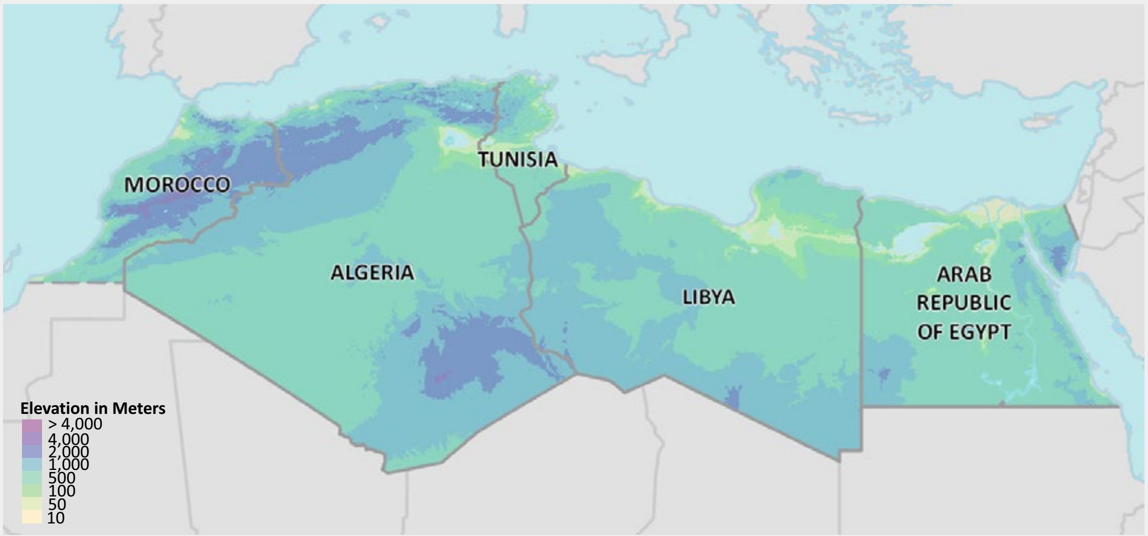
[16] See World Bank income classifications (this report reflects updates as of fiscal 2021): https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups. Libya experienced a deep recession in 2013–2016, followed by a rapid economic expansion driven by a large increase in oil production, with GDP growth averaging 21 percent in 2017–2018. That expansion was disrupted by the outbreak of war around Tripoli in April 2019, when GDP growth slowed to 2.5 percent in 2019 and continued declining in 2020 due to a sharp drop in oil production (World Bank 2020b).

Figure 2.1: Country boundaries and elevation in North Africa

a. Country boundaries

b. Elevation



Extreme poverty in North Africa has declined over the past two decades.[17] In terms of income inequality, the most recent Gini indices range from 27.6 in Algeria to 39.5 in Morocco.[18] Of the 189 countries ranked in the 2020 Human Development Index, Algeria was No. 91, Tunisia was No. 95, Libya was No. 105, Egypt was No. 116, and Morocco was No. 121 (UNDP 2020). On the Human Capital Index, Algeria, Egypt, Morocco and Tunisia all have values around 0.5.[19]

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[17] See World Bank data on poverty headcount ratio at $1.90 a day (2011 PPP) (% of population): https://data.worldbank.org/indicator/SI.POV.DDAY?locations=DZ-EG-LY-MA-TN. No data for Libya.

[18] The Gini index measures the extent to which the distribution of income (or, in some cases, consumption expenditure) among individuals or households within an economy deviates from a perfectly equal distribution. A Gini index of 0 represents perfect equality, while an index of 100 implies perfect inequality. See World Bank data: https://data.worldbank.org/indicator/SI.POV.GINI?locations=DZ-EG-LY-MA-TN. No data for Libya.

[19] The Human Capital Index calculates the contributions of health and education to worker productivity. The final index score ranges from 0 to 1 and measures the productivity as a future worker of child born today relative to the benchmark of full health and complete education. See World Bank data: https://data.worldbank.org/indicator/HD.HCI.OVRL?locations=DZ-EG-LY-MA-TN. No data are available for Libya.

The industrial, public, and service sectors, which are concentrated in urban centers, support livelihoods for much of the subregion's population (Arezki et al. 2019). Recent institutional and legal reforms have aimed to diversify economies. As a result, foreign direct investment to the subregion has increased. Inflows to Morocco, for example, have helped modernize the economy and improve performance in key industries, particularly in finance, renewable energy, infrastructure, and automotive (AfDB 2020). Almost all new robotics installations in Africa since 2017 have been concentrated in North Africa—roughly 75 percent of them in the Moroccan auto industry, and the others in Egypt and Tunisia. The energy sector remains paramount for North Africa, especially oil and gas (Gatti et al. 2021). Morocco, Tunisia, and Egypt are oil importers, while Algeria and Libya are oil exporters.

There are important differences in the share of each country's land that is arable, but overall, agriculture is important for employment and livelihoods in North Africa (Table 2.1). With limited arable land and water, the subregion depends heavily on food imports, especially for major commodities, such as cereals. A sharp increase in global food prices has been identified as one of the contributing factors for the Arab Spring (Ianchovichina 2018).

Table 2.1: Agriculture sector indicators for North Africa

	Algeria	Egypt	Libya	Morocco	Tunisia
Arable land (% of land area) (2018)	3.2	2.9	1.0	16.8	16.8
Agriculture, forestry, and fishing, value added (% GDP)	12.3	11.0	1.8	12.2	10.4
Agriculture (% employment)	9.6	20.6	16.4	33.3	13.8
Rural population (% of total population)	26.8	57.3	19.6	37.0	30.7

Source: All 2019 data, except where indicated, from World Bank Open Data (http://databank.worldbank.org).

Agricultural livelihoods are diverse across geographic and climate zones. Industrial-scale farming produces cash crops such as sugar beets and vegetables, using extensive irrigations systems dependent on rain, spring-fed rivers, and pumped groundwater (Verner 2012). In Algeria, Tunisia, and Morocco, which are already under severe water stress, agriculture is still dominated by small-scale rainfed family farms, which account for a large share of water consumption. The Maghreb's mountainous areas, such as those of Morocco, also support agriculture. Rainfed farming systems in highland areas produce cereals, legumes, and tree crops, such as olives and fruits (Jihad 2016). At lower elevations, including on coastal plains, rainfed systems supplemented with groundwater provide the majority of winter crops (such as barley and lentils), fodder crops, tree crops (including nuts and grapes), and cattle. Drylands receiving less than 300 millimeters of precipitation per year use some irrigation and produce barley and wheat, but agricultural production is less stable due to increased exposure to drought. These areas also support cattle, as well as large numbers of sheep and goats. Finally, semiarid steppes and arid/desert areas produce few crops outside of oases, but support cattle, sheep, and goats. These areas are also major sources of food for the subregion, but support relatively few people through employment, due to their low population densities (Verner 2012).

Water availability and increased water demand present a central challenge to North African countries. The subregion is heavily reliant on groundwater resources, has transboundary aquifers shared between several neighboring countries, and is already considered a global hotspot for challenges in the sustainable use of both groundwater and surface water (World Bank 2018). For instance, the Nubian aquifer is shared by Libya, Egypt, Chad, and Sudan, while the North Western Sahara Aquifer System is shared by Algeria, Libya, and Tunisia.

Large differences in the population density of coastal urban centers versus rural interiors create disparities in public services and infrastructure, and there are also significant inequalities within cities (World Bank 2020a). Despite policy efforts to foster spatial and economic integration and thus narrow economic gaps—for instance, through large capital investments in transport corridors—cities remain physically and economically fragmented. Spatial and economic mobility remain low, and regional economies can be isolated. There are also disparities in access to transportation, internet service, and other infrastructure, as well as public and health services, food and water, and education (Abdellatif, Pagliani, and Hsu 2019).

Rural areas suffer higher poverty rates than urban areas, with large shares of workers employed informally, often lacking safety-net benefits and labor protections (Abdellatif, Pagliani, and Hsu 2019). Even with post-Arab Spring reforms, unemployment rates for youth and women in particular remain high in some countries (Kabbani 2019; Table 2.2). North Africa is among the few regions in the world where the risk of being unemployed increases with higher levels of education (Bjerde 2020; AfDB 2020).

In addition, women's labor force participation rates are among the lowest in the world, ranging from 19 percent in Algeria to 37 percent in Libya as of 2019. There is also a generational gap, with a 5–12 percentage-point difference in labor participation between younger and older women (Arezki et al. 2019). That said, while younger women are likelier to be educated, career-oriented, and gainfully employed, labor force participation rates for older women may be much higher than official estimates due to high levels of subsistence work, especially in Tunisia and Egypt.

Table 2.2: Employment indicators for North Africa

	Algeria	Egypt	Libya	Morocco	Tunisia
Unemployment, youth total (% of labor force ages 15–24)	29.7	26.5	49.5	22.3	35.8
Unemployment, female (% of female labor force)	20.4	21.3	24.1	10.5	22.4
Labor force participation rate, female (% of female population ages 15–64)	18.7	20.0	36.5	23.4	28.1

Source: All 2019 data except where indicated from World Bank Open Data (http://databank.worldbank.org); indicators are modeled ILO estimates.

Population dynamics

As of 2019, the five North African countries were home to about 195 million people, with annual population growth rates of 1–2 percent (UN DESA 2019). By 2050, the population is expected to grow to 213 million under the unequal development pathway (SSP4) and 234 million under the moderate development pathway (SSP2), as shown in Figure 2.2.[20]

North Africa will also see significant demographic changes to mid-century as birth rates decline and life expectancy rises across the subregion, along with median age. Fertility rates are expected to decline from 2–3 births per woman, to 1.6–1.8, below the population replacement rate (JRC 2018). An aging population is bound to intensify the pressure on countries to reap the demographic dividend within the next 40 years.

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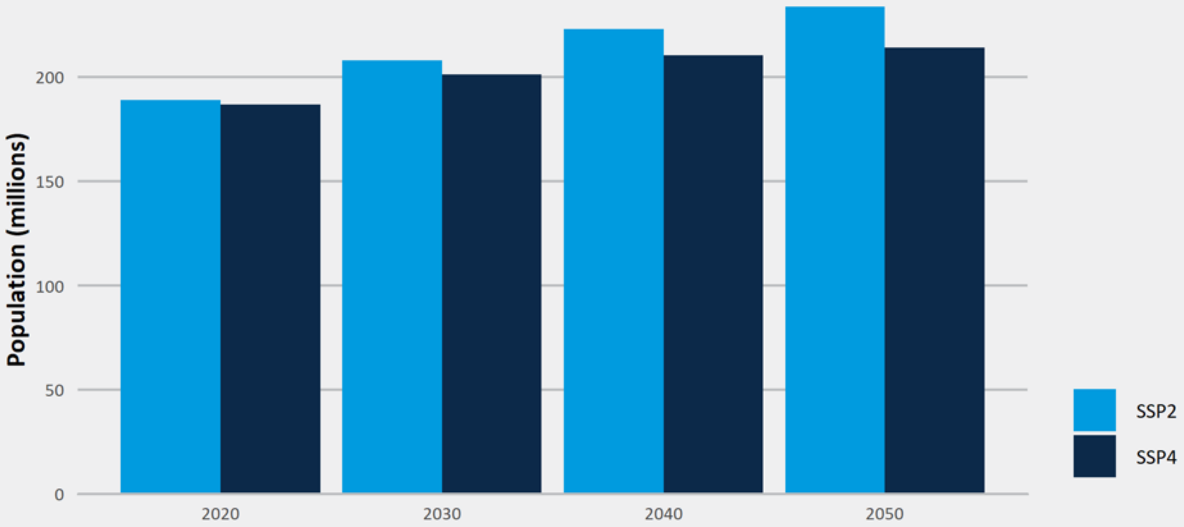
[20] These SSP population scenarios use data from World Population Prospects 2010 for the baseline; see https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=10#v2 and further details in Riahi et al. (2017). Under SSP4, population growth is particularly high in low-income countries, but low in middle-income countries. Under SSP2, population growth is moderate in middle-income countries; thus, in most of North Africa, there is slightly more population growth on the more inclusive development pathway.

Figure 2.2: Projected population in North Africa under two Shared Socioeconomic Pathways, 2020–2050



Source: Jones and O'Neill (2016).
Note: SSP2 = moderate development and SSP2 = unequal development.

Migration dynamics

North Africa has a long history of both internal and cross-border migration. Within countries, rural to urban flows have been linked to economic modernization, improved education, service sector growth, and the concentration of economic activities in towns and cities (Bilgili and Marchand 2016). Rural populations, sometimes in seminomadic or nomadic communities, tend to live in mountainous and arid zones in more extreme climatic conditions that can make access to food, water, and economic resources more challenging. Policies to improve basic services in rural areas have had little effect on rural-urban migration (Serageldin, Vigier, and Larsen 2014). Informality in the labor market, coupled with little access to job-related public benefits in rural areas, has also driven rural workers to migrate (Ramos 2019). Young people often see moving to a city as an investment in their future, expecting to find industrial or service jobs with better pay and security than the often-seasonal employment available in their rural communities. Yet, despite better economic and social prospects in cities for social mobility, urban youth unemployment rates remain significantly higher than in rural areas (AfDB 2018).

Environmental stress, including water scarcity, associated pressures on agriculture and water, and accelerated desertification and land degradation may already be driving increased internal mobility (Mohamed and Squires 2018; Wodon and Liverani 2014). A study based on household surveys found that perceptions of worsening climate change are associated with a higher probability of both temporary and permanent migration (Wodon et al. 2014). In Algeria and Morocco, more than 70 percent of households surveyed perceived rain to be more erratic and temperatures hotter, while in Egypt, where irrigation is more prevalent, the share was 40 percent. In addition, almost all households indicated they had experienced an extreme weather event, with income, crop, and livestock losses listed as the main economic impacts. However, focus groups highlighted that other factors play a larger role in the decision to move—including lack of jobs and services—and that migration is not necessarily the first strategy used to cope with adverse climate events.

North Africa also sees international migration and is a transit region for migrants from other countries. The subregion's proximity to Europe has made it a transit point for migrants from Sub-Saharan Africa (IOM 2019). Climate change stress, combined with population growth, ongoing social and economic crises and well-established migration networks, may serve to increase both flows. As of 2019, almost 12 million North Africans were living outside their countries of birth, with roughly half in Europe and 3.3 million living in Gulf States.

Remittances from internal and international migrants are an important source of education financing for many households, and many people migrate to earn money to pay for education (AfDB 2020). Despite the COVID-19 pandemic, remittance flows to the subregion grew modestly in 2020, and a projected decline in remittances did not materialize, mostly due to strong flows to Egypt and Morocco (Ratha, Kim, and Plaza 2021).

Conflicts in several countries in the Middle East and North Africa region have compounded economic and other drivers of migration, displaced people internally, and created cross-border refugee flows. Civil wars in Libya, the Republic of Yemen, and Syria, combined with the growth of extremist militant organizations, have disrupted millions of lives. Conflict and instability also deepen potential drivers of mobility, including the effects of economic hardship, water scarcity, and land degradation, while also increasing migrants' vulnerability to shocks such as drought and other extreme weather events (World Bank 2018). The linkages between climate change, fragility, and mobility are discussed in Chapter 4 for countries of the Mashreq subregion.

Adverse climatic events, in turn, can increase the risk of conflict by interacting with other important drivers, such as low socioeconomic development and state capabilities (see, e.g., Burke, Hsiang, and Miguel 2015; Mach et al. 2019). Marginalized populations, including ethnic and religious minorities, are often disproportionately affected, and climate change impacts often fall disproportionately on the poorest and most vulnerable in situations of fragility and conflict (World Bank 2018). Furthermore, vulnerability to climate change impacts may not end once people have moved out of precarious areas. Refugee camps and other host areas, including cities and towns receiving large numbers of migrants or displaced persons, are often at increased risk of resource scarcity (Bündnis Entwicklung Hilft and IFHV 2019).

Climate trends

North Africa covers a diverse physical terrain of mountains, plateaus, deserts, coastal lands, and wetlands (Figure 2.1). Three defining features are the Sahara Desert in the south, the Atlas Mountains in the west, and the Nile River and its delta in the east. The subregion's vast desert and drylands are prone to dust storms and high heat that may be exacerbated by climate change (World Bank 2019c). In contrast to the hyperarid climate in the south, the north has a Mediterranean climate, with winter rains and dry summers. It also has considerable forest cover, mainly in Morocco, Algeria, and Tunisia.[21] The subregion's coldest temperatures occur in the winter in the northern Atlas Mountains, in Algeria and Morocco. Due to North Africa's extensive coastline and otherwise dry interior, aquifers are an important source of water for most of the countries; Egypt also relies heavily on the Nile. Mountains provide another important source of freshwater, helping store precipitation as snow and providing water to downstream river systems.

North Africa is particularly vulnerable to the effects of climate change (Schilling et al. 2020; World Bank 2014). Scarce water supplies are a major existing concern, as freshwater is expected to become scarcer as rainfall decreases and droughts intensify, and groundwater resources are increasingly diminished, with implications across economic sectors. Climate change impacts are also set to exacerbate already existing environmental issues in the subregion, including soil degradation, desertification, and deforestation (World Bank 2014). As coastal populations and assets continue to grow, exposure to impacts associated with sea-level rise is also increasing. At the same time, extreme heat, combined with increased dust storms and associated deposition, can have wide-ranging impacts on air quality and on human health, especially respiratory diseases (World Bank 2019c).

Climate data for North Africa show significant warming trends over the last decades, with increases in very hot days (especially in the summer), high nighttime temperatures, and longer heat waves (Schilling et al. 2020; World Bank 2014). In much of the subregion, mean precipitation during the wet season (October to March) has also decreased over the last decades, with the strongest declines over the Mediterranean parts of Morocco and Algeria and in parts of Libya, while Mediterranean Egypt has seen a slight increase (Schilling et al. 2020).

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[21] See FAOStat data on forest cover: http://www.fao.org/faostat/en/#data/GF (accessed March 2021).

These trends are expected to continue. Under the RCP8.5 pathway, median temperatures are projected to rise by up to 7°C in the summer and 4°C in the winter, accompanied by strong increases in heat waves (Schilling et al. 2020). In Cairo, for example, the warm spell duration index could increase to 53 days in a 2°C world and to 94 days in a 4°C world (World Bank 2014). Precipitation is also expected to decrease by 10–20 percent over large parts of the subregion, resulting in greater aridity (Schilling et al. 2020).

The Inter-Sectoral Impact Model Intercomparison Project (ISIMIP) water availability and crop productivity model results for the North African countries used in this report broadly confirm these projected trends (see Appendix A.1 for further details, including maps):

- ISIMIP water models show a mostly drying trend in the northwest and west areas of the subregion, and a mostly wetter trend in eastern areas by 2050. Large areas of the Sahara show dramatic changes—both positive and negative—in water availability, but the baseline is extremely low, so results must be interpreted with caution (see Figure A.1). In the second half of this century, the RCP8.5 scenarios for water availability in the northern areas (with a more Mediterranean climate) are dire, with declines of 70–90 percent over much of those areas (Figure A.2).

- ISIMIP crop models to 2050 show a modest increase in the Nile Valley in some models, similar to oasis areas in the southwest of Libya. Results for the coastal areas of Tunisia and Algeria, and for Morocco west of the Atlas Mountains, display both areas of increased productivity and patches of decline, some of them significant (Figure A.3). The crop productivity models for 2050–2100 show declines in the northwest portion of the subregion, and in the west, declines of 30–50 percent under RCP8.5 are projected (Figure A.4).

Along the subregion's coastline, rising sea levels threaten many urban areas, agricultural lands, and economic assets (World Bank 2014). Though slightly below-average sea-level rise is anticipated in the Mediterranean basin, with 4°C of warming, cities such as Tunis could still experience a 0.56 meter (0.38–0.96 m) sea-level rise by the end of the century (2081–2100) relative to 1986–2005. On the Atlantic coast, a 0.58 meter (0.39–0.98 m) sea-level rise is projected for Tangier. Meanwhile, Alexandria is ranked at the top among cities with projected increased losses of local GDP as a result of damages from sea-level rise by 2050 (Abadie et al. 2020). Land subsidence, shoreline erosion, and rising coastal groundwater tables may also be exacerbated by sea-level rise and large storms (Befus et al. 2020; World Bank 2014). In the vast agricultural lands along the Nile Delta, rising sea levels could lead to saltwater intrusion, threatening access to freshwater for drinking and agriculture. Sea-level rise of 1 meter in the Nile Delta could lead to the loss of a third of current agricultural land (Schilling et al. 2020).

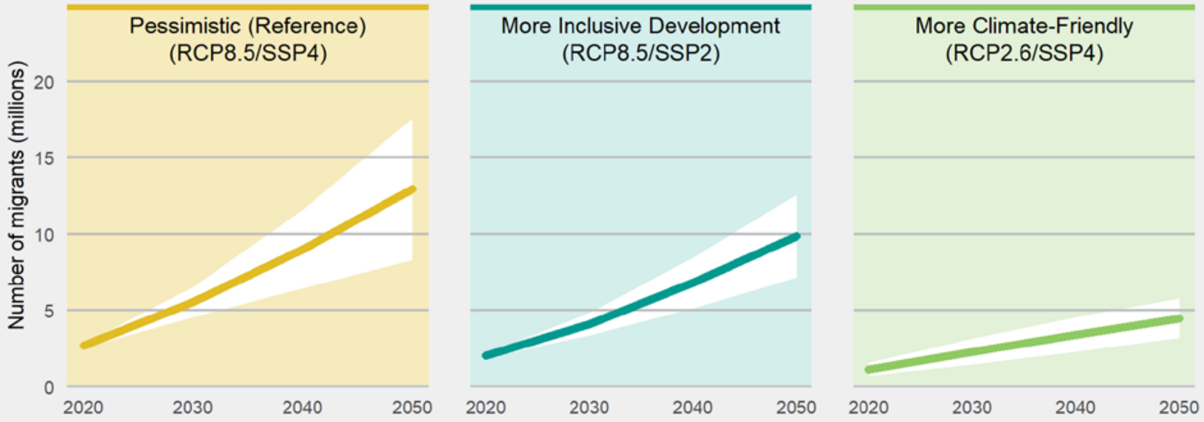
2.1.2 Projections of Climate Migration

Projected numbers of climate migrants

The number of climate migrants in North Africa is projected to increase to 2050, reaching 13.0 million (6.0 percent of the total population) in the pessimistic reference scenario (see Figure 2.3). The pessimistic reference and more inclusive development scenarios show a similar scale in 2020, but the latter shows slower growth, reaching 9.9 million climate migrants by 2050 (4.2 percent of the total population). In the more climate-friendly scenario, the number of climate migrants reaches 4.5 million by 2050 (2.1 percent of the total population). The differences between scenarios highlight the roles of both more inclusive development pathways and global emission reductions in easing climate pressures on livelihood systems and population centers.

The share of internal migrants projected to be climate migrants over the next three decades varies by scenario. The number of other internal migrants in the subregion is set to rise to 5.8 million under SSP2 and 15.0 million under SSP4 (Figure 2.4). In the pessimistic reference scenario, which combines high global emissions and SSP4's higher levels of inequality, climate and other internal migrants start from similar numbers in 2020, but by 2050, other internal migrants exceed climate migrants. However, climate migrants still make up 46 percent of total internal migrants by 2050 in that scenario.

Figure 2.3: Projected number of internal climate migrants in North Africa in three scenarios, 2020–2050

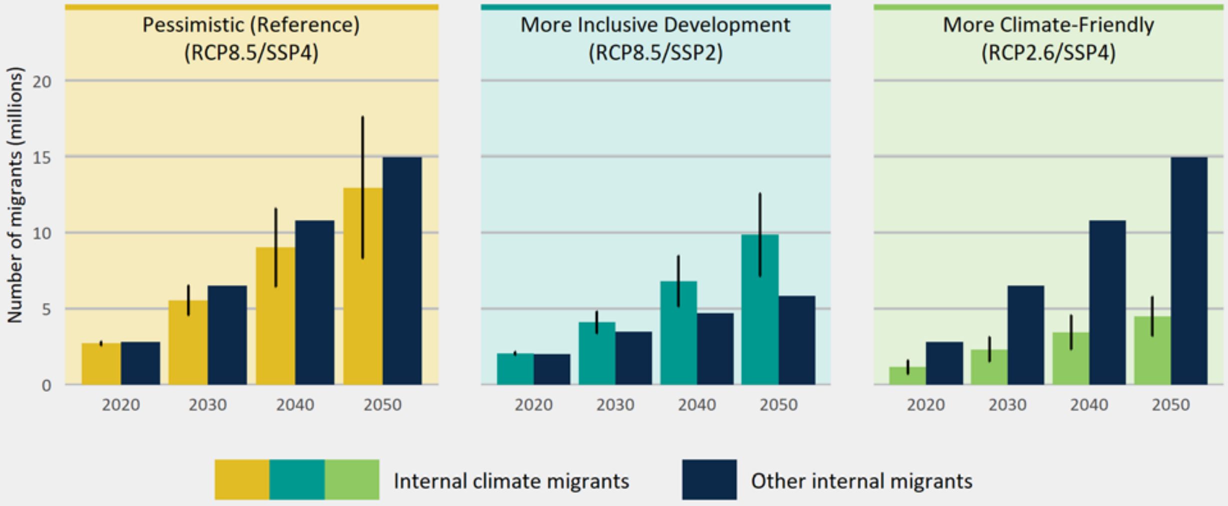


Climate migrants as a percentage of the total population

Year	2020	2030	2040	2050	2020	2030	2040	2050	2020	2030	2040	2050
%	1.4	2.8	4.3	6.0	1.1	2.0	3.0	4.2	0.6	1.1	1.6	2.1

Note: Dark lines represent the average runs for each scenario. The white areas around the central trend line represent the confidence intervals, which reflect the degree of agreement among the four model runs used to provide estimates for each scenario. Narrower confidence intervals indicate greater agreement among the model runs for each scenario. The confidence intervals get larger with each successive time interval due both to momentum that builds over time for each model run, and to increasing divergence among models as the climate change signal increases.

Figure 2.4: Projected number of climate and other internal migrants in North Africa in three scenarios, 2020–2050



Note: The whiskers on the climate migrant bars represent the 95th percentile confidence interval for the four model runs for each scenario. There are no confidence intervals for other internal migrants because only a single development trajectory is used.

In the more inclusive development scenario, meanwhile, which also reflects continued high emissions and heightened climate change impacts, climate migrants could exceed other internal migrants as early as 2030. Another important reason for this is that under SSP2, which represents a more equitable development pathway, urbanization slows and education disparities between rural and urban areas narrow, resulting in less other internal migration. In the lower-emissions, more climate-friendly scenario, in contrast, other internal migrants exceed climate migrants over the whole period, and the difference grows over time.

Projected spatial patterns of climate migration

The population of North Africa is heavily concentrated along the Nile Valley and Delta and along the Mediterranean coast, with some clusters scattered in oases in the Sahara, and extremely low population densities in most arid areas (Figure 2.5a). Projected population density patterns to 2050 in the pessimistic reference scenario are similar (Figure 2.5b). The largest cities are clustered in the north, with denser settlements along the coast. In 2018, the largest urban centers were Cairo (20 million inhabitants), Alexandria (5.0 million), Casablanca (3.7 million), Algiers (2.7 million), Tunis (2.3 million), Rabat (1.8 million), Fes (1.2 million), Tripoli (1.2 million), and Tangiers (1.1 million) (UN DESA 2018a).

The share of North Africans living in urban areas has grown steadily over the past 50 years, except in Egypt, where it has stabilized since the 1970s and remains one of the lowest in the Middle East and North Africa region (UN DESA 2018b). Two reasons behind the expansion of cities are a high rate of natural increase in towns, leading to their reclassification as urban areas, and high levels of rural-urban migration, as discussed above. By 2015–2020, urban population growth had begun to slow in most of the region, to 1.5–2.6 percent per year (UN DESA 2018b). By 2050, the urban share of the five countries' population is expected to reach around 77 percent.

Figure 2.6 displays the change between the baseline 2010 population density and the 2050 population density projection for the pessimistic reference scenario, in terms of both the absolute change and the percentage change. The largest absolute projected increases in population density occur in the Nile Valley and Delta, a small area close to Tripoli, and the Algerian coast. Absolute declines appear in the north of Tunisia and north and west of Morocco, where some points of increase are also visible. There are some high percentage changes in the desert regions, but they are a function of low baselines.[22]

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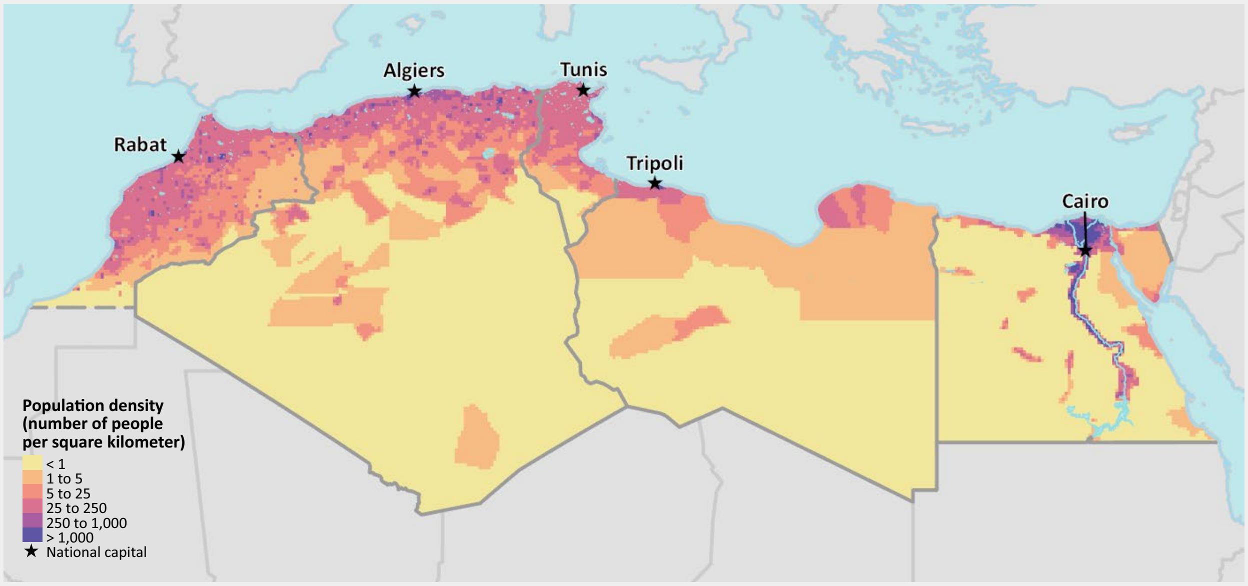
[22] Larger census units in southern Algeria and Libya spread small populations over large areas, in some cases resulting in fractions of people per grid cell. Doubling or halving of the population in this context is not meaningful. Egypt, by contrast, has higher resolution census data and more "zero population" areas in the desert.

Figure 2.5: Baseline population density, 2010, and projected population density in the pessimistic reference scenario, 2050, North Africa

a. 2010



b. 2050

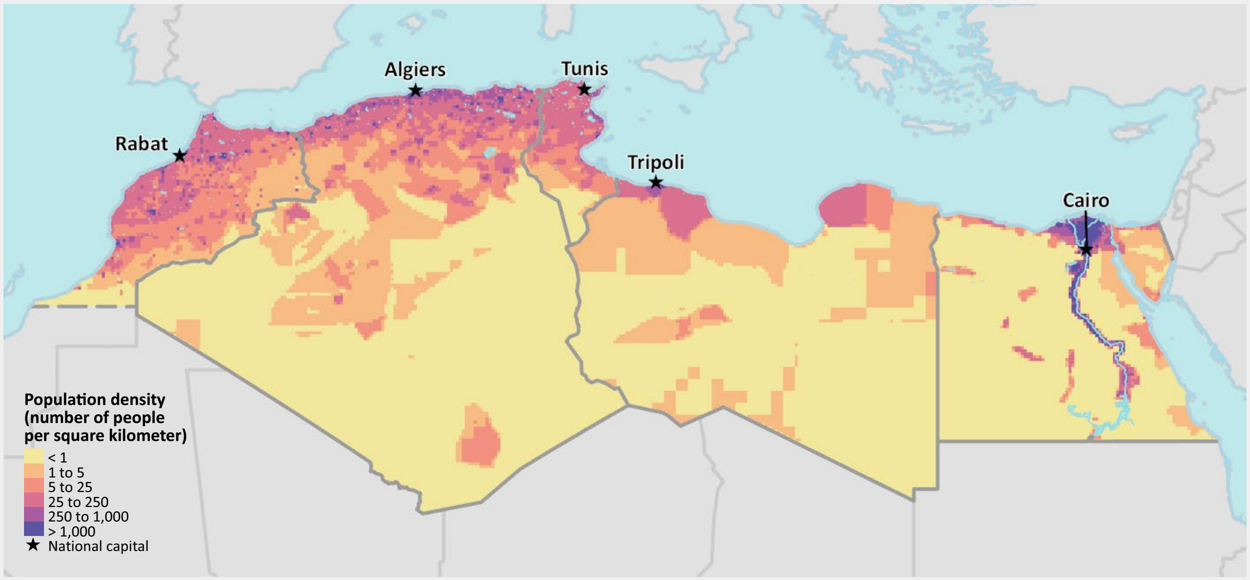
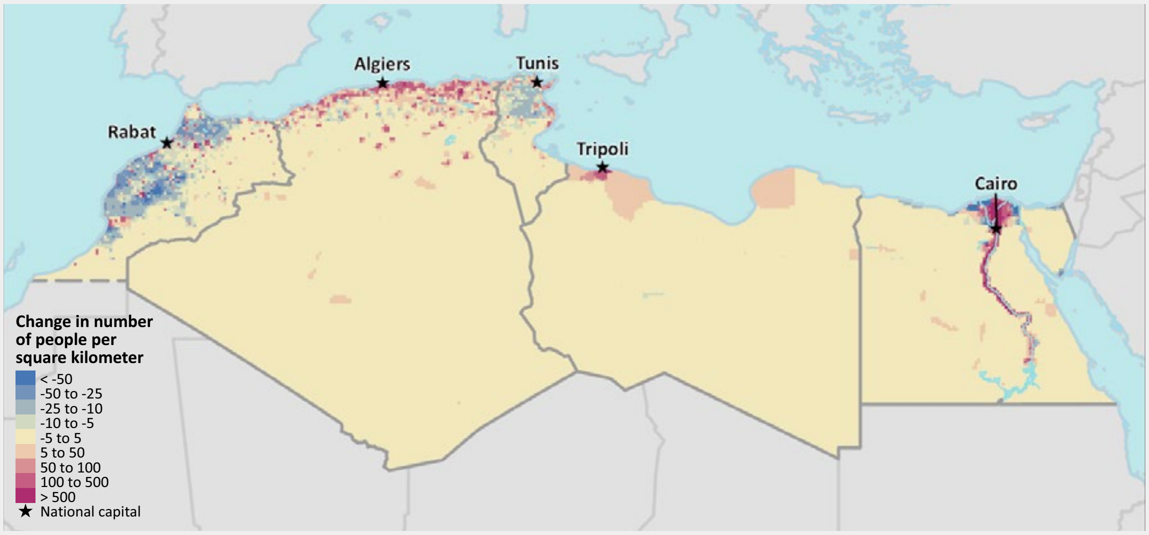
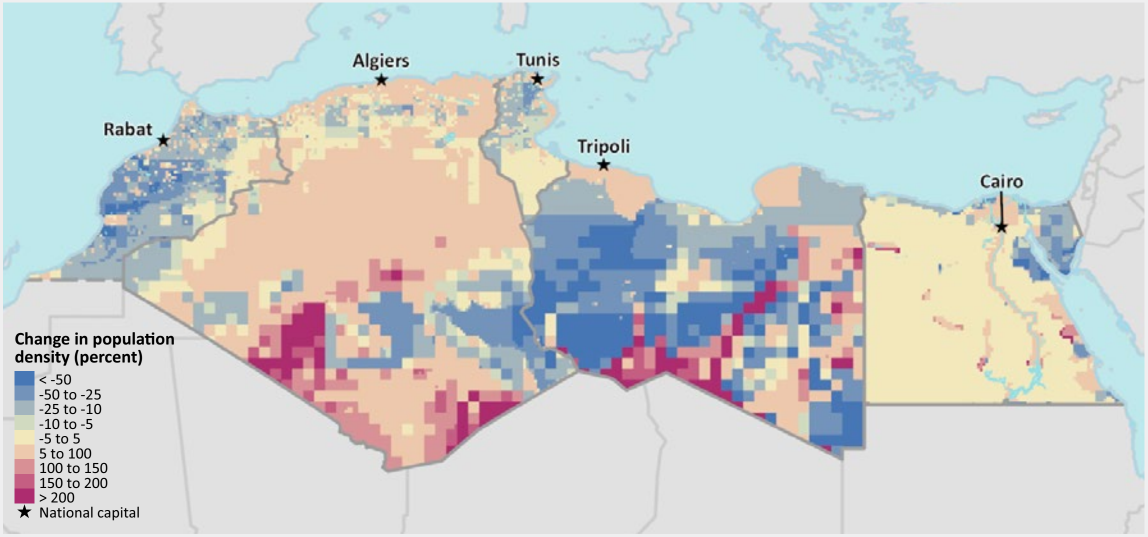


Figure 2.6: Absolute and percentage change in population density in North Africa in the pessimistic reference scenario, 2010–2050

a. Change in population density



b. Percentage change in population density



By 2030, climate migration hotspots begin to emerge, and by 2050, these spread and intensify all over the subregion (Figure 2.7). Climate out-migration hotspots include important coastal areas, such as the eastern and western parts of the Nile Delta (including Alexandria); the northeast coast of Tunisia, including Kelibia; coastal areas in northwest Algeria, including Oran; and smaller areas of the west and southwest coast of Morocco, including Agadir and Safi. Overall, rural coastal areas also tend to see climate out-migration. Driven mainly by declining water availability, population growth in these coastal areas could thus be dampened. In the Nile Delta, sea-level rise and decreased water availability drive climate out-migration. Certain inland areas affected by increasing water scarcity are also projected to be climate out-migration hotspots, such as the central Atlas foothills of Morocco, which are mainly rainfed cropland areas.

Climate in-migration hotspots are expected in the Nile Valley and central Delta; the north and south coast of Tunisia, including the Gulf of Gabes; the eastern section of the Algerian coast, and the northern coast of Morocco. These climate in-migration hotspots include large and mid-size urban areas such as Cairo, Algiers, Tunis, Tripoli, the Casablanca-Rabat corridor, and Tangiers, amplifying projected population growth trends in these areas. Mainly due to topography—either moderately higher elevations, as in the central Nile Delta, or coastal escarpments, as in much of the rest of North Africa— the impacts of sea-level rise may be less pronounced, and they may be offset by better climate conditions. Specifically, climate in-migration hotspots coincide with areas projected to have increased crop productivity and water availability in many of the ISIMIP model runs, including very arid areas in southern Algeria (where the oasis and city of Tamanrasset are located). These projections do not take into account the current carrying capacity of agricultural lands in the Nile Valley and arid areas.[23] If the model placed limits to growth in already heavily populated or resource-constrained agricultural regions, it is likely that migrants would be pushed elsewhere, perhaps further to cities. Libya has far fewer hotspots for several reasons including population density and spatial patterns, and convergence of the water availability and crop productivity models.[24]

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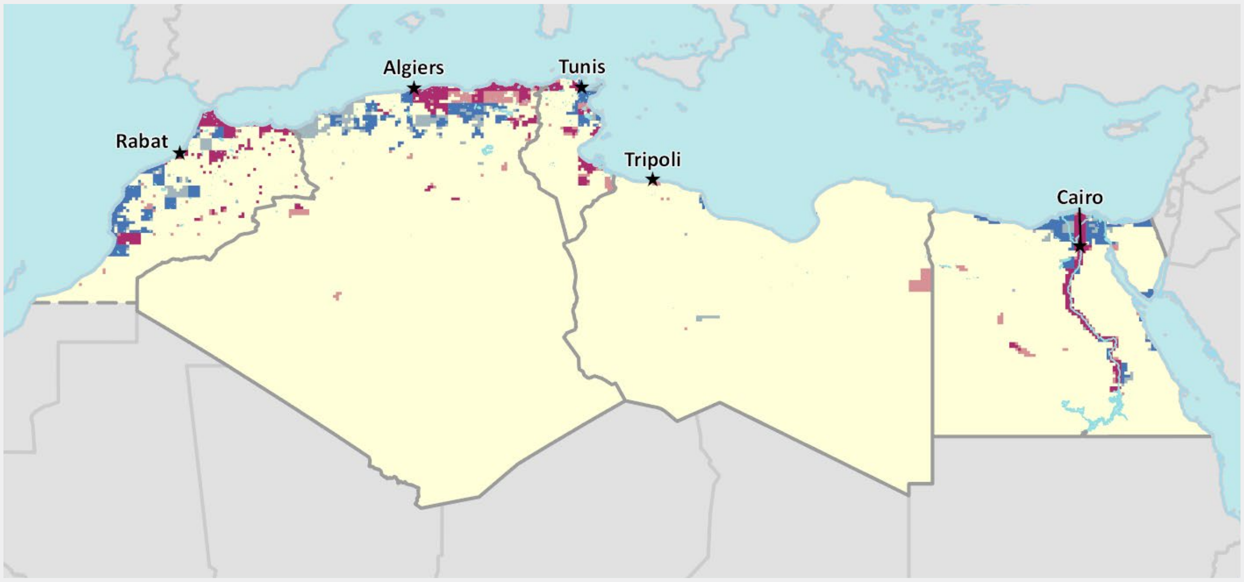
[23] They also ignore technological advances or adaptation responses that might make these regions better able to sustain large populations.

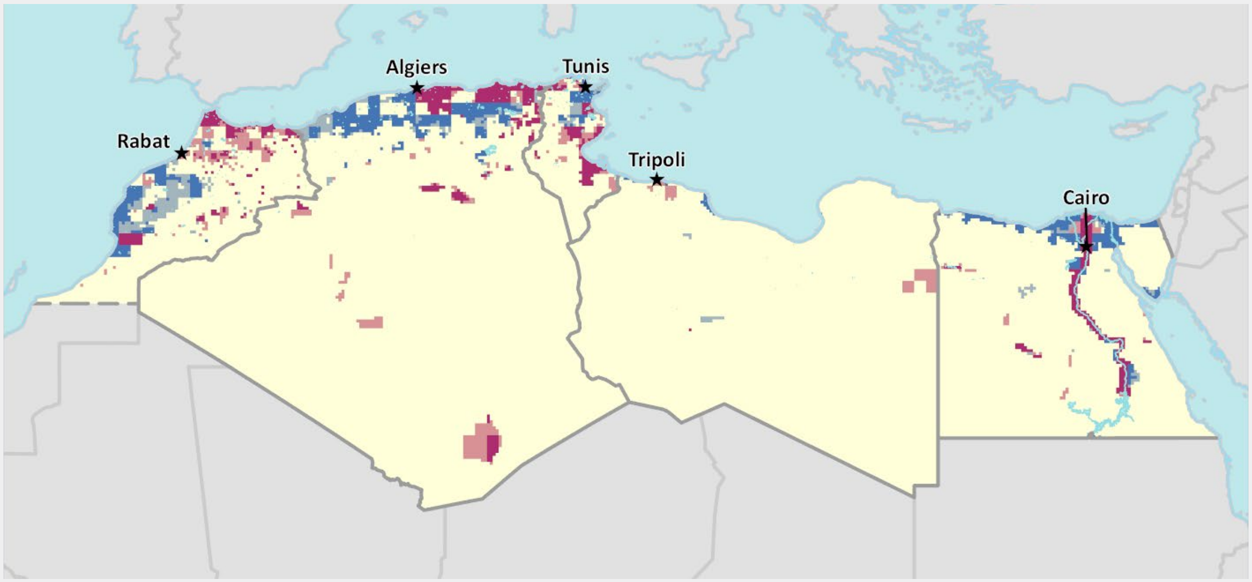
[24] The main reason why Libya has far fewer hotspots is that with only 6.7 million inhabitants, the country is home to less than 3 percent of the subregion's population. By definition, hotspots generally occur in more densely populated areas. In the case of North Africa, this would be Egypt (42 percent of subregion's population), Algeria (18 percent), and Morocco (15 percent). Libya's population is half the size of Tunisia's but spread over a much greater area. Second, about 93 percent of Libya's population lives within 100 kilometers of the coast, which means that mobility is circumscribed within a very narrow band. Lastly, there is divergence in the ISIMIP water availability and crop productivity models in that coastal band. Particularly, the Hadley model projects the opposite of the IPSL model, meaning that the likelihood of two out of three or three out of three scenarios agreeing (definition of hotspots) is far smaller in Libya than in other countries.

Figure 2.7: Hotspots projected to have high levels of climate in-migration and climate out-migration in North Africa, 2030 and 2050

a. 2030



b. 2050



IN-MIGRATION

- ■ High certainty in high levels of climate in-migration
- □ Moderate certainty in high levels of climate in-migration

OUT-MIGRATION

- ■ High certainty in high levels of climate out-migration
- □ Moderate certainty in high levels of climate out-migration

Note: High certainty reflects agreement across all three scenarios modeled, and moderate certainty reflects agreement across two scenarios. In- and out-migration hotspots are thus areas in which at least two scenarios concur on density changes in the top 10th percentile of the density distribution, which in North Africa represents an increased population density in 2050 of about 0.72 to 2.66 people per km^2, depending on the scenario. For decreased population density, it is about minus-1.03 to minus-2.74 people per km^2.

Trends in livelihood zones

The distribution of livelihood zones is presented in Figure 2.8 for the baseline year of 2015, following the anthropogenic biome classes defined by Ellis et al. (2010).[25] Seminatural and wildlands cover most of North Africa. A band of pastoral lands and rangelands (which widens from east to west) separates those from the rainfed croplands on and near the Mediterranean coast. Irrigated crops occupy the Nile Valley and Delta, with some patches in the rainfed croplands of Tunisia, Algeria, and Morocco. There are dense settlements across the subregion, including oasis towns in the very arid south, such as Tamanrasset in Algeria and Murzuq in Libya.

Figure 2.9 shows the projected net change in the number of climate migrants by 2050 for each livelihood zone. It is important to recognize that this represents migration into or out of the zones and does not imply changes in the livelihoods of those who migrate. Positive net climate migration is expected in dense settlements in the three scenarios, and to lesser extent in rice-growing areas (concentrated almost exclusively in the low-lying Nile Delta), due to better water availability conditions. Negative net climate migration on the order of 350,000–1.2 million people, depending on the scenario, is projected for irrigated croplands, many of which are close to coastal areas threatened by sea level rise—for example, in Egypt. Rainfed croplands also see negative net climate migration, but to a lesser extent.

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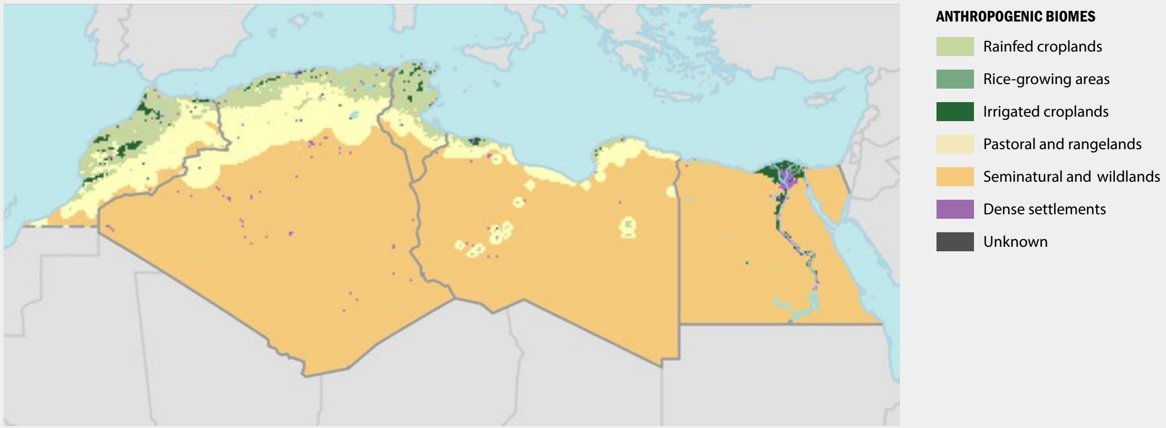
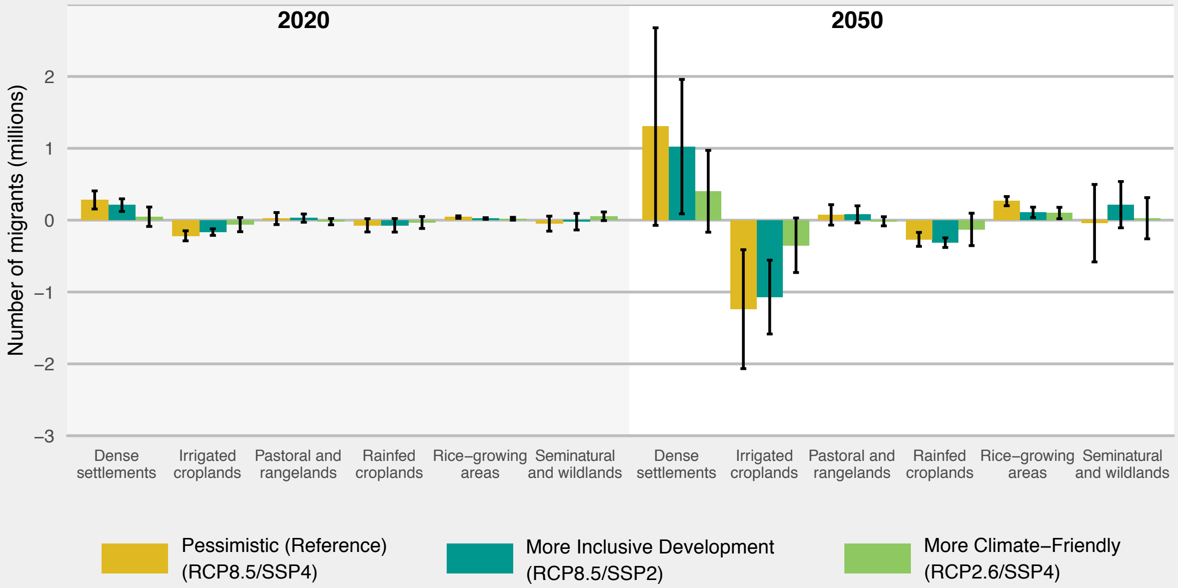
[25] The livelihoods zones used in the Groundswell reports represent an aggregation of anthropogenic biome classes in Ellis et al. (2010) into areas with relatively coherent livelihood characteristics. Note that although it is known that zones will shift with climate change, no projections of those shifts are available, so for the modeling presented in this report, the distribution of zones is assumed to remain static through 2050.

Figure 2.8: Livelihood zones in North Africa, by anthropogenic biome, 2015



Source: Ellis et al. (2010).

Figure 2.9: Projected net climate migration in and out of livelihood zones in North Africa in three scenarios, 2020–2050

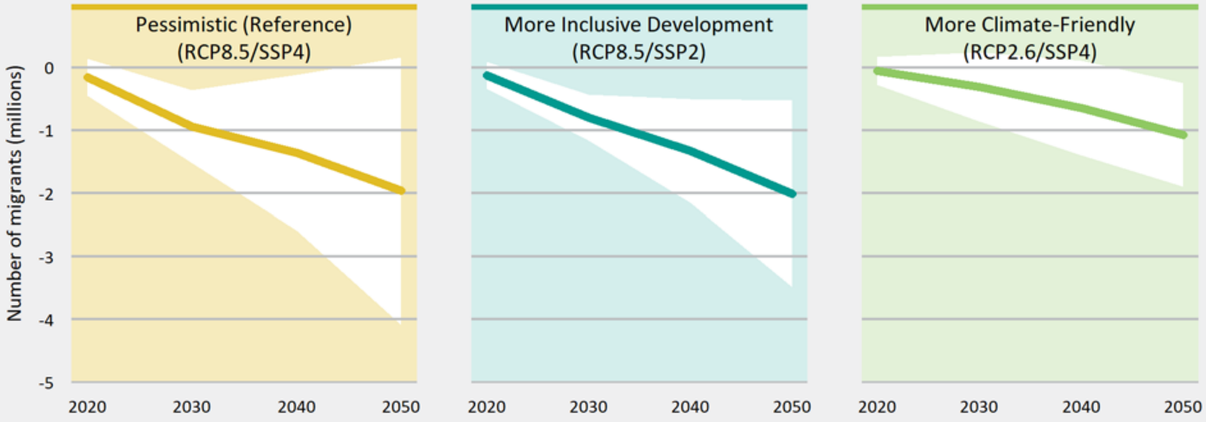


Note: Whiskers show 95th percentile confidence intervals for climate migrants.

Trends in coastal zones

As noted, some coastal areas in North Africa are highly exposed to the impacts of sea-level rise and, in some areas, increased water scarcity, with the model shows several becoming climate out-migration hotspots. Other coastal areas are less impacted by seal-level rise due to their topography and are expected to see improved crop productivity and water availability. They are projected to be hotspots of climate in-migration. On balance, however, coastal areas are projected to experience net negative climate migration across the three scenarios (Figure 2.10), at around minus-2 million in the high-emissions scenarios (pessimistic reference and more inclusive development) and around minus-1 million in the more climate-friendly scenario. As mentioned earlier, the Nile Delta is a significant contributor to these net out-migration numbers. There is high uncertainty under the RCP8.5 scenarios, however, due to large variations across the model runs in results for other climate change impacts, water availability, and crop productivity.

Figure 2.10: Projected net climate migration in and out of coastal zones in North Africa in three scenarios, 2020–2050



Note: Dark lines represent the average runs for each scenario. The white areas around the central trend line represent the confidence intervals, which reflect the degree of agreement among the four model runs used to provide estimates for each scenario. Narrower confidence intervals indicate greater agreement among the model runs for each scenario. The confidence intervals get larger with each successive time interval, due both to momentum that builds over time for each model run, and to increasing divergence among models as the climate change signal increases.

Trends in urban areas

From a baseline of 54 million people in 2010, urban populations in North Africa are projected to increase to 73–82 million by 2050 (under SSP2 and SSP4, respectively). Similarly, the spatial extent of urban areas is projected to increase by 2050 (Figure 2.11). Climate migration projections in the three scenarios indicate positive net climate migration for urban areas, amplifying projected urban population growth trends. This reinforces projections that several major cities will be in-migration hotspots, including Cairo, Tripoli, Tunis, Algiers, and Rabat (Figure 2.12). The numbers are much larger for the pessimistic reference scenario (around half a million by 2050), compared with the more inclusive development and the more-climate friendly scenarios (both below 250,000 by 2050). However, these numbers are a small fraction of the projected 2050 urban population for the subregion. Uncertainty is also high, as shown by the confidence intervals ranging from negative to positive values.[26] Overall, the picture for urbanization for North Africa suggests that climate migration will give a modest boost to population numbers.

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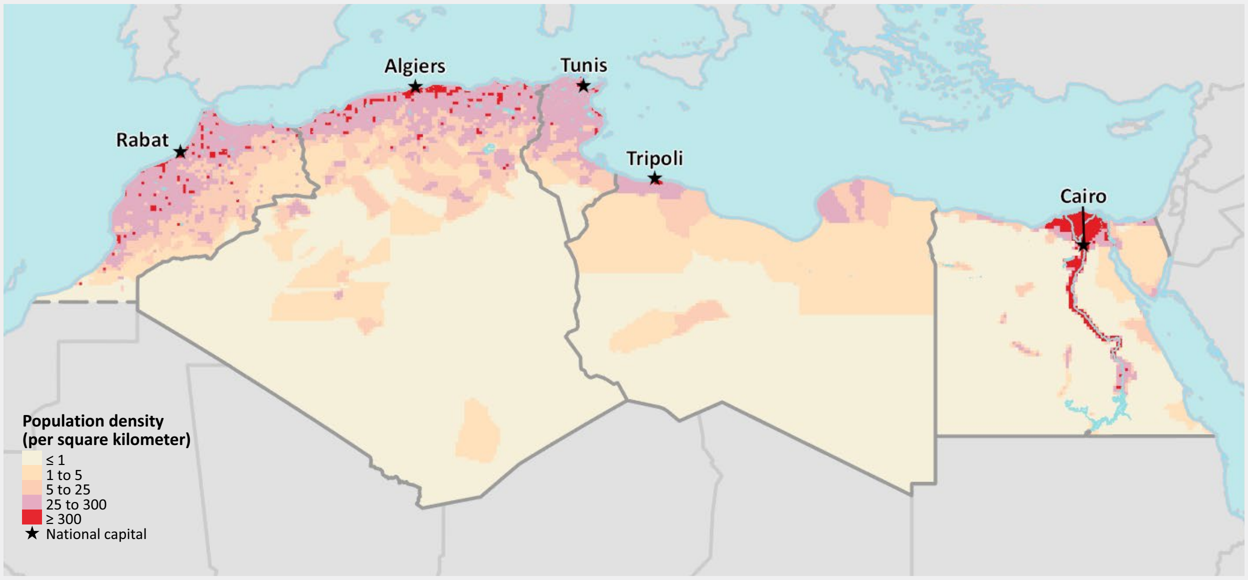
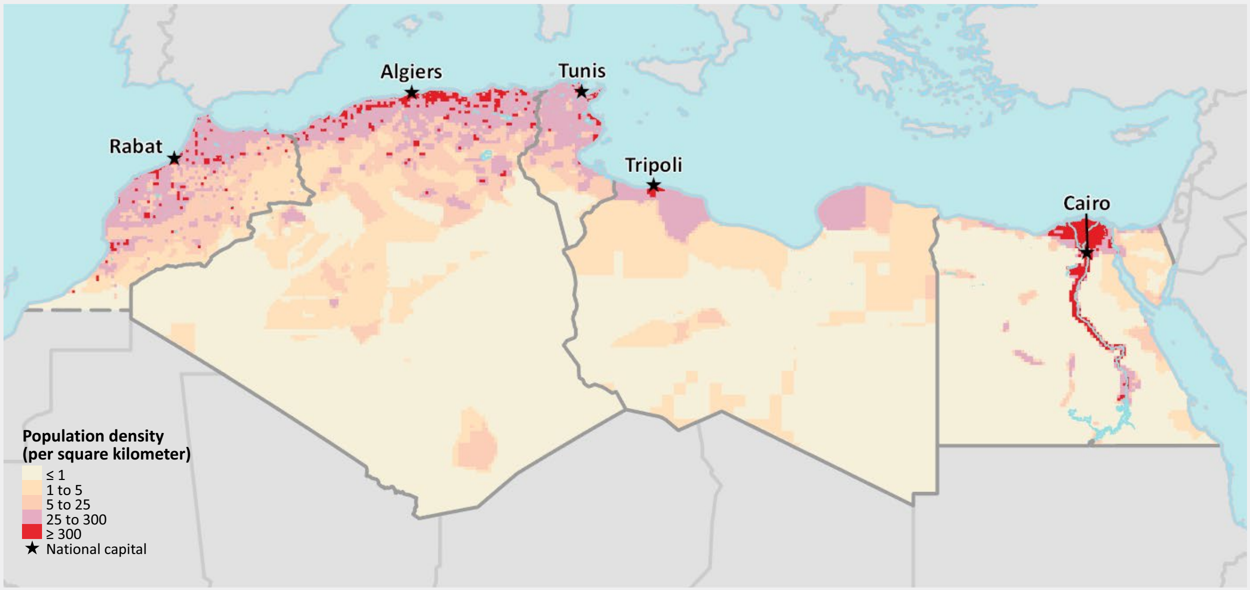
26. Generally, the smaller the area, the larger the confidence intervals, because of the impact of extreme values in small areas on the spread.

Figure 2.11: Baseline and projected population density in urban areas of North Africa, 2010 and 2050

a. 2010

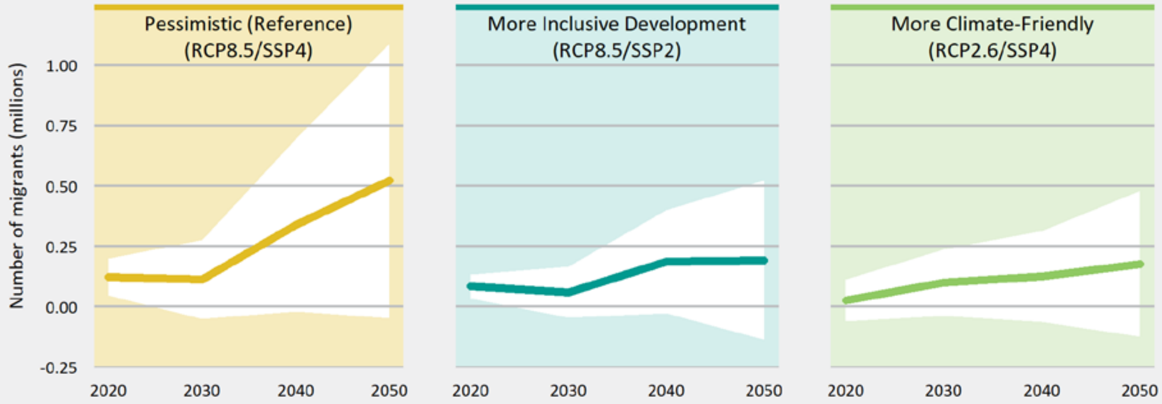


b. 2050



Note: An "urban" area is an area with density of at least 300 people per km^2. The map for 2050 shows all areas in which any one of the three scenarios has populations of such density. It thus represents plausible urbanization outcomes rather its more likely spread.

Figure 2.12: Projected net climate migration in and out of urban areas in North Africa in three scenarios, 2020–2050



Note: Dark lines represent the average runs for each scenario. The white areas around the central trend line represent the confidence intervals, which reflect the degree of agreement among the four model runs used to provide estimates for each scenario. Narrower confidence intervals indicate greater agreement among the model runs for each scenario. The confidence intervals get larger with each successive time interval, due both to momentum that builds over time for each model run, and to increasing divergence among models as the climate change signal increases.

Photo Credit: World Bank

2.2 CLIMATE MIGRATION PROJECTIONS FOR THE LOWER MEKONG

Key Findings

- **The analysis for the Lower Mekong subregion shows internal climate migration increasing by 2050 in all three scenarios. In the pessimistic reference scenario, the projected number of climate migrants is 6.3 million, or 2.7 percent of the total population of the subregion. In the more inclusive development scenario, the projection is 4.1 million (1.6 percent of the total population), and in the more climate-friendly scenario, it is 3.3 million (1.4 percent of the total population).**

- **The share of internal migration that is driven by climate change by 2050 varies by scenario: from 12 percent in the more climate-friendly scenario, to 22 percent in the pessimistic reference scenario, to 29 percent in the more inclusive development scenario.**

- **Climate out-migration hotspots by 2050 are projected in the coastal portions of the Vietnam Mekong Delta, Ho Chi Minh City, coastal areas of northern Vietnam near Thanh Hoa and Vinh, as well as central Thailand and Myanmar, with a dampening effect on projected population growth trends in these areas. Hotspots in the Mekong Delta, Ho Chi Minh City, and south of Hanoi near Thanh Hoa correspond to areas projected to be affected by sea-level rise, while those in central Thailand and Myanmar coincide with areas affected by declines in water availability and crop productivity, respectively.**

- **Climate in-migration hotspots are expected in southern Thailand (Malay Peninsula); the inner portions of the Vietnam Mekong Delta (surrounding the out-migration hotspots); coastal areas of eastern Vietnam; the Red River Delta in northern Vietnam, including Hanoi (downstream from the out-migration hotspot); a small area southeast of Phnom Penh in Cambodia along the Mekong River; southern Myanmar around Hinthada; and patches along the Irrawaddy River upstream from the delta. Climate change could amplify projected population growth trends in these areas. A common pattern in the Mekong and Irrawaddy Deltas is population growth in upstream, higher-elevation areas. Hotspots along the coast of Vietnam and in southernmost Thailand, along the Gulf of Thailand, coincide with areas projected to see increases in water availability, while those in Cambodia and Myanmar are in areas expected to see increases in both water availability and crop productivity. Rainfed croplands and rice growing areas are key livelihood zones that are likely to see greater population growth due to climate in-migration.**

2.2.1 Subregional Context

Development and economic context

The Lower Mekong subregion comprises Cambodia, Lao PDR, Thailand, and Vietnam (Figure 2.13). Cambodia, Lao PDR, Myanmar and Vietnam are classified as lower-middle income, while Thailand is considered upper-middle income.[27] Total GDP for the subregion was US$927 billion in 2019.[28] Thailand and Vietnam, which had GDPs of US$544 billion and US$262 billion, respectively, in 2019, have by far the largest economies, together accounting for 86–87 percent of the subregion's economic output every year since 2010.[29] The economy of the subregion is closely tied to that of neighboring China, and it has benefited from China's rise. The Thai economy boomed in the 1980s, and this was followed by rapid growth in Vietnam in the 2000s and more recent growth in Cambodia and Lao PDR. With the exception of Thailand, which was hard-hit by the 2008 financial crisis and has seen fluctuating growth rates since, the region enjoyed robust growth in 2010–2018, averaging 6.5–7.6 percent per year, though Lao PDR and Myanmar's growth slowed in 2019.[30]

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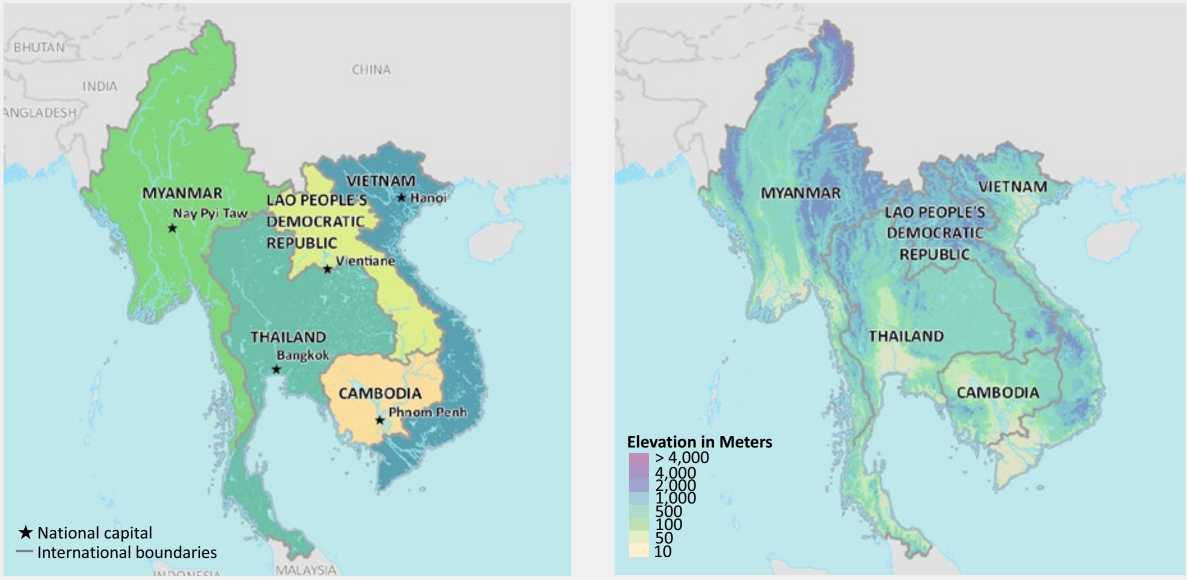
[27] See World Bank income classifications (this report reflects updates as of fiscal 2021): https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups.

[28] In current U.S. dollars—see World Bank GDP data: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=KH-LA-MM-TH-VN.

[29] Prior to 2010, the two countries' share of the subregion's economic output was even greater, as high as 93 percent in 2002. All data in current U.S. dollars—see World Bank GDP data: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=KH-LA-MM-TH-VN.

[30] See World Bank GDP annual growth data: https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?locations=KH-LA-MM-TH-VN.

Figure 2.13: Country boundaries and elevation for the Lower Mekong


a. Country boundaries

b. Elevation

Agriculture and natural resources from the Mekong River and its tributaries continue to play a dominant role in the economies and livelihoods of all Lower Mekong countries (World Bank 2020c; WWF 2016; Stillman and Rillo 2015). Urban livelihood opportunities have expanded in recent years, especially in manufacturing, services, and construction. Urban employment often provides more reliable wage-labor opportunities, higher pay, and greater access to public services such as health care and education (UNESCO et al. 2018a). Though sectoral breakdowns vary by country, overall, the subregion's economy is diversified, with about 45 percent of GDP coming from the service sector, 33 percent from industry, and 22 percent from agriculture (WWF 2016).

Despite the accelerated economic growth in recent decades, poverty gaps still persist, with significant differences across countries. While only 0.5 percent of people in Thailand lived on less than US$3.20 per day as of 2018, the share was 6.6 percent in Vietnam, 15.0 percent in Myanmar, and 37.4 percent in Lao PDR.[31] Of the 189 countries ranked in the 2020 Human Development Index, Thailand was No. 79, Vietnam was No. 117, Lao PDR was No. 137, Cambodia was No. 144, and Myanmar was No. 147 (UNDP 2020). Human Capital Index values range from 0.5 in Lao PDR and Myanmar, to 0.7 in Vietnam.[32] Women made up 40 percent of Myanmar's labor force in 2019, and 46–49 percent in the other countries.[33]

Agriculture remains one of the most important livelihood sources in the subregion, although the sector's importance has declined as all the countries' economies diversify (Table 2.3). The sector accounts for a significant share of employment, and large shares of all the countries' population live in rural areas, though to a lesser extent in Thailand. Agricultural livelihoods center mainly on rice production, which uses about 40 percent of the subregion's cropland (Cosslett and Cosslett 2018). In Cambodia, rice accounts for 70 percent of crop production and 80 percent of cultivated land (Oudry, Pak, and Chea 2016). Vietnam and

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[31] See World Bank poverty headcount data (2011 PPP): https://data.worldbank.org/indicator/SI.POV.LMIC?locations=KH-LA-MM-TH-VN. The Myanmar figure is for 2017, as no 2018 figure was available as of this writing. No US$3.20 poverty headcount data were available for Cambodia, and the latest poverty headcount by the country's own national poverty line was from 2012: 17.7 percent. See https://data.worldbank.org/indicator/SI.POV.NAHC?locations=KH-LA-MM-TH-VN.

[32] The Human Capital Index calculates the contributions of health and education to worker productivity. The final index score ranges from 0 to 1 and measures the productivity as a future worker of child born today relative to the benchmark of full health and complete education. See World Bank data: https://data.worldbank.org/indicator/HD.HCI.OVRL?locations=KH-LA-MM-TH-VN.

[33] See World Bank data for female share of the labor force: https://data.worldbank.org/indicator/SL.TLF.TOTL.FE.ZS?locations=KH-LA-MM-TH-VN.

Thailand, where fertile deltas and extensive irrigation systems facilitate large-scale commercial cultivation, are the fifth and sixth largest rice-producing countries in the world, respectively.[34] In Vietnam, the Mekong Delta produces about half the country's supply of rice, 65 percent of aquaculture, and 70 percent of fruit, as well as 95 percent of rice exports and 60 percent of fish exports (MRC 2019b).

Table 2.3: Agriculture sector indicators for the Lower Mekong

	Cambodia	Lao PDR	Myanmar	Thailand	Vietnam
Agriculture, forestry, and fishing, value added (% GDP)	20.7	15.3	21.4 (2018)	8.0	14.0
Agriculture (% employment)	34.5	61.4	48.9	31.4	37.2
Rural population (% of total population)	76.2	64.4	69.1	49.3	63.4

Source: All 2019 data, except where indicated, from World Bank Open Data (http://databank.worldbank.org).

Fisheries are also vital sources of food and livelihoods for millions of people in the subregion. The inland captured fisheries of the Lower Mekong Basin are among the world's largest, with a total catch estimated at 2.3 million tons and valued at US$11 billion per year.[35] In Cambodia, the world's fourth largest inland fishery, fisheries represent 10 percent of GDP and 80 percent of animal protein in the average diet (Oudry, Pak, and Chea 2016). Between 2008 and 2017, aquaculture production grew by an average of 20 percent per year, driven by urbanization, exports, and changes in consumption patterns (Joffre et al. 2019).

The Mekong River is central to the development of the subregion not only for its role in agriculture and fisheries, but also as a source of water and hydropower and a means of transportation (Sabo et al. 2017; MRC 2019b). Even in Vietnam, where the delta is a smaller portion of total land area, the Mekong Delta produces 12.6 percent of GDP (World Bank 2020c). However, several factors are limiting the river's ability to continue to sustain the subregion, including engineering projects and other impacts of development and urbanization, related changes in sedimentation and water flows, and climate change. Dams and altered river flow can restrict nutrients, modify riverbank erosion and flood patterns, and affect crop production and fish stocks. Such impacts increase susceptibility to sea-level rise and saltwater intrusion, while altering the river's hydrological regime (Yoshida et al. 2020; Olson and Morton 2018).

Population dynamics

As of 2019, around 243 million people lived in the Lower Mekong countries, with annual population growth rates between 0.3 percent (Thailand) and 1.5 percent (Lao PDR).[36] The rates of natural increase (births minus deaths) range from 0.2 percent (Thailand) to 1.6 percent (Lao PDR) (PRB 2020). As shown in Figure 2.14, by 2050, the population is expected to grow to 252 million under the moderate development pathway (SSP2) and decrease to 235 million under the unequal development pathway (SSP4).[37]

Urbanization is an important factor in the demographic dynamics of Lower Mekong countries. The entire subregion has seen increased urbanization in recent years, though the urban share of their respective populations varies significantly, from an estimated 24.2 percent in Cambodia, to 51.4 percent in Thailand (UN DESA 2018b). As shown in Figure 2.15, though the urban share of the population is still projected to continue to grow in 2020–2050, urban population growth is projected to slow significantly across the subregion, except in Myanmar, with the most significant slowdown in Thailand.

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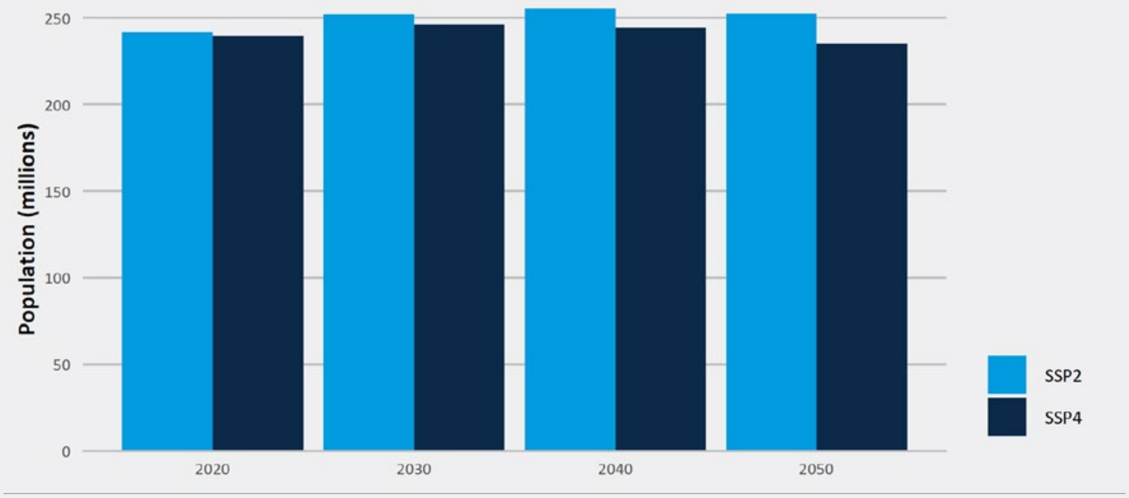
[34] See FAOSTAT data on paddy rice production for 2017–2019: http://www.fao.org/faostat/en/#data/QC (retrieved April 10, 2021).

[35] See the Mekong River Commission's fisheries information page: https://www.mrcmekong.org/our-work/topics/fisheries/ (accessed January 20, 2021).

[36] See World Bank data on annual population growth: https://data.worldbank.org/indicator/SP.POP.GROW?locations=KH-LA-MM-TH-VN.

[37] These SSP population scenarios use data from World Population Prospects 2010 for the baseline; see https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=10#v2 and further details in Riahi et al. (2017). Under SSP4, population growth is projected to be low in middle-income countries. All the Lower Mekong countries are classified as middle-income, and the SSP4 scenario assumes low population growth or even modest declines for these countries. Under SSP2, population growth is moderate in middle-income countries.

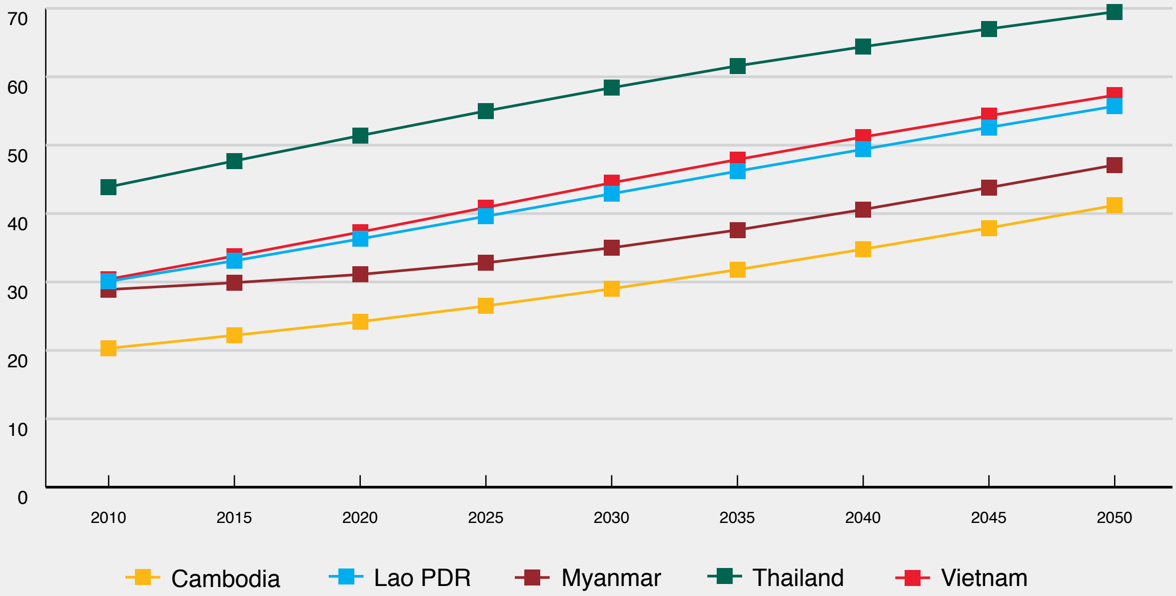
Figure 2.14: Projected population in the Lower Mekong region under two Shared Socioeconomic Pathways, 2020–2050



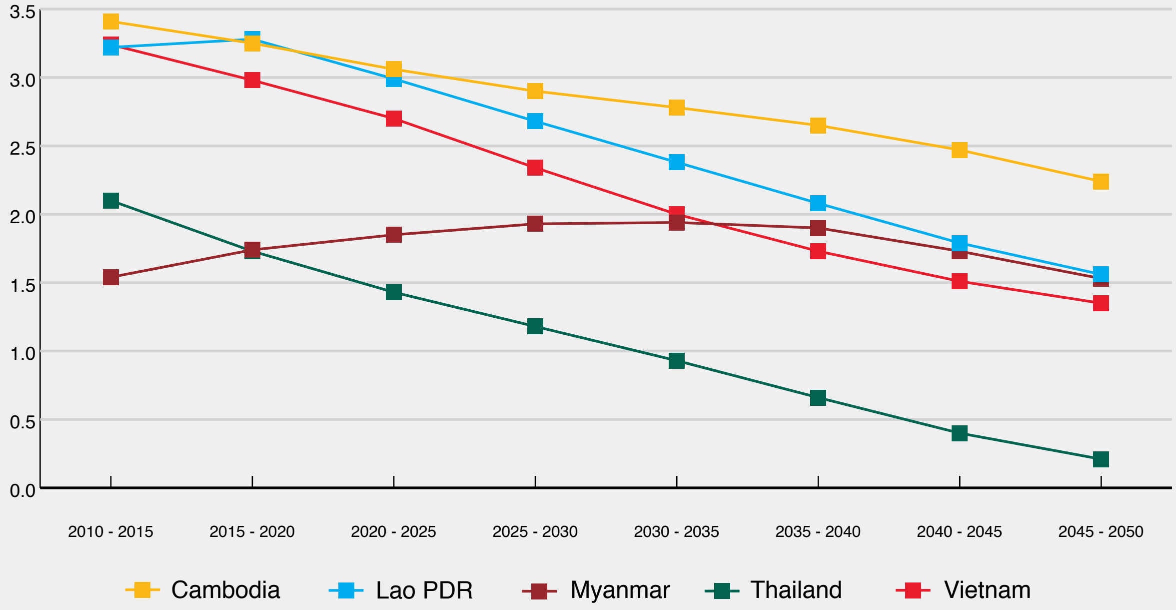
Source: Jones and O'Neill (2016). Note: SSP2 = moderate development and SSP2 = unequal development

Figure 2.15: The urban transition in Lower Mekong countries

a. Urban share of population (percent), historical and projected, 2010–2050



b. Average annual growth rate of urban population (percent), historical and projected, 2010–2050



Source: Urban share of population and growth rate – UN DESA (2018b).

Migration dynamics

The Lower Mekong countries of Vietnam, Cambodia, and Lao PDR were wracked by conflicts through the end of the 1970s, which resulted in massive displacement and refugee flows. Countries in the subregion followed different paths after that, with countries experiencing greater (Thailand) or lower (Vietnam, Myanmar, Lao PDR, Cambodia) levels of internal migration and urbanization based on their policies and economic development. Overall, large differences in poverty rates between urban and rural areas, together with changes in agriculture and labor demand in cities, fueled out-migration from rural areas and increasing urbanization (UNESCO et al. 2018a; Hugo 2016). Recent conflict situations, particularly in Myanmar, have also led to refugee flows into neighboring countries.[38]

Key push factors for migration both within and between countries in the subregion include high rates of rural poverty, landlessness, displacement due to land development and land use change, population pressures, and environmental stressors such as severe floods and drought (Bylander 2016; UNESCO et al. 2018a). Population pressures and overexploitation of natural resources can also drive small-scale farms and fisheries into debt, exacerbating poverty and landlessness in rural populations (Betcherman, Haque, and Marschke 2021).

Rural to urban migration is an important driver of urban growth and tends to be long-term, although migration patterns are complex, and there is also some circular migration (ADB 2016). Higher-paid urban jobs attract migrants from rural areas, and they often send remittances from the cities, which mitigate rural poverty. Such migration can also diminish the rural labor force, however, reducing the number of young workers and agricultural productivity (UNESCO et al. 2018a). In some cities, including Vientiane, rural-urban migration has also overburdened the urban labor market to a certain extent and become a driver for cross-border labor migration (UNESCO et al. 2018c). Migration also occurs through resettlement programs that target high flood risk areas or dam construction zones (Ty, Van Westen, and Zoomers 2013; UNESCO et al. 2018b; 2018d).

Women make up a growing share of internal migrants in the subregion. Constrained labor markets in rural areas, along with gendered roles in livelihoods such as rice production, have pushed women to migrate and seek opportunities in cities—for instance, in Vietnam (Lovell, Shennan, and Thuy 2020). Studies also suggest that women are likelier to undertake seasonal labor migration, while men are likelier to stay behind. For example, in Myanmar, where agricultural employment is already highly seasonal, with about two-thirds of days worked in the wet season and the remainder in the dry season, women's work is even more seasonal than men's (Testaverde, Moroz, and Dutta 2020).

Climate risks are significant stressors across the subregion that influence mobility patterns. Vietnam, Thailand, and Myanmar consistently ranked in the top 10 countries for climate-related loss events in the 1999–2018 period, and Cambodia was in the top 20 (Eckstein et al. 2019).[39] Where livelihoods are no longer economically viable in the Lower Mekong, some households have adopted a practice of seasonal relocation for labor (see, e.g., Jiao, Zheng, and Liu 2020).

Several strategies, including migration, are used to cope with periods of prolonged climatic stress and with the seasonality of agricultural production, land pressure, and economic crises in the subregion (Warner et al. 2012). Research carried out in Ban Puang subdistrict in Lamphun province, south of Chiang Mai in northern Thailand, found that villagers reported being regularly exposed to rainfall-related stress, including dry spells, heavy rainfall, and flash floods (Curran and Meijer-Irons 2014). Most had access to assets that enabled them to cope, and migration was seen as an additional option to manage environmental and other risks and make households more resilient, such as by using remittances to finance education and diversify livelihoods. Another study, focused on the impact of climate change on both out-migration and return migration to Nang Rong District in northeastern Thailand, a drier area of the country, found that climate factors appeared to play a greater role in reducing return migration than in driving the original departures (Entwisle, Verdery, and Williams 2020).

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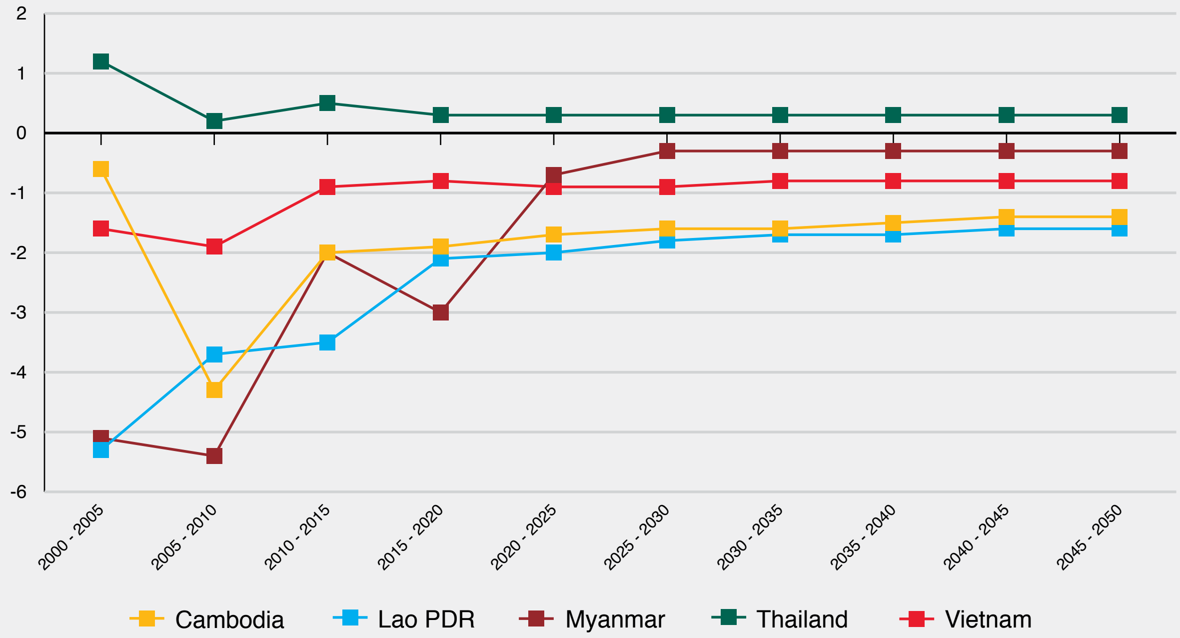
[38] As of mid-2020, there were an estimated 1 million Rohingya refugees and asylum-seekers, mostly in Bangladesh (860,000), Malaysia (101,000) and India (18,000), as well as smaller numbers in Indonesia, Nepal, Thailand, and other countries (UNHCR 2021). An estimated 600,000 Rohingya continue to remain in Rakhine State, Myanmar, of whom 142,000 are internally displaced.

[39] Lao PDR is the only country in the subregion that had a lower ranking (below 50th).

Figure 2.16: Estimated (2000–2020) and projected (2025–2050) net migration rates (percent per 1,000 population) for the Lower Mekong countries



Source: UN DESA (2019).

Intraregional migration, meanwhile, has long been a hallmark of Southeast Asia (Miller 2015). Cambodia, Lao PDR, Myanmar, and Vietnam are all mainly sending countries, while Thailand mainly receives migrants. Figure 2.16 illustrates these differences, which reflect countries' levels of development and disparities in incomes and job opportunities (Hugo 2016). Thailand is the only country with a positive net migration rate, albeit a small one, while the rest of the countries have negative net migration rates.

Continued economic growth in Thailand has created consistent demand for workers, and years of labor migration have created social networks of migrants in Thailand that prospective migrants in other Lower Mekong countries leverage to facilitate their own relocation (IOM 2019; Bylander 2016). Migration, especially by high-skilled workers, has a generally positive impact on the Thai economy and labor market, increasing productivity, output, firm profitability, and employment (Tipayalai 2020; World Bank 2012). Through remittances and circular migration, meanwhile, sending countries can also benefit and reduce poverty, particularly when returning migrants and those in the diaspora enable technology transfers and strengthen human capital and business networks (ADB and World Bank 2018).

Much of the migration in the subregion is still irregular (IOM 2017; ADB 2013). These migrants typically find themselves in very vulnerable situations, employed informally, living in informal settlements in peri-urban areas, and without access to public services, basic infrastructure, or social safety-net programs (UNESCO et al. 2018a). In Lao PDR, for instance, people living in informal settlements account for over 30 percent of the total urban population (UNESCO et al. 2018c).


Photo Credit: World Bank

There has been growing recognition from regional governments to address the rights of migrant workers. In 2018, the Association of Southeast Asian Nations introduced the ASEAN Consensus on the Protection and Promotion of the Rights of Migrant Workers (ASEAN 2018), a non-legally binding agreement in which all Member States, including the Lower Mekong countries, committed to sets of obligations for in- and out-migration countries to protect labor migrants. These obligations included measures to ensure inclusion and support to labor migrants, educate labor migrants and employers on formal channels of migration and migrant employment, and protect migrants from exploitation. Lower Mekong countries are also signatories to the UN Global Compact for Safe, Orderly and Regular Migration.[40]

Climate trends

The Lower Mekong Basin comprises 85.6 percent of the land area of Cambodia, 89.9 percent of Lao PDR, 35.7 percent of Thailand, 21.4 percent of Vietnam, and 3.2 percent of Myanmar (World Bank 2020c). The catchment of the Mekong River is 795,000 square kilometers, and the river stretches across nearly 5,000 kilometers, originating in the northeastern rim of the Tibetan Plateau and then flowing through Myanmar, Thailand, Lao PDR, Cambodia, and Vietnam before reaching the South China Sea (ICEM 2013). Snowmelt from the Tibetan Plateau flows into the Upper Mekong, providing about 16 percent of its water. The Mekong Delta has a land area of around 50,000 square kilometers, making it the third-largest delta plain in the world (Liu et al. 2017). As shown in Figure 2.13, the delta region and areas along the river are topographically flat and low-lying, but to the east (Lao PDR and Vietnam) and west (Thailand, Myanmar) of the river, the topography becomes more rugged, characterized by plateaus and biodiverse forests (Murray et al. 2020).[41]

The mountainous upper reaches of the Lower Mekong have historically been heavily forested, though forest cover has diminished significantly in the past few decades, especially between 1970 and the early 2000s (Ganz et al. 2016). From 2002 to 2019, Cambodia lost 29 percent of its humid primary forest; Vietnam, 9.8 percent; Lao PDR, 9.3 percent, and Thailand, 2.1 percent.[42] Deforestation can increase disaster risks in the event of torrential rains, including severe floods and landslides.

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[40] See https://refugeesmigrants.un.org/migration-compact.

[41] See the Mekong River Commission's overview of geographic regions: https://www.mrcmekong.org/about/mekong-basin/geography/geographic-regions/.

[42] See Global Forest Watch data for each country: https://www.globalforestwatch.org/dashboards (accessed January 21, 2021).

Seasons and climate patterns in the subregion are largely shaped by the tropical monsoon climate (Lee and Dang 2019). The dry season typically lasts from November to April. The wet season, when about 85 percent of the annual precipitation occurs, lasts between May and October. The interior Lower Mekong Basin is largely tropical savanna, with warm temperatures year-round, dry winters, and a rainy summer season. Precipitation varies accordingly from east to west of the Mekong Basin. Mountainous regions in the east, primarily in Lao PDR and Vietnam, receive higher precipitation than the low-lying plains of eastern Thailand and Cambodia.

As with other major river basin and delta systems, the Mekong River has cyclical flooding (Try et al. 2019). River levels can vary by 8 to 10 meters between the wet and dry seasons. Three-quarters of the Mekong's annual discharge occurs between July and October, creating expansive floodplains and seasonal wetlands, and redistributing silt throughout the watershed and sustaining deltaic systems on the coasts (Belay et al. 2010). In the lower reaches of the basin, water discharge can be difficult to manage alongside human development, since 35–50 percent of the area is flooded during peak rainfall periods. In 2000, unusually widespread monsoon floods deluged nearly 800,000 square kilometers of land in Cambodia, Vietnam, Thailand, and Lao PDR (Warner et al. 2009). In 2018, summer monsoon floods led to deaths and affected over 100,000 people in Myanmar alone.[43]

While it is challenging to predict the flows of the Mekong River, including due to upstream land use and water resource development, the variability and intensity of the Mekong flood pulse is expected to increase with climate change (Try et al. 2020). Changes in precipitation, together with increasing glacier melt in the upper stretches of the river, are expected to increase annual runoff in the short term and heighten flood risks, especially in downstream regions (Zhang et al. 2020). Upstream impoundments can also affect flooding, and as rainfall patterns grow more erratic, non-seasonal precipitation increases, and dam construction continues, floods may become less predictable (Anh et al. 2019). In the long run, a combination of stressors from climate change impacts, glacial melt, damming, and evaporation could result in declines in the annual flow of the Mekong River (Raitzer et al. 2016).

Climate information shows that average temperatures have steadily risen throughout the Lower Mekong subregion (Evers and Pathirana 2018). In particular, observed trends show mean temperature increases around Southeast Asian seas at an average rate of 0.27°C to 0.4°C per decade since the 1960s, more than twice the global average rate of about 0.13°C per decade for 1956–2005 (World Bank 2014). Hot days and warm nights have increased significantly, while cool days and cold nights have decreased. Extreme precipitation events have also become more frequent and intense, though this varies across the subregion. Total annual precipitation has increased as well, but it may also be declining in certain critical periods, as indicated by the downward trend during the rainy season along the western coastal regions (Satyanarayana, Dodla, and Srinivas 2020; Evers and Pathirana 2018; Warner et al. 2012; Dun 2011). These trends have implications for water scarcity, with major economic repercussions, particularly in the south and east of the basin (Evers and Pathirana 2018; Lee and Dang 2019). For instance, major droughts occurred in the Lower Mekong Basin in 1992, 1997, 1998, 2002, and 2004–2005, and there were dry spells in smaller areas in 2015–2016 (MRC 2019a). Models indicate that drought severity and duration are greater in the upper Lower Mekong Basin than in the Mekong Delta (Thilakarathne and Sridhar 2017).

Future projections suggest that under RCP4.5 and RCP8.5, annual average daily maximum temperatures could increase by 1.5°C and 3°C, respectively, by 2060 (Trisurat et al. 2018). The largest changes are expected to occur in the southeast of the Lower Mekong Basin, especially during the wet season (ICEM 2013). Annual precipitation is also projected to increase by 2060 throughout the basin, again especially during the wet season, with a maximum increase of 20 percent from a 2010 baseline in Vietnam (Thilakarathne and Sridhar 2017; Trisurat et al. 2018). In contrast, northeast Thailand could see substantial losses of annual rainfall overall under both RCP 4.5 and RCP8.5 (Trisurat et al. 2018). Models also indicate a decrease in mean monthly precipitation during dry months from September to December (Thilakarathne and Sridhar 2017). The period of agricultural drought each year may thus increase in large areas in the south and east of the basin by 2050, including the Cambodian floodplain, Vietnamese Central Highlands, southern Lao PDR, and areas of the delta (ICEM 2013). At the same time, peak daily

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[43] Data from the EM-DAT database: https://public.emdat.be (accessed January 23, 2021).

precipitation is also projected to increase, by 5–16 percent, with the potential to affect flash floods, hillslope erosion, and downstream flooding. Results from more recent studies also indicate similar future trends (Thilakarathne and Sridhar 2017).

The ISIMIP water availability and crop productivity model results for the Lower Mekong countries used in this report broadly confirm these projected trends (see Appendix A.2 for further details, including maps):

- ISIMIP water models to 2050 depict both increases and decreases in water availability depending on the area (Figure A.5). Declines in water availability (of 10–30 percent) are projected in the central portions of the Lower Mekong subregion, including Cambodia and northern Laos, with pockets in northern Thailand facing potential declines of 30–50 percent. The coastal areas and mountains of Vietnam largely face increases, as do the Malay Peninsula of Thailand and western portions of Myanmar. Increased wetness will prevail in the northern parts of the subregion out to 2050–2100, but with continued drying in the subregion's interior (Figure A.6).

- ISIMIP crop productivity model results generally show crop productivity holding steady or slightly increasing by 2050 (Figure A.7). However, depending on the model (particularly under RCP8.5), parts of central Thailand, Lao PDR, northern Vietnam, and northern Myanmar could experience 10–30 percent declines, mainly in highland areas. Projections for 2050–2100 generally show a slight accentuation of these trends (Figure A.8).

Sea-level rise is of particular concern for the low-lying Mekong Delta (Minderhoud et al. 2019). Sea-level rise and increasing average flood volumes are projected to increase the depth and duration of average and extreme floods, particularly in the Vietnamese Mekong Delta (Dang et al. 2018; Evers and Pathirana 2018; ICEM 2013). Large areas of the Mekong Delta that rarely or never flooded significantly in the past are projected to be regularly inundated to depths of 0.5–1 meter by 2050 (ICEM 2013). When cyclones coincide with extreme floods and high tides, maximum flood depth could also increase in the Mekong Delta. Saline intrusion in the Mekong Delta, which is already occurring, would also be heightened under these conditions (Vu, Yamada, and Ishidaira 2018).

2.2.2 Projections of Climate Migration

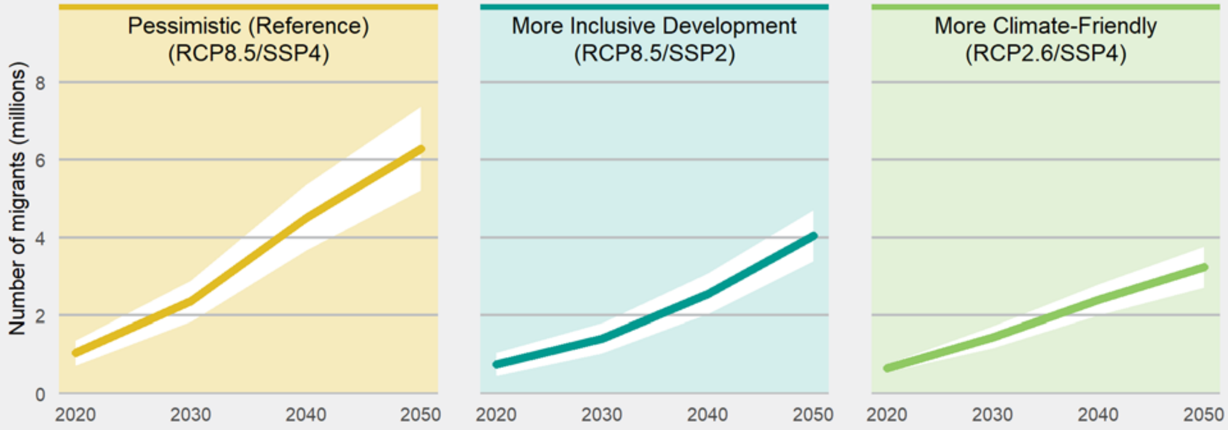
Projected numbers of climate migrants

The number of climate migrants in the Lower Mekong is projected to increase to 2050 across scenarios (Figure 2.17). In the pessimistic reference scenario, the number would reach 6.3 million (2.7 percent of the total population); in the more inclusive development scenario, 4.1 million (1.6 percent of the total population); and the more climate-friendly scenario, 3.3 million (1.4 percent of the total population).

Climate migration accelerates fastest in the pessimistic reference scenario and most slowly in the more climate-friendly scenario. This suggests that lowering global greenhouse gas emissions would reduce the magnitude and rates of climate migration in the Lower Mekong by mitigating impacts on water availability, crop productivity, and sea-level rise. The lower number of climate migrants in the inclusive development scenario also indicates the benefits of more equal development efforts, though heightened climate change impacts could still accelerate climate migration in the second half of the century.

The share of internal migrants projected to be climate migrants over the next three decades varies by scenario. The number of other internal migrants in the subregion is projected to reach 9.9 million by 2050 in SSP2 (moderate development scenario) and 22.9 million in SSP4 (unequal development scenario). As illustrated in Figure 2.18, in the pessimistic reference scenario, climate migration would rise sharply, but so would other internal migration; by 2050, 21 percent of all internal migrants would be climate migrants. In the more inclusive development scenario, which reflects the lower SSP2 projections for other internal migrants combined with continued high emissions, 29 percent of all internal migrants would be climate migrants by 2050. In the more climate-friendly scenario, climate migration would grow more slowly, while other internal migration would still rise sharply (per the SSP4 projections), and by 2050, 12 percent of internal migrants would be climate migrants.

Figure 2.17: Projected number of climate migrants in the Lower Mekong in three scenarios, 2020–2050

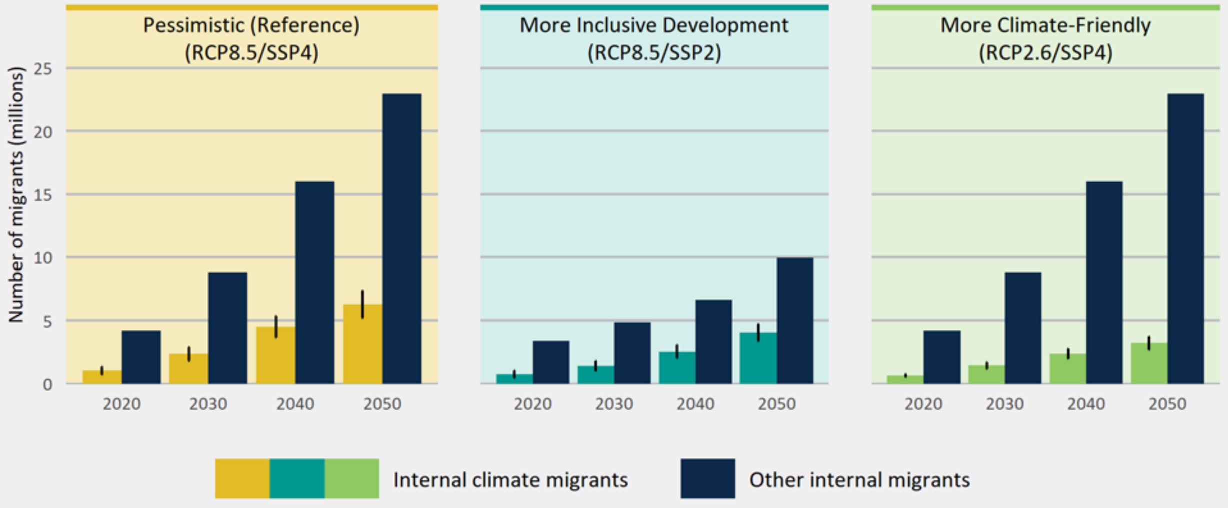


Climate migrants as a percentage of the total population

Year	2020	2030	2040	2050	2020	2030	2040	2050	2020	2030	2040	2050
%	0.4	1.0	1.8	2.7	0.3	0.6	1.0	1.6	0.3	0.6	1.0	1.4

Note: Dark lines represent the average runs for each scenario. The white areas around the central trend line represent the confidence intervals, which reflect the degree of agreement among the four model runs used to provide estimates for each scenario. Narrower confidence intervals indicate greater agreement among the model runs for each scenario. The confidence intervals get larger with each successive time interval, due both to momentum that builds over time for each model run, and to increasing divergence among models as the climate change signal increases.

Figure 2.18: Projected number of climate and other internal migrants in the Lower Mekong in three scenarios, 2020–2050



Note: The whiskers on the climate migrant bars represent the 95th percentile confidence interval for the four model runs for each scenario. There are no confidence intervals for other internal migrants because only a single development trajectory is used.

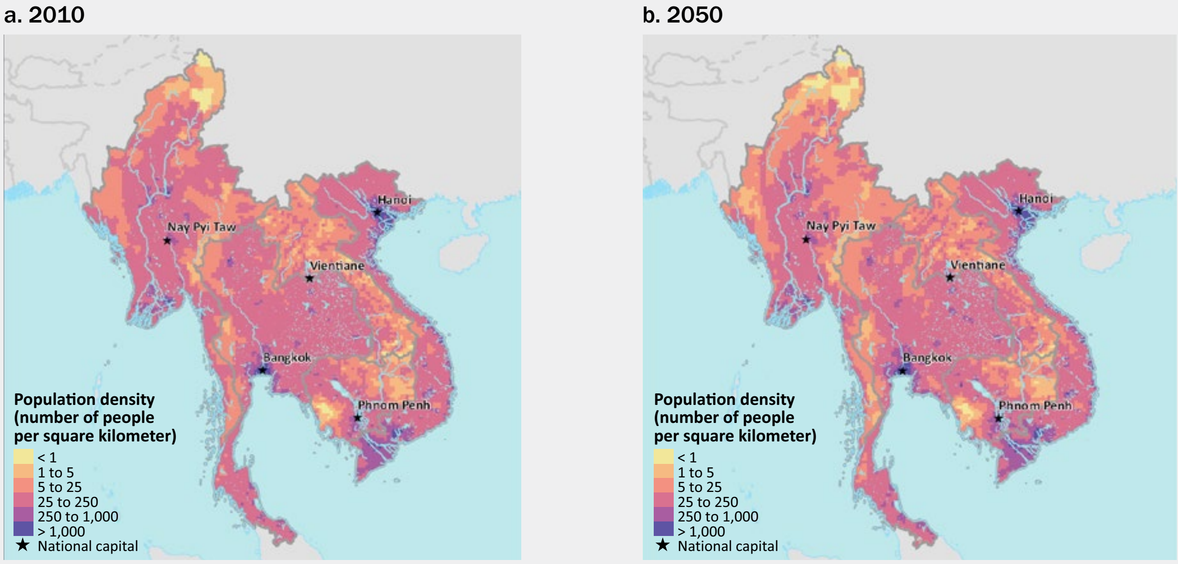
Projected spatial patterns of climate migration

The areas with the highest population density in the Lower Mekong region are the deltas of the Irrawaddy, Salween, Mekong, and Red River (Figure 2.19). Lower-density areas include the highlands, particularly in Lao PDR, northern and eastern Myanmar, and northwestern and western Thailand, as well as areas of northern and southern Cambodia. In the pessimistic reference scenario, the projected population distribution in 2050 is very similar to 2010 patterns, with some differences. Already dense urban areas, including Bangkok and Hanoi, are projected to see greater population growth, while the population density is expected to decline in the north and east of Myanmar, and in parts of the highlands of Lao PDR, Vietnam, and Cambodia.

Differences in population density are more visible in Figure 2.20, which displays absolute and relative differences between the 2010 baseline and the pessimistic reference scenario in 2050. The projections for Myanmar, Thailand, and northern Vietnam suggest that rural areas will depopulate more rapidly, and there will be an influx into several large cities, including Bangkok, Hanoi, and Yangon (Figure 2.20a). This is particularly true in southern Vietnam, where Ho Chi Minh City would grow, whereas parts of the Mekong Delta to the south would see declines in population density. In Lao PDR and Cambodia, a larger number of small and mid-size cities and towns are projected to grow, such as Luang Prabang and Pakse in Lao PDR, and Krong Siem Reap and Krong Battambang in Cambodia, resulting in a more diffuse population growth pattern.

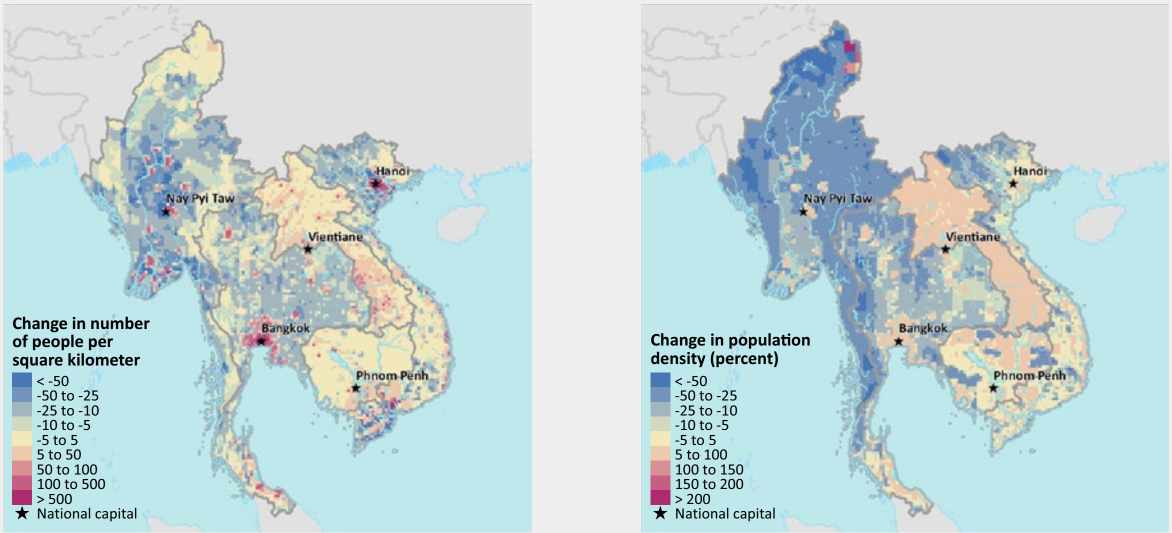
In terms of relative differences, most of Myanmar, Thailand, and northern Vietnam would lose population density (Figure 2.20b). The highlands of Lao PDR, Cambodia, and Vietnam, meanwhile, would see a moderate increase in density. It is important to note that large percentage changes, both positive and negative, are often due to a small baseline population (e.g. in northernmost Myanmar, much of the highlands of northern Vietnam, and parts of northern and western Thailand).

Figure 2.19: Baseline population density, 2010, and projected population density in the pessimistic reference scenario, 2050, Lower Mekong


a. 2010

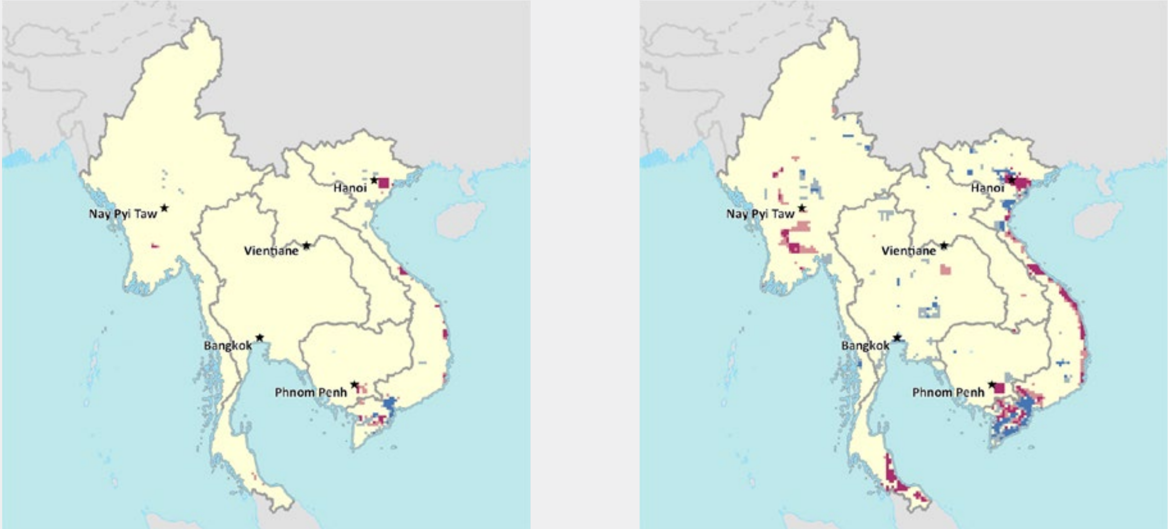
b. 2050

Figure 2.20: Absolute and percentage change in population density in the Lower Mekong in the pessimistic reference scenario, 2010–2050


a. Change in population density

b. Percentage change in population density

Figure 2.21: Hotspots projected to have high levels of climate in-migration and climate out-migration in the Lower Mekong, 2030 and 2050


a. 2030

b. 2050

IN-MIGRATION

🟥 High certainty in high levels of climate in-migration

🟥 Moderate certainty in high levels of climate in-migration

OUT-MIGRATION

🟦 High certainty in high levels of climate out-migration

🟦 Moderate certainty in high levels of climate out-migration

Note: High certainty reflects agreement across all three scenarios modeled, and moderate certainty reflects agreement across two scenarios. In- and out-migration hotspots are thus areas in which at least two scenarios concur on density changes in the top 10th percentile of the density distribution, which in the Lower Mekong represents an increased population density in 2050 of about 7.6 to 14.06 people per km^2, depending on the scenario. For decreased population density, it is about minus-4.01 to minus-8.45 people per km^2.

Climate migration hotspots are already visible in 2030, and they spread and intensify by 2050 (Figure 2.21). Climate out-migration hotspots appear in the coastal areas of northern Vietnam near Thanh Hoa and Vinh, the Vietnam Mekong Delta and Ho Chi Minh City, and central Thailand and Myanmar. The out-migration hotspots in the Mekong Delta, Ho Chi Minh City, and south of Hanoi near Thanh Hoa are areas projected to be affected by sea-level rise. The out-migration hotspots in central Thailand and Myanmar are areas expected to see declines in water availability and crop productivity, respectively. It is important to note that in climate out-migration hotspots in Vietnam, climate change impacts will slow projected population growth, but those areas will continue to support large populations.

Climate in-migration hotspots are expected in southern Thailand (Malay Peninsula), the inner portions of the Mekong Delta in Vietnam (adjacent to the out-migration hotspots, but at higher elevations); coastal areas of eastern Vietnam; the Red River Delta in northern Vietnam, including Hanoi (downstream from the out-migration hotspot); a small area to the southeast of Phnom Penh in Cambodia, along the Mekong River; and southern Myanmar around Hinthada, as well as patches along the Irrawaddy River upstream from the delta. Climate in-migration hotspots along the coast of Vietnam and in southernmost Thailand along the Gulf of Thailand coincide with areas projected to see increases in water availability across multiple models. Climate in-migration hotspots in Cambodia and Myanmar are areas that are expected to see increases in both water availability and crop productivity. Particularly for coastal areas, these in-migration hotspot patterns suggest that better water availability may attract people to areas that also face heightened risks from sea-level rise and extreme weather events, including tropical cyclones. This has implications for resilience planning and disaster risk management.

Trends in livelihood zones

The distribution of livelihood zones is presented in Figure 2.22 for the baseline year of 2015, following the anthropogenic biome classes defined by Ellis et al. (2010).[44] Influenced by topography, altitude, and climate, the livelihood zones in the Lower Mekong are predominantly seminatural and wildlands; there are spots of irrigated croplands in the highlands, and larger areas of rainfed croplands and irrigated rice cultivation at lower altitudes and in coastal areas. Dense settlements are scattered over the whole subregion.

Figure 2.23 shows the projected net change in the number of climate migrants by 2050 for each livelihood zone. It is important to recognize that this represents migration into or out of the zones and does not imply changes in the livelihoods of those who migrate. By 2050, dense settlements display negative net climate migration across the three scenarios, though the magnitudes are small. Rainfed croplands show net climate in-migration in larger numbers, matching hotspots identified in the Malay Peninsula in Thailand and along the Irrawaddy River in Myanmar. The same is true of rice-growing areas in the inner portion of the Mekong Delta, eastern coastal Vietnam, and the area around Hanoi and the Red River Delta. Seminatural and wildlands, meanwhile, are projected to experience negative net climate migration, matching smaller out-migration hotspots identified in central Thailand and Myanmar. There is significant uncertainty in these projections, with the confidence intervals for nearly all livelihood zones extending into both positive and negative ranges. The exception is rainfed croplands in the more climate-friendly scenario, which show average positive net migration of around 290,000 people by 2050. The central projection for rice-growing areas in the pessimistic reference scenario is positive net migration of just over 550,000 people by 2050, but projections range from negative 590,000 to positive 1.7 million. The central projection for seminatural and wildlands is net negative 575,000 by 2050, but with a range from negative 1.5 million to positive 350,000.

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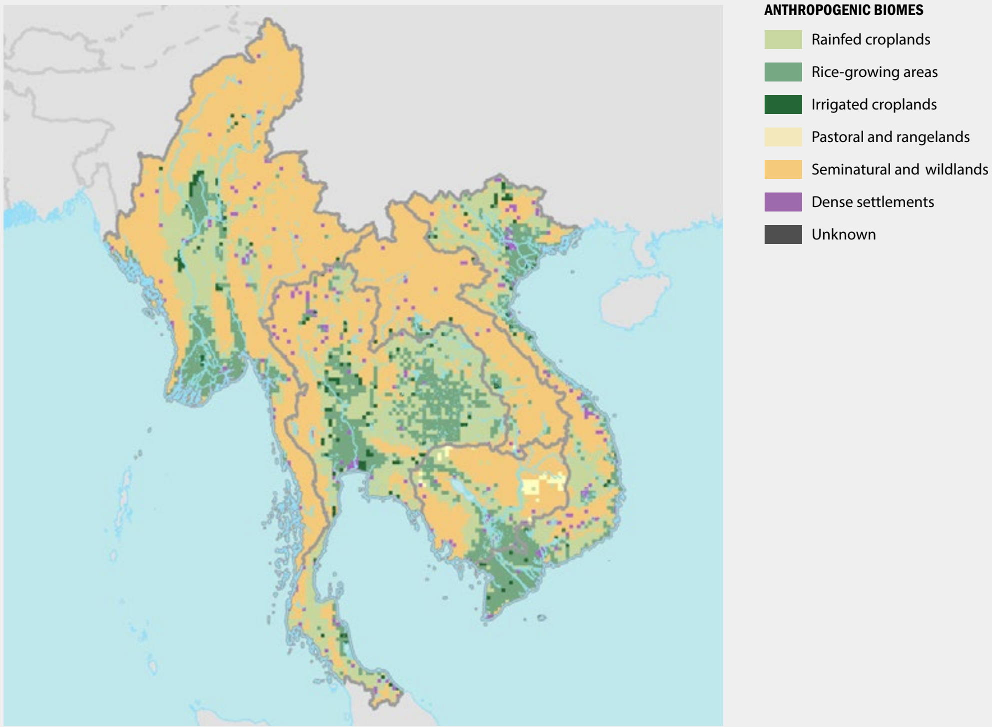
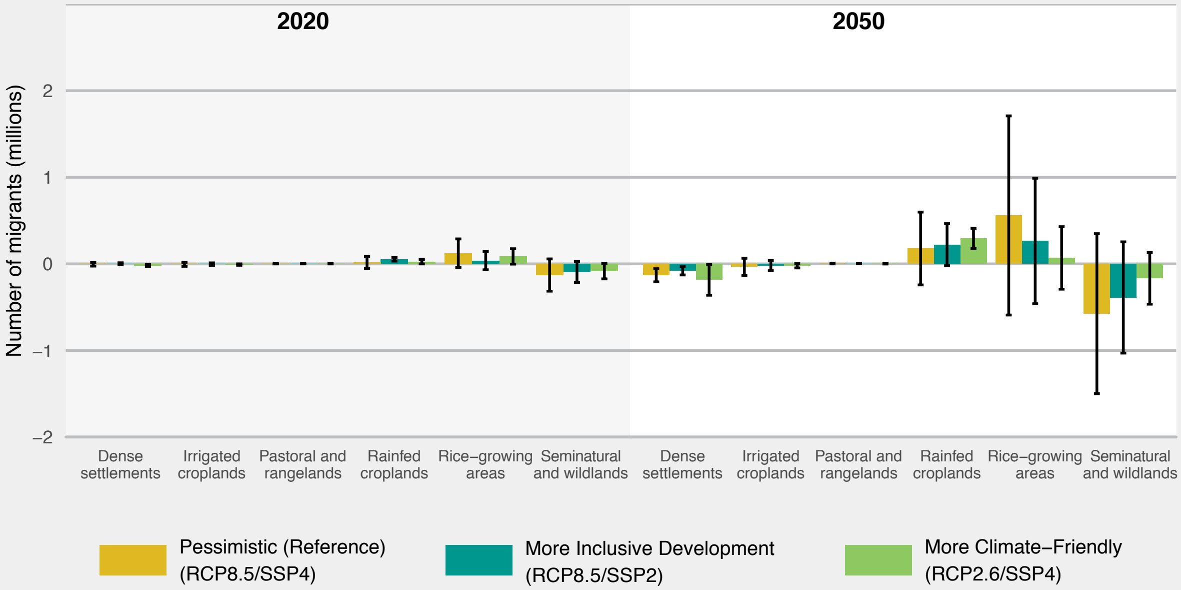
[44] The livelihoods zones used in the Groundswell reports represent an aggregation of anthropogenic biome classes in Ellis et al. (2010) into areas with relatively coherent livelihood characteristics. Note that although it is known that zones will shift with climate change, no projections of those shifts are available, so for the modeling presented in this report, the distribution of zones is assumed to remain static through 2050.

Figure 2.22: Livelihood zones in the Lower Mekong, by anthropogenic biome, 2015



Source: Ellis et al. (2010).

Figure 2.23: Projected net climate migration in and out of livelihood zones in the Lower Mekong in three scenarios, 2020–2050

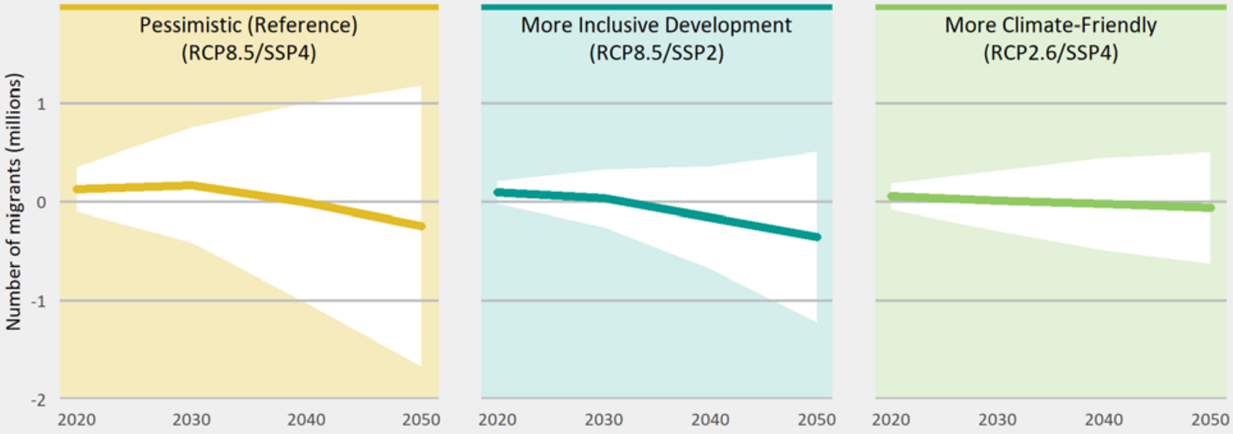


Note: Whiskers show 95th percentile confidence intervals for climate migrants.

Trends in coastal zones

Coastal areas (defined as the land area within 10 kilometers of the coast) in the Lower Mekong are increasingly exposed to sea-level rise, storm surges and saltwater intrusion, particularly in the low-lying deltas of the Mekong and the Red River. Net climate migration is projected to be slightly positive up to 2040 in the pessimistic reference and more inclusive development scenarios and negative afterwards, reaching net out-migration of just over 350,000 in the high-emissions, more inclusive development scenario (Figure 2.24). In the more climate-friendly scenario, the trend is declining slightly throughout the period. However, confidence intervals are very large across scenarios in the latter decades. This is likely due to the counteracting influences of increased water availability in the coastal zones of Vietnam and Thailand, as described above, and the impacts of sea-level rise.

Figure 2.24: Projected net climate migration in and out of coastal zones in the Lower Mekong in three scenarios, 2020–2050



Note: Dark lines represent the average runs for each scenario. The white areas around the central trend line represent the confidence intervals, which reflect the degree of agreement among the four model runs used to provide estimates for each scenario. Narrower confidence intervals indicate greater agreement among the model runs for each scenario. The confidence intervals get larger with each successive time interval, due both to momentum that builds over time for each model run, and to increasing divergence among models as the climate change signal increases.

Trends in urban areas

From a baseline of 72 million in 2010, urban populations are projected to increase to 137 million and 160 million under SSP2 and SSP4, respectively (Jiang and O'Neill 2017; KC and Lutz 2017), and urban areas are projected to continue to expand (Figure 2.25).[45] Climate migration projections for urban areas indicate positive net migration in the three scenarios, but on a relatively small scale compared with the expected urban growth for the region (Figure 2.26). However, uncertainty is very high, as shown by the confidence intervals crossing from positive to negative values, reflecting the mix of urban centers as both climate in-migration hotspots, such as Hanoi, and out-migration hotspots, such as Ho Chi Minh City.

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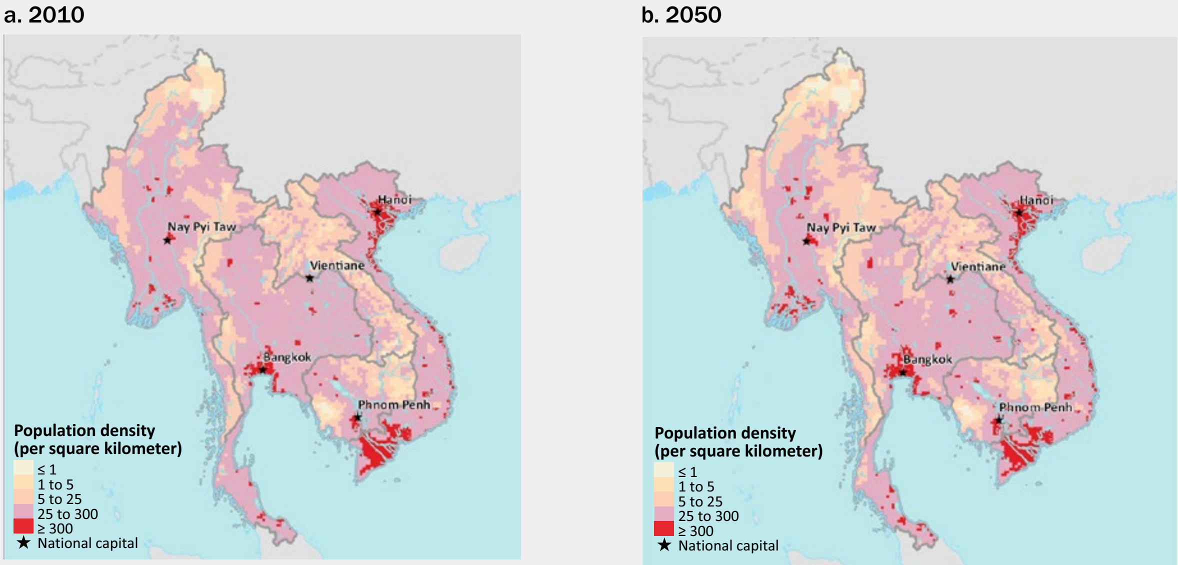
[45] Urban areas are mapped using a simplified definition of 300 persons per km^2 population density, as defined by the European Union, so some of the areas in red in Figure 2.25 may not be what is traditionally classified as urban in Southeast Asia.

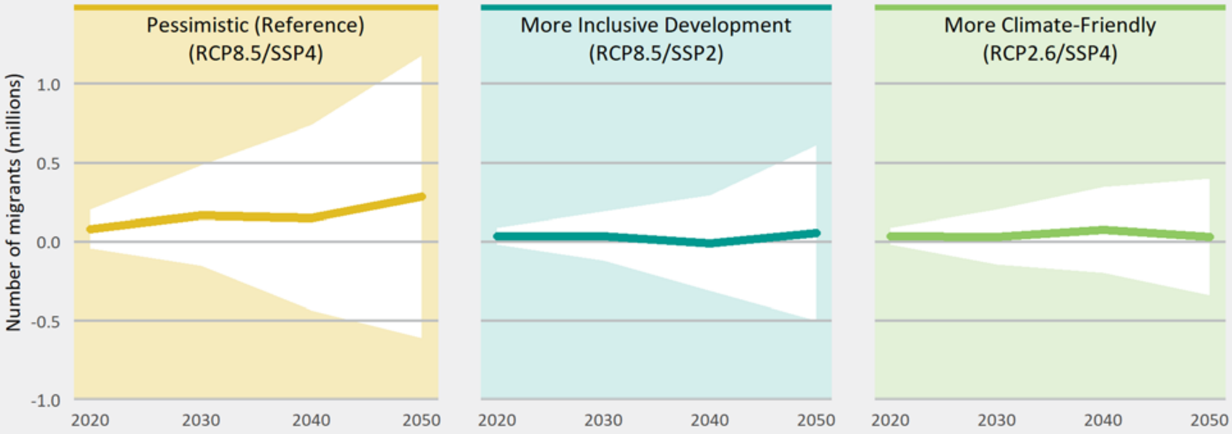
Figure 2.25: Baseline and projected population density in urban areas of the Lower Mekong, 2010 and 2050


a. 2010

b. 2050

Note: An “urban” area is an area with density of at least 300 people per km^2. The map for 2050 shows all areas in which any one of the three scenarios has populations of such density. It thus represents plausible urbanization outcomes rather its more likely spread.

Figure 2.26: Projected net climate migration in and out of urban areas in the Lower Mekong in three scenarios, 2020–2050



Note: Dark lines represent the average runs for each scenario. The white areas around the central trend line represent the confidence intervals, which reflect the degree of agreement among the four model runs used to provide estimates for each scenario. Narrower confidence intervals indicate greater agreement among the model runs for each scenario. The confidence intervals get larger with each successive time interval, due both to momentum that builds over time for each model run, and to increasing divergence among models as the climate change signal increases.

2.3 CLIMATE MIGRATION PROJECTIONS FOR CENTRAL ASIA

Key Findings

- **The analysis for the Central Asia subregion shows internal climate increasing by 2050 in all three scenarios. In the pessimistic reference scenario, the projected number of climate migrants is 2.4 million (3.4 percent of the total population). In the more inclusive development scenario, the projection is 1.9 million (2.5 percent of the total population), and in the more climate-friendly scenario, 1.7 million (2.4 percent of the total population).**

- **The share of internal migration projected to be driven by climate change by 2050 is 20 percent in the more climate-friendly scenario, 26 percent in the pessimistic reference scenario, and 38 percent in the more inclusive development scenario.**

- **Climate in-migration hotspots by 2050 are projected in the Ferghana Valley, the area around Tashkent, and lower elevation areas of southern Tajikistan (including Dushanbe), along with denser settlements (Karagandy, Nur-Sultan, and Kostanay) and rainfed croplands in northern Kazakhstan. These are largely due to projected increases in both water availability and crop productivity. Climate in-migration would amplify projected population growth trends in these areas, particularly in urban and peri-urban areas, and in the Ferghana Valley.**

- **Climate out-migration hotspots by 2050 are expected along the southern border of Kazakhstan, pockets surrounding the Ferghana Valley in Uzbekistan and Tajikistan, and the area around Bishkek, due to projected decreases in water availability and crop productivity. Smaller pockets of irrigated croplands in eastern Turkmenistan and southern Uzbekistan, along the Amu Darya River, are also projected to be climate out-migration hotspots for the same reasons. Climate out-migration would exacerbate projected declines in population densities in these areas.**

2.3.1 Subregional Context

Development and economic context

Central Asia comprises Kazakhstan, the Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan (Figure 2.27). All five countries were part of the Soviet Union until its dissolution in 1991, then transitioned into independent nations and economies. The end of the Soviet command-and-control economy, industrial and agricultural subsidies, and health and education systems triggered economic contraction, a deterioration of public services, and decreases in life expectancies and other socioeconomic and development indicators (World Bank 2019b; Laruelle and Peyrouse 2012). In the late 1990s and early 2000s, Central Asian countries underwent extensive institutional and policy reforms, developing new governance structures and entering global markets (Laruelle 2013). Following this transformative period, Central Asian economies experienced average annual GDP growth rates between 4 and 13 percent, as they improved their macroeconomic policies, global commodity prices climbed, and labor migration and remittance networks developed across Central Asia and with Russia.

The geographic position of the subregion is an important factor in its development trajectory. Situated at the crossroads of Asia and Europe, and with economic shifts in China, Russia, and Turkey, Central Asian countries have drawn new interest as commercial and investment hubs (Fengler and Vallely 2019). China's Belt and Road Initiative is expected to have a particularly large impact on the subregion's future. Overall, the initiative, which includes major transportation infrastructure projects, is projected to increase trade by 2.7–9.7 percent for economies along the corridor, boost incomes by as much as 3.4 percent, and lift 7.6 million people out of extreme poverty (World Bank 2019a). However, realizing the initiative's potential to improve trade, foreign investment, and living conditions in Central Asia will require policy reforms to increase transparency, expand trade, improve debt sustainability, and mitigate environmental, social, and corruption risks (Fengler and Vallely 2019) .

Figure 2.27: Country boundaries and elevation in Central Asia

a. Country boundaries

b. Elevation

The Central Asian countries are at different stages of development and face different economic outlooks. Kazakhstan and Turkmenistan are oil exporters and are classified as upper-middle income, while the Kyrgyz Republic and Uzbekistan, which import oil, are classified as lower-middle income, and Tajikistan, also an oil importer, is also classified as lower-middle income.[46] Across the subregion, GDP grew by 4.8 percent in 2019 (IMF 2020), but there were significant differences among countries.[47] Despite the impacts of the oil price collapse early in 2020, Kazakhstan and Turkmenistan weathered the effects of the COVID-19 pandemic better than most oil exporters in the Middle East, with a GDP contraction of 2.6 percent and growth of 0.8 percent, respectively; the oil importers' economic performance varied more widely, from an 8 percent contraction in the Kyrgyz Republic, to 4.5 percent growth in Tajikistan (IMF 2021). In 2021, all five countries are projected to see GDP growth, from 3.2 percent in Kazakhstan, to 6.0 in the Kyrgyz Republic.

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46. See World Bank income classifications (this report reflects updates as of fiscal 2021): https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups. For oil export and import data, see The World Factbook data at https://www.cia.gov/the-world-factbook/field/crude-oil-exports/country-comparison and https://www.cia.gov/the-world-factbook/field/crude-oil-imports/country-comparison.
47. See World Bank data on GDP growth (annual %): https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?end=2019&locations=KZ-KG-TJ-TM-UZ&start=1991.

Natural resources and raw commodities are crucial to the subregion's economy. Mining and energy are key sectors, though their centrality has diminished since the end of the Soviet Union (Kotilainen et al. 2015). Kazakhstan, Turkmenistan, and Uzbekistan rely particularly heavily on mining and fossil fuel production. Uzbekistan is also one of the world's major producers and exporters of natural gas. Tajikistan and the Kyrgyz Republic lack fossil fuel deposits, but both have mineral resources. In the Kyrgyz Republic, the Kumtor gold mine accounted for 6 percent of the country's GDP in 2014 (World Bank 2015). TALCO, the state-owned aluminum company in Tajikistan, is a key part of the country's industrial base, accounting for 5–7 percent of GDP and around 40 percent of exports (Besant-Jones et al. 2013). It is also the largest consumer of electricity. There has been a push by Central Asian governments over the last decade to promote the growth of the service sector and modernize industry to reduce vulnerability to volatile global commodity prices (Mukhitidinova 2015).

Agriculture remains an important economic sector, and some Central Asian countries are major food producers (Burunciuc 2019).[48] Kazakhstan is one of the world's largest wheat exporters, selling 7–9 million tons per year.[49] Uzbekistan also has a large agricultural sector and has steadily grown its agricultural exports since 2017 (Burunciuc 2019). The Kyrgyz Republic and Tajikistan have fast-growing dairy and beef sectors, which increasingly target export markets within and outside Central Asia. The share of GDP from agriculture and related sectors varies across countries but is relatively important for most; it is even more central for employment (Table 2.4).

The large role of agriculture in Central Asian livelihoods is notable given the countries' small share of arable land. Overall, only about 8 percent of the subregion's total land area is arable, two-thirds of which is rainfed, and nearly all of which lies in relatively temperate northern Kazakhstan (White, Tanton, and Rycroft 2014). The other third of the subregion's arable land is irrigated, mainly with water from precipitation runoff and snow and glacial melt from the eastern mountains. Livestock production is a key subsector, given that most of Central Asia is rangelands—the world's largest contiguous grazing land (Mirzabaev et al. 2016). A large share of arable land in Central Asia also supports livestock feed crops. Raising wheat for fodder and cotton for export utilizes 80 percent of Central Asia's arable land, limiting the area available to produce food for domestic consumption; the majority of agricultural livelihoods are linked to either livestock production or the global cotton market (Peyrouse 2013).

Table 2.4: Agriculture sector indicators for Central Asia

	Kazakhstan	Kyrgyz Republic	Tajikistan	Turkmenistan	Uzbekistan
Arable land (% of land area) (2018)	11.0	6.8	5.1	4.1	9.2
Agriculture, forestry, and fishing, value added (% GDP)	4.5	12.1	19.2	9.3 (2015)	25.6
Agriculture (% employment)	14.9	19.3	44.7	20.1	25.7
Rural population (% of total population)	42.5	63.4	72.7	48.0	50.0

Source: All 2019 data, except where indicated, from World Bank Open Data (http://databank.worldbank.org).

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[48] See World Bank regional overview: https://www.worldbank.org/en/region/eca/brief/central-asia.

[49] See World Grain Council data: https://www.igc.int/en/markets/marketinfo-sd.aspx. Estimated exports for 2020–2021 are 7.4 million tons; in 2018–2019, exports reached 8.8 million tons.

Climate change poses multiple threats to agriculture in Central Asia, including through droughts, desertification, floods, glacier retreat, and changes in the flow of major rivers (Blondin 2019). Without changes to agricultural practices, Central Asia could experience significant climate-related negative impacts on GDP (Burunciuc 2019). However, it has been estimated that by adopting modern agricultural techniques and methods, the subregion could increase its crop yields by over 20 percent by 2030, and by 50 percent by 2050.

Central Asia's future economic development, including energy and water security, will depend to a great extent on how effectively countries manage their water resources, especially under increased pressures from climate variability, economic growth, and population expansion.[50] Inadequate water supply and sanitation now cost the subregion an estimated US$2.1 billion per year (using 2017 data), although these costs differ from country to country—ranging from almost 0.5 percent of GDP in Kazakhstan to around 4.25 percent in Tajikistan (World Bank 2019d). Climate-related impacts on water by 2050 could reduce GDP by up to 10.7 percent under business-as-usual policies, while under policies encouraging better water allocation, GDP could increase by up to 11.5 percent (World Bank Group 2016).

Hydropower is expected to have a growing role in Central Asia's energy mix, with implications for water resource management (World Bank 2019d). Hydropower resources are concentrated in the Kyrgyz Republic and Tajikistan, upstream on the Syr Darya and Amu Darya rivers, respectively; the two countries produce over 90 percent of their total electricity from hydropower.[51] Under changing climate conditions, increased droughts and water shortages could reduce water availability, while glacial melt and changes in snowmelt and precipitation patterns are also likely to affect hydropower reliability in the coming decades (USAID 2018). However, hydropower reservoirs could also have flow management benefits for climate change adaptation, including flood and drought prevention and mitigation, as well as timely delivery of irrigation and drinking water (World Bank 2019d).

Concentrated natural resources create geographical wealth gaps within countries, compounding existing urban-rural divides (Bussolo et al. 2018). In Kazakhstan, oil-rich provinces near the Caspian Sea can have per capita GDPs many times greater those of agriculture-dependent provinces in the country's southeast (Mirzabaev et al. 2016). The 2017 Global Hunger Index found severe food insecurity in Tajikistan, moderate in Uzbekistan and Turkmenistan, and low in Kazakhstan and the Kyrgyz Republic (von Grebmer et al. 2017). Mountain societies, frequently isolated in remote areas in the Pamir and Tien Shan Mountains, tend to score lower on the Human Development Index, are likely to be poorer, and are more vulnerable to climate change impacts and environmental stressors in general (Manandhar et al. 2018).

Overall, inequality across the subregion remains relatively high, but it varies among countries (Bussolo et al. 2018). Poverty rates also vary, from 4.3 percent (at the national poverty line) in Kazakhstan in 2018, to 27.4 percent in Tajikistan.[52] Of the 189 countries ranked on the 2020 Human Development Index (UNDP 2020), Kazakhstan did best among the Central Asian nations, at No. 51, followed by Uzbekistan (No. 106), Turkmenistan (No. 111), the Kyrgyz Republic (No. 120), and Tajikistan (No. 125). Human Capital Index values for the subregion range from 0.5 in Tajikistan, to 0.8 in Kazakhstan.[53] The female labor force participation rate varies widely between countries, from 30.7 percent in Tajikistan, to 71.8 percent in Kazakhstan, with the other countries at around 50 percent as of 2019.[54]

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[50] See World Bank regional overview: https://www.worldbank.org/en/region/eca/brief/central-asia.

[51] See Kyrgyz Republic energy profile from the Internal Energy Agency (IEA) at https://www.iea.org/reports/kyrgyzstan-energy-profile and Tajikistan country page in the World Bank Climate Change Knowledge Portal at https://climateknowledgeportal.worldbank.org/country/tajikistan.

[52] See World Bank data on poverty headcount ratio at national poverty lines: https://data.worldbank.org/indicator/SI.POV.NAHC?locations=KZ-KG-TJ-TM-UZ.

[53] The Human Capital Index calculates the contributions of health and education to worker productivity. The final index score ranges from 0 to 1 and measures the productivity as a future worker of child born today relative to the benchmark of full health and complete education. See World Bank data: https://data.worldbank.org/indicator/HD.HCI.OVRL?locations=KG-TJ-KZ-TM-UZ.

[54] See World Bank data on Labor force participation rate, female (% of female population ages 15-64) (modeled ILO estimates): https://data.worldbank.org/indicator/SL.TLF.ACTI.FE.ZS?locations=KZ-KG-TJ-TM-UZ.

Migration to Russia and to Kazakhstan helps make up for weak labor markets in the other Central Asian countries, providing migrants with higher wages and opportunities to send remittances (Hanks and Tatibekov 2018). Internal rural-urban and international migration are important channels for upward mobility, with migration to Russia representing a “safety valve” for countries with political instability, helping ease social and political tensions related to unemployment (Malyuchenko 2015). The Kyrgyz Republic and Tajikistan are the third- and fourth-most remittance-dependent countries in the world, receiving remittances equivalent to around 28.4 and 26.7 percent of GDP in 2019, respectively.[55] For both countries, international migration and remittances play significant roles in reducing poverty (Murodova 2018). In 2020, remittance flows to the broader Europe and Central Asia region are estimated to have fallen by 9.7 percent due to the COVID-19 pandemic and other effects, including weak oil prices and the devaluation of the Russian ruble (Ratha, Kim, and Plaza 2021).

Population dynamics

Central Asia was home to an estimated 73.2 million people as of 2019, more than two-thirds of them in just two countries: Uzbekistan, with 33 million, and Kazakhstan, with 18.6 million (UN DESA 2019).[56] By 2050, the subregion’s population is projected to decrease to 69 million under the unequal development pathway (SSP4) and increase slightly to 74 million under the moderate development pathway (SSP2) as shown in Figure 2.28.[57]

The dissolution of the Soviet Union shifted population trends in the subregion, as shown in Figure 2.29. From the 1980s until the late 1990s, there was a pronounced decline, followed by a period of recovery and stabilization (but without reaching the levels of the 1980s). Country trends are similar, although the timing and intensity of growth are slightly different. The population of Kazakhstan, for example, declined in the 1990s mainly due to out-migration by people of Russian ethnicity (Bandey and Rather 2013). Over the last five years, population growth in all Central Asian countries, except Tajikistan, has slowed, reflecting declining fertility rates and continued out-migration. These trends are expected to continue.

The subregional economic context and demographic factors (e.g. population composition) have influenced changes in fertility (Spoorenberg 2015). Fertility declined sharply between the 1980s and early 2000s, going from 4.1 to 2.5 children per woman of reproductive age, before increasing again to 2.8 by 2020 (UN DESA 2019). Declining fertility is one of the main factors for the rise in the median age of the population, from 20.5 years in 1980 to 27.6 years in 2020. There are differences across countries, however: for example, only 3.2 percent of Tajikistan’s population is over 65, whereas in Kazakhstan, it is 7.9 percent.

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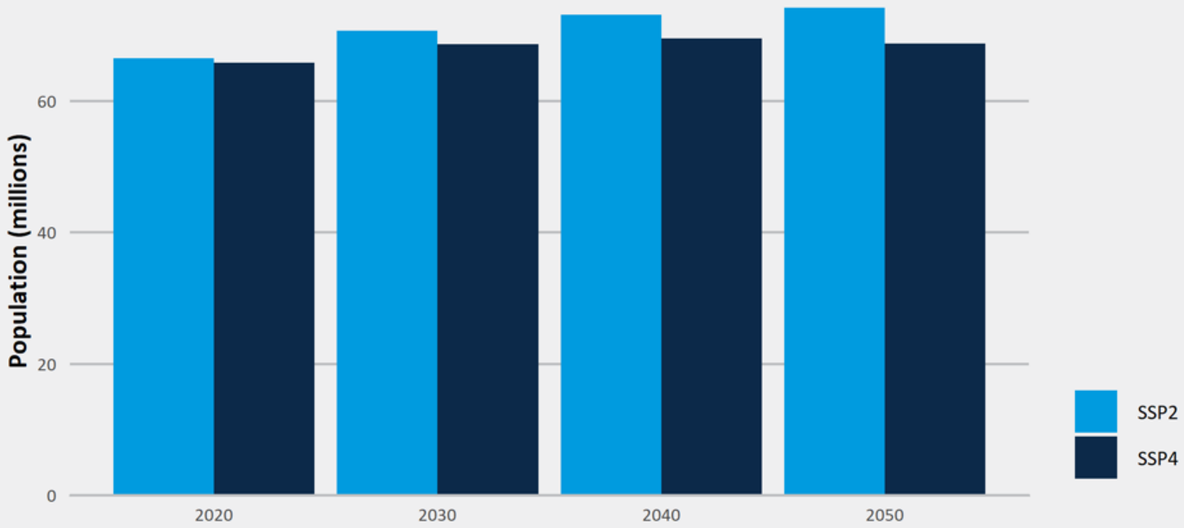
[55] See World Bank data on personal remittances received (% of GDP): https://data.worldbank.org/indicator/BX.TRF.PWKR.DT.GD.ZS?locations=KZ-KG-TJ-TM-UZ.

[56] Tajikistan had 9.5 million, the Kyrgyz Republic, 6.6 million, and Turkmenistan, 5.9 million (UN DESA 2019).

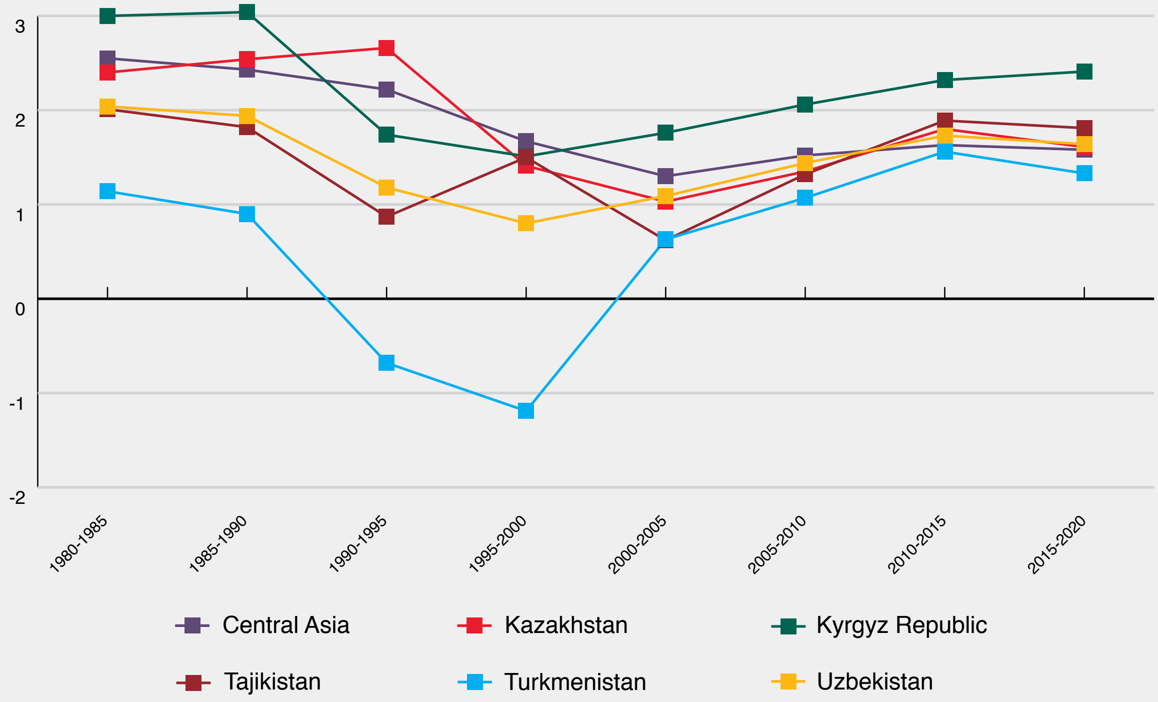
[57] These SSP population scenarios use data from World Population Prospects 2010 for the baseline; see https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=10#v2 and further details in Riahi et al. (2017). Under SSP4, population growth is particularly high in low-income countries, but low in middle-income countries. Under SSP2, population growth is moderate in middle-income countries. Four out of five countries in the region are classified as middle-income, and the SSP4 scenario assumes low population growth or even modest declines for these countries.

Figure 2.28: Projected population in Central Asia under two Shared Socioeconomic Pathways, 2020–2050



Source: Jones and O'Neill (2016). Note: SSP2 = moderate development and SSP2 = unequal development

Figure 2.29: Average annual rate of population change (percent) in Central Asia, 1980-2020



Source: UN DESA (2019).

Migration dynamics

Central Asian societies are increasingly mobile, with significant migration both within and across countries, often to and from cities (Laruelle 2013). There are about 10 million people considered to be “on the move” in Central Asia today, over a fifth of the combined populations of Tajikistan, the Kyrgyz Republic, and Uzbekistan, where most migrants originate (IOM 2017). Migrants, mostly of working age, increase the size of the labor force in the receiving countries, raising productivity and boosting growth (World Bank, 2019b). Estimates from 2013 found about 25 to 35 percent of the Kyrgyz Republic’s economically active population living abroad, with 98 percent of those migrants in either Russia or Kazakhstan. Similarly, Tajikistan had about 25 to 30 percent of its active population living and working in neighboring countries. Age is also an important factor in migration, with an increasingly young labor force seeking jobs outside their countries.

Environmental factors are already driving mobility in Central Asia, particularly as water stress and land degradation affect rural livelihoods, including patterns of transhumance and pastoralism (Blondin 2019). Salinization, for example, already affects over 60 percent of irrigated lands in Central Asia (Laruelle and Peyrouse 2012). Environmental migration and displacement have also occurred after disasters or as part of resettlement programs (Blondin 2019). Research suggests that climate change may contribute to an intensification of both internal migration, and external migration to Russia (Reyer et al. 2017). At the same time, in some situations, migration might be desired, but not accessible; involuntary immobility can lead to compromised livelihoods along with new strategies to maintain them (Blondin 2019). Other times, deep ties to places, family, and community may keep people in certain areas despite deteriorating conditions (Khakimov and Mahmadbekov 2007, cited in Blondin 2019).

Migration dynamics are different for unskilled and skilled workers in the subregion. The cost of travel can limit options, especially for unskilled workers in the poorest Central Asian countries—the Kyrgyz Republic, Tajikistan, and Uzbekistan. As a result, they move mainly to countries in close proximity. Uzbek, Tajik, and Kyrgyz migrants travel to Kazakhstan seasonally, often with their families, to harvest cotton and do other farm work (Marat 2009). In general, many rural people in Central Asia actively migrate for work, particularly through family and social networks (Di Bartolomeo, Makaryan, and Weinar 2014). High-skilled workers, meanwhile, are likelier to move to countries with greater economic opportunities, which can stifle development and economic dynamism in their home countries by depleting the pool of skilled and educated workers (Mukhitidinova 2015).

The number of women labor migrants has been rising in Central Asia. Men have historically been likelier to migrate for work, with one in three working-age men being abroad in the case of Tajikistan, for example (Laruelle 2013). However, women’s employment is changing across the subregion. A study of gender and labor migration to the Russian Federation found women made up 31 percent of labor migrants from the Kyrgyz Republic in 2015, 13.4 percent of those from Uzbekistan, and 9.6 percent from Tajikistan (Rocheva and Varshaver 2018). Female migrants tend to be employed in the service industry and trade, while male migrants are more often engaged in construction and earn more than the women. While these patterns are consistent throughout the region, there are important national and subnational variations, particularly in areas where women typically have less formal education, fewer opportunities for paid labor, and are married earlier than their male counterparts.

Migrants can be particularly vulnerable to health risks such as depression and alcohol abuse, and this is particularly true for women, who are at higher risk of poor health and underutilization of health services (Ismayilova et al. 2014). A survey of female migrants from Commonwealth of Independent States (CIS) member countries found women from Central Asia were the most vulnerable group in terms of living conditions and lack of adequate access to medical services; they also sent home the largest portion of their salaries as remittances (Tyuryukanova 2011, cited in Rocheva and Varshaver 2018).

Russia remains the destination for the large majority of Central Asian migrants, including for 95 percent of migrants from Tajikistan, 83 percent of migrants from the Kyrgyz Republic and 60 percent of migrants from Uzbekistan (Rocheva and Varshaver 2018). Longstanding Kyrgyz and Tajik communities in parts of Russia provide networks that assist new migrants in relocating and finding employment—an advantage which, in turn, attracts more migrants to those communities (IOM 2019).

Kazakhstan has also become an important recipient of subregional migrants. Growth in the construction and services industries in the country has encouraged intraregional migration (IOM 2017). Over 1 million Uzbeks, Tajiks, and Kyrgyz live and work in Kazakhstan with government authorization (nearly 15 percent of the Kazakh labor force), and at least as many, without it (Hanks and Tatibekov 2018; IOM 2019). The Central Asian countries' relatively stable political relations with Russia and with Kazakhstan and visa-free programs can facilitate migration, while political conflict and turmoil in home countries can increase out-migration (Di Bartolomeo, Makaryan, and Weinar 2014).

Given the large migrant flows across the subregion, Central Asian governments increasingly recognize the need to protect both local and migrant workers' rights and safety, and to adopt more proactive and progressive policies (IOM 2019). With a growing population and declining remittances, Tajikistan, for example, has developed a labor market development strategy to expand and formalize its domestic labor market. Such approaches could help keep more workers—including those with higher skills—in the country and reduce the country's vulnerability to economic shocks in migration destination states (Hanks and Tatibekov 2018).

Another major concern that governments are trying to address across the broader region—including Southeastern Europe, Eastern Europe and Central Asia—is human trafficking (IOM 2015). Most trafficking cases in the region involve women and girls but a growing proportion involves labor trafficking, including men and boys. Tajikistan was the first Central Asian country to adopt an anti-trafficking law in 2004; Kazakhstan has also made efforts to address human trafficking (Marat 2009).

Internal labor migration, meanwhile, is hindered by the difficulties in finding affordable housing and by cumbersome residency registration requirements that may limit access to public benefits (Bussolo et al. 2018). Inadequate educational services in rural areas can also make it difficult to gain the qualifications required to find a good job in the city. In Kazakhstan, internal migration flows during 2010–2015 accounted for around 1.7–2.3 percent of the population. One of the biggest constraints to labor mobility was the high cost of living in Almaty, Kazakhstan's largest city, and Nur-Sultan, the capital. Significant gains could be made in improving channels for safe migration and removing obstacles to labor migration, including upskilling and job creation, simplification or elimination of registration requirements, and the development of a well-functioning housing market (Arias et al. 2014). Greater internal mobility, in turn, could facilitate agglomeration of local economies and better labor-market matching.

Climate trends

The geography of Central Asia is defined by high mountain ranges in the south and vast deserts and steppes in the center and north of the subregion. The countries are landlocked, and large areas are arid or semiarid (Yu et al. 2019). Ecosystems within the vast territory include grasslands, rangelands, deserts, woodlands, fertile river valleys, and high arid plateaus. Average temperatures and aridity increase from the Eurasian Steppe of northern Kazakhstan to the deserts in Uzbekistan and Turkmenistan in the south. The deserts transition to plains and foothills abutting mountain ranges in the east, bordering China and Afghanistan (Reyer et al. 2017). There are several major mountain chains in the subregion (Figure 2.27): the Altai Mountains in northeastern Kazakhstan, bordering Russia, China, and Mongolia; the Tien Shan Mountains, along the border of the Kyrgyz Republic and China; and the Pamir-Alai mountain chain, along northern Tajikistan. The majority of the region's freshwater is stored in high mountain glaciers (Radchenko et al. 2017). Runoff from glaciers and high-mountain permafrost reaches downstream populations by way of rivers, primarily the Syr Darya River and Amu Darya River, which flow west to the Aral Sea (Reyer et al. 2017).

Given the range of elevation, Central Asian countries experience distinct differences in climate. The Kyrgyz Republic, for instance, has 70 percent of its land more than 2,000 meters above sea level and much of the population living in the foothills; it receives relatively heavy rainfall, but is also prone to drought (USAID 2018). Tajikistan, meanwhile, is primarily subtropical and semiarid, with half of its land area above 3,000 meters in elevation, while most of Turkmenistan is a vast, flat desert (the Karakum Desert).

The stark elevation differences, coupled with constant seismic activity, result in many natural hazards, mainly floods, landslides, and earthquakes. From 2010 through 2020, more than 40 natural disasters occurred in the five Central Asian countries, affecting more than 300,000 people and causing 270 deaths and over US$332 million in economic damages.[58] Sudden-onset events have displaced thousands of people in Kazakhstan, the Kyrgyz Republic, and Tajikistan in the past decade alone.[59] The year 2015 was particularly devastating, with severe floods in Kazakhstan, and severe floods, mudslides, and earthquakes in the Kyrgyz Republic and Tajikistan (OCHA 2015).

Central Asia is also home to two closed basin seas: the Aral and Caspian. The Aral Sea is one of the iconic environmental calamities of the 20th century. Over-abstraction of water for cotton and rice production from the Syr Darya and Amu Darya rivers has resulted in a 90 percent reduction in water volume since 1960 and, as a result, a 75 percent reduction in the area under cultivation.[60]

Average mean temperatures in Central Asia between June and September fall between 20°C and 40°C, though summer temperatures vary depending on elevation and climatic zone. The extensive cold season lasts from November to March, with temperatures ranging from –25°C to 7°C (Reyer et al. 2017; Gerlitz et al. 2018). Summer daily maximum temperatures can be as high as 50°C in the deserts, while winter daily minimum temperatures can drop as low as –45°C in some mountainous areas and as low as –18°C in northern parts of the subregion (USAID 2018). Seasonal precipitation varies, but is generally highest in the spring and winter and lowest in the summer (Haag, Jones, and Samimi 2019). Annual average precipitation across highly mountainous Tajikistan is around 500 millimeters, largely during spring and early summer, while Uzbekistan receives less than half as much (USAID 2018). In southern Central Asia, the Karakoram and Hindu Kush mountain ranges see up to 60 percent of total annual precipitation during the winter months alone (Gerlitz et al. 2018).

Climate data for Central Asia consistently show that temperatures are rising, though the rate of increase varies across the subregion. Since 1950, average annual temperatures have increased by 0.3–1.2°C in Tajikistan and 1.1–2.4°C in Turkmenistan (USAID 2018). Temperatures have increased, on average, by 0.4°C per decade over the past 30 years in Tajikistan, and around 0.5°C per decade over the past 30 years in the Kyrgyz Republic. Temperature increases have been highest in winter months, particularly November and December, with mean winter air temperatures rising by 2.4°C in semiarid Central Asia (Radchenko et al. 2017; USAID 2018). Trends in precipitation have been more variable across the region. Uzbekistan and the Kyrgyz Republic have seen increases of 4–7 percent in total annual precipitation over the past 30 years, while Turkmenistan has seen slight decreases; there have been no clear trends in Kazakhstan or Tajikistan (USAID 2018).

Future climate projections indicate that average annual temperatures are likely to rise by about 2°C across the subregion by 2050 (USAID 2018). By 2085, the Kyrgyz Republic and Tajikistan could see increases of 2°C to 5.7°C. Projected changes in precipitation vary across the subregion and are highly uncertain. There is agreement that annual precipitation is likely to increase in Uzbekistan, by 12–20 percent by 2085, and that it is likely to slightly decrease in Turkmenistan in that same period. Precipitation for November to April is broadly expected to increase, by up to 50 percent in the Kyrgyz Republic by 2085 and by up to 30 percent in Uzbekistan. In other months, no overall change or slight decreases are projected. In addition, along with the increased concentration of rainfall in winter months, a higher

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[58] Data from the EM-DAT database: https://public.emdat.be (accessed April 13, 2021).

[59] See country profiles from the Internal Displacement Monitoring Centre (accessed April 13, 2021): https://www.internal-displacement.org/countries.

[60] See NASA Landsat 8 images (July 2012): https://www.nasa.gov/mission_pages/landsat/news/40th-top10-aralsea.html.

frequency of heavy rain events is expected for the subregion. Central Asia is also likely to experience an increased incidence of drought and longer dry spells.

ISIMIP water availability and crop productivity model results for the Central Asian countries used in this report broadly confirm these projected trends (see Appendix A.3 for further details, including maps):

- ISIMIP water models show declines in water availability relative to the historical baseline by 2050 in the southern and particularly the southwestern portions of the subregion, corresponding to areas that are already semiarid (Figure A.9). Yet the northern areas, mostly in Kazakhstan, are projected to see increases in water availability under both low and high emission scenarios and across water models.

- ISIMIP crop models are more varied, with increases in crop productivity by 2050 in the north (consistent with the water model runs) and the mountainous southeast (Figure A.11). Patchy areas of declines in crop productivity are expected in western Kyrgyz Republic, eastern Uzbekistan and eastern Kazakhstan, in the relatively limited areas suitable for rainfed agriculture.

- Projections for 2050–2100 show more extreme changes, but the picture is less coherent for both water and crop model outputs (Figures A.10 and A.12), with models driven by the IPSL-CM5a-LR model showing dramatic drying and models driven by HADGEM2-ES showing generalized increases in rainfall runoff under the high emissions RCP8.5 scenarios.

Climate change is also expected to worsen Central Asia's already significant exposure to extreme weather events. The subregion can expect to see increased aridity, with the potential for the development and expansion of interior deserts (Yu et al. 2019). Droughts could further exacerbate land degradation and desertification. In Kazakhstan, for example, a remote sensing analysis found that in six years over the period 2000–2016, more than half of the land area displayed drought conditions (Dubovyk et al. 2019). By the year 2100, arid and semiarid deserts could cover as much as half of the Kyrgyz Republic's territory, up from about 15 percent in 2000 (World Bank 2014). Large stretches of Turkmenistan and Uzbekistan could also become arid. At the same time, rising temperatures could open other areas to agriculture, such as northern and eastern Kazakhstan, or at higher elevations (Blondin 2019). However, these positive effects could be compromised by other adverse impacts on ecosystem services, including the appearance of invasive species and pests and more frequent extreme weather events in the fragile mountain terrains.

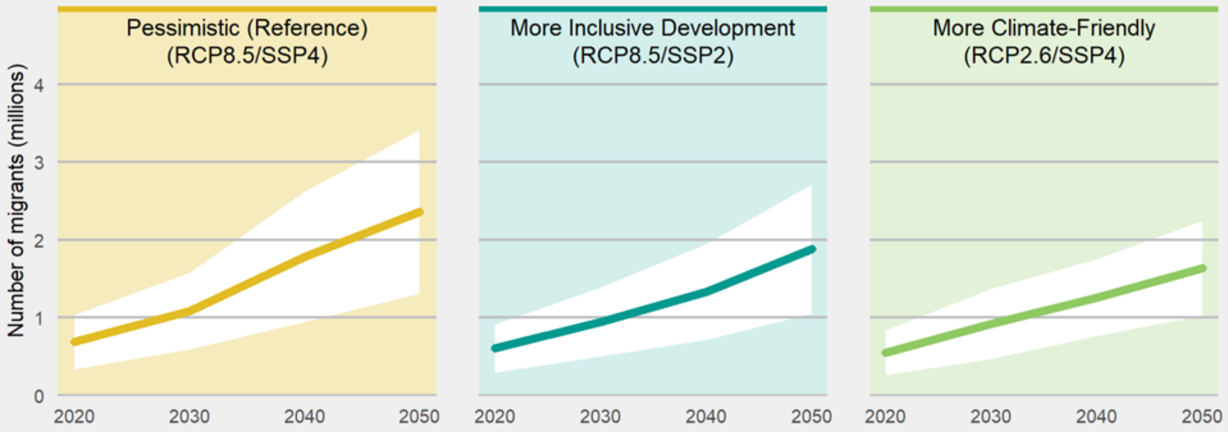
Warmer mean temperatures during the winter could also lead to increased precipitation and glacial melt. Central Asia has lost nearly a third of its glacial area since 1930 due to increased temperatures, reduced winter snowpack, and a larger share of precipitation falling as rain (World Bank 2014). This has significantly reduced the flows of the subregion's major rivers. Glacial melt, most extreme in the Tien Shan mountains, is one of the most pressing threats to regional food security and water supply because of its potential impacts on crop production in large irrigated areas that depend on the Amu Darya and Syr Darya (Warner et al. 2009). Tien Shan mountain glaciers could be reduced by about 30 percent with just 1.5°C of global warming (World Bank 2014). Central Asian glaciers more generally could retreat by 50 percent with 2°C of warming, and by two-thirds with 4°C of warming. Peak flows of key rivers would also shift towards spring, with a 25 percent reduction in flows during the critical summer growing season. In the short and medium term, increasing runoff could lead to increasing floods and landslides (Blondin 2019). With potentially reduced flows in the long term, challenges over water resources among downstream and upstream countries along the Amu Darya and Syr Darya rivers are yet another risk, highlighting the need for sustainable water management (Bernauer and Siegfried 2012; Siegfried 2009).

2.3.2 Projections of Climate Migration

Projected numbers of climate migrants

The number of climate migrants in Central Asia is projected to increase to 2050 across scenarios (Figure 2.30). In the pessimistic reference scenario, it rises to 2.4 million (3.4 percent of the total population) by 2050, though there is a greater spread in the results relative to other scenarios (1.1–3.6 million). In the more inclusive development scenario, the number of climate migrants is projected to rise to 1.9 million (2.5 percent of the total population), and in the more climate-friendly scenario, to 1.7 million (2.4 percent of the total population).

Figure 2.30: Projected number of internal climate migrants in Central Asia in three scenarios, 2020–2050



Climate migrants as a percentage of the total population

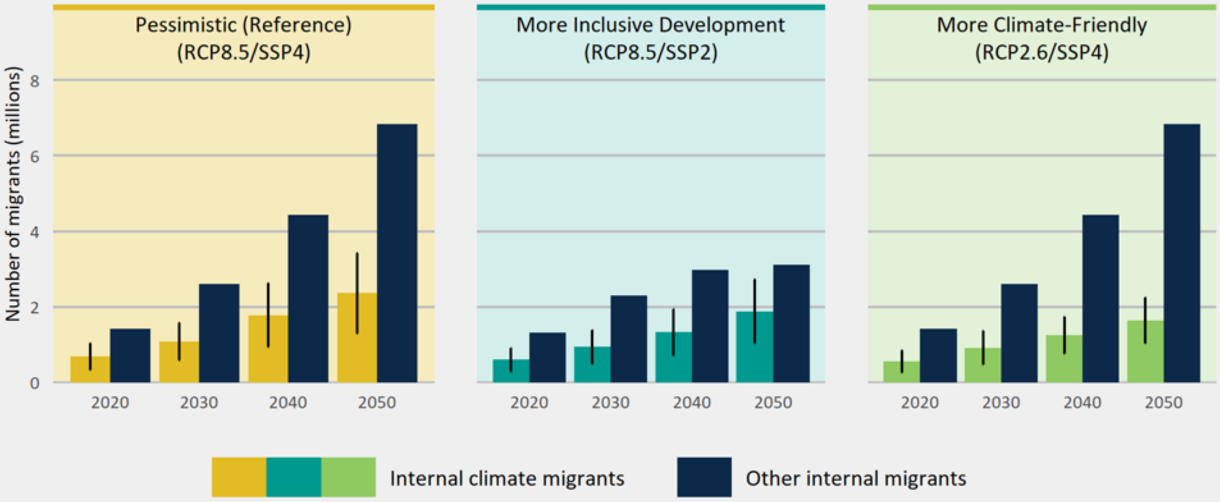
Year	2020	2030	2040	2050	2020	2030	2040	2050	2020	2030	2040	2050
%	1.0	1.6	2.6	3.4	0.9	1.3	1.8	2.5	0.8	1.3	1.8	2.4

Note: Dark lines represent the average runs for each scenario. The white areas around the central trend line represent the confidence intervals, which reflect the degree of agreement among the four model runs used to provide estimates for each scenario. Narrower confidence intervals indicate greater agreement among the model runs for each scenario. The confidence intervals get larger with each successive time interval, due both to momentum that builds over time for each model run, and to increasing divergence among models as the climate change signal increases.

The model shows the pace of increase of climate migration accelerating after 2030 in the pessimistic reference scenario, and after 2040 in the more inclusive development scenario, while it remains more linear in the more climate-friendly scenario. This suggests that while the scale of climate migration may initially be similar in the more inclusive development and more climate-friendly scenarios, climate change impacts in the more inclusive development scenario, which has continued high emissions, could accelerate the pace of climate migration beyond 2050. These results align with the ISIMIP model results for the second half of the century, which project the subregion to be hotter and drier, though some water models show increased water availability in certain areas. Lower global emissions could help reduce the scale and pace of climate migration by lessening impacts on water availability and crop productivity.

The share of internal migrants projected to be climate migrants over the next three decades varies by scenario. The number of other internal migrants in the subregion is projected to rise to 3.2 million under SSP2 and 6.9 million under SSP4 (Figure 2.31). In the more climate-friendly scenario, climate migrants make up 20 percent of all internal migrants by 2050, compared with 26 percent in the pessimistic reference scenario and 38 percent in the more inclusive development scenario. The latter reflects reduced internal migration due to more equitable development patterns between rural and urban areas, but worsening climate change impacts over time. Conversely, lower global emissions trajectories sharply reduce the role of climate change impacts in driving internal migration in the more climate-friendly scenario.

Figure 2.31: Projected number of climate and other internal migrants in Central Asia under three scenarios, 2020–2050



Note: The whiskers on the climate migrant bars represent the 95th percentile confidence interval for the four model runs for each scenario. There are no confidence intervals for other migrants because only a single development trajectory is used.

Projected spatial patterns of climate migration

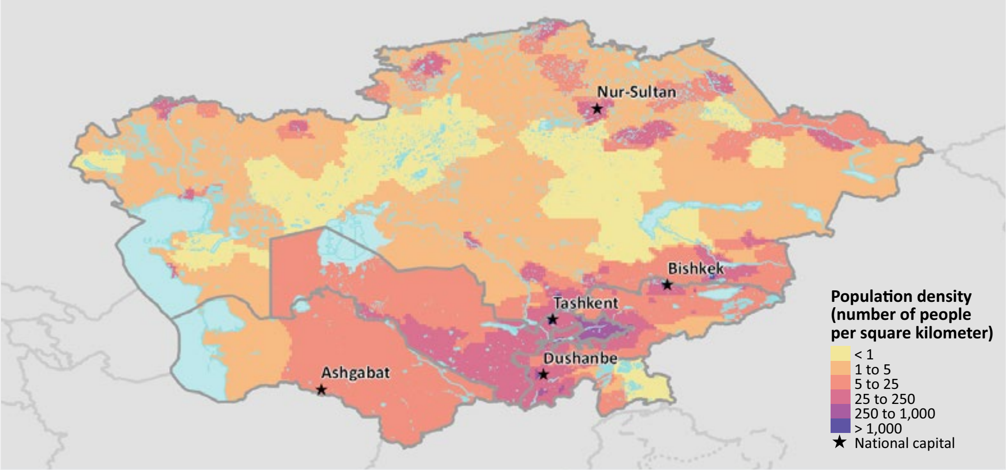
The population of Central Asia is unevenly distributed, with the largest concentrations in the southern mountain regions, particularly in the Ferghana Valley, and in clusters in northern Kazakhstan (Figure 2.32). The rest of the subregion is more sparsely populated, including large areas with densities below 5 persons per square kilometer. Projections to 2050 for the pessimistic reference scenario show similar patterns, except in central and western areas of Kazakhstan, which are projected to be more sparsely populated than in 2010.

The urban population in the subregion reached 34.6 million in 2018 (UN DESA 2018b), representing 48 percent of the total population, but with large differences across countries (from 27 percent in Tajikistan to 57 percent in Kazakhstan). The whole region has just 17 cities of 300,000 or more inhabitants, nine of them in Kazakhstan.

The Ferghana Valley in the Tien Shan mountain range is a hub of agriculture, industry, and ethnic and cultural diversity that is shared between Uzbekistan, Tajikistan, and the Kyrgyz Republic. Agricultural productivity in the valley makes it an appealing site for settlement and immigration (Stratfor 2013). Nearly a quarter of the population of Central Asia resides in this zone, which accounts for 5 percent of the region's total land area.

Figure 2.32: Baseline population density, 2010, and projected population density under the pessimistic reference scenario, 2050, Central Asia

a. 2010



b. 2050

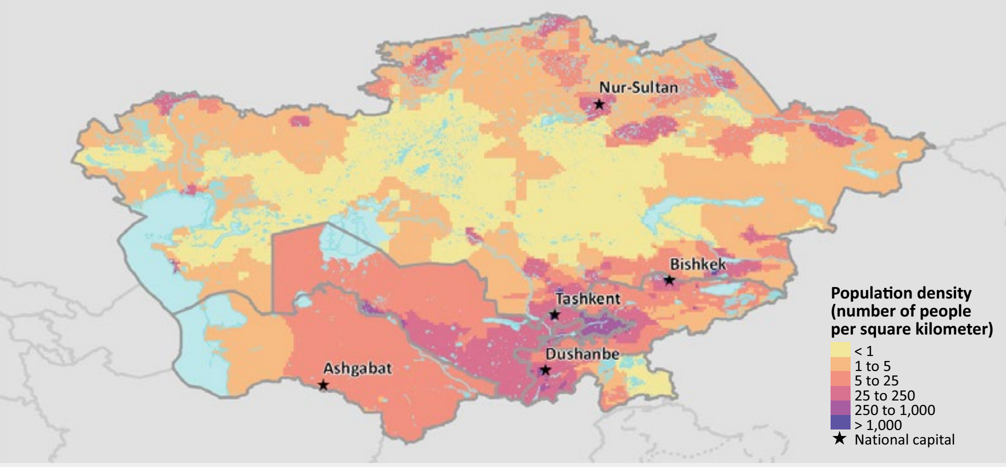
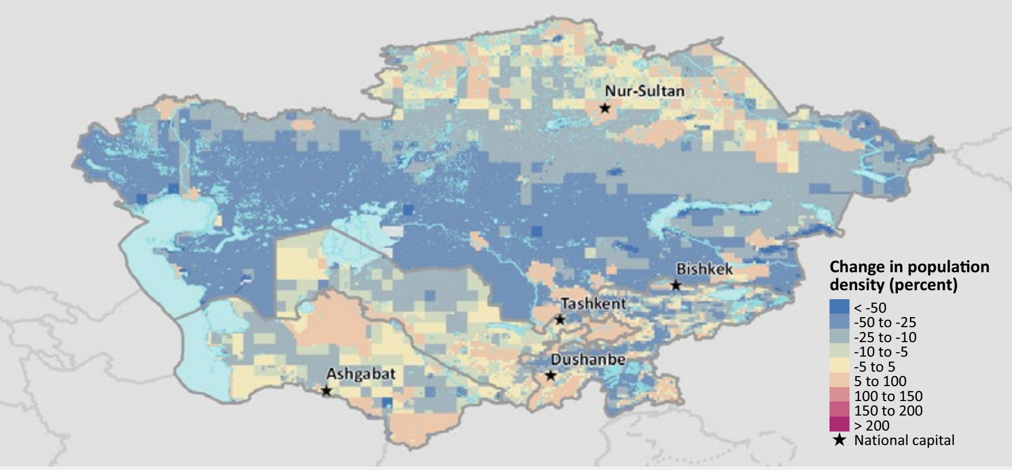


Figure 2.33 shows the change between the baseline 2010 population density and the 2050 population density projection for the pessimistic reference scenario, in terms of both the absolute change and the percentage change. Absolute increases in density are clearly visible in the south (notably in the area of the Ferghana Valley and, to a lesser extent, in northern Kazakhstan and southern Tajikistan and Turkmenistan). Large relative declines, expressed in terms of percentage change, are more pronounced in some areas, largely due to a very low baseline population, including in dryland areas of southern Kazakhstan. There are also high relative declines in the mountainous areas to the north and south of the Ferghana Valley and in the Altai Mountains, both of which have higher baseline populations than the drylands. Both absolute and relative increases are visible in the Ferghana Valley.

Figure 2.33: Absolute and percentage change in population density in Central Asia in the pessimistic reference scenario, 2010–2050

a. Change in population density

b. Percentage change in population density

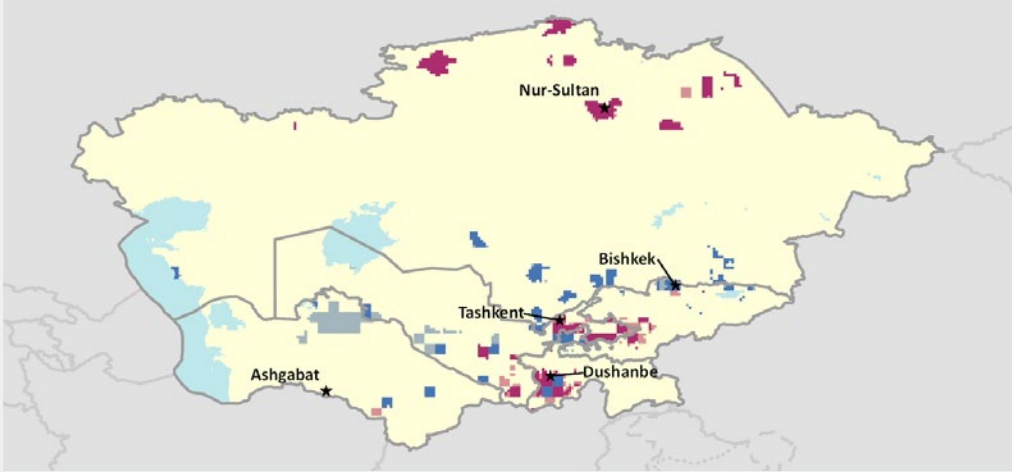


Climate migration hotspots are already well defined in 2030, expanding and intensifying in 2050 (Figure 2.34). The Ferghana Valley, the area around Tashkent, and lower-elevation areas of southern Tajikistan (including Dushanbe) are projected to be climate in-migration hotspots, along with denser settlements in northern Kazakhstan (Karagandy, Nur-Sultan, and Kostanay). These reflect projected increases in both water availability and crop productivity in many of the ISIMIP model runs. Climate in-migration will amplify projected population growth trends in these areas, particularly in urban and peri-urban areas, as well as in the Ferghana Valley.

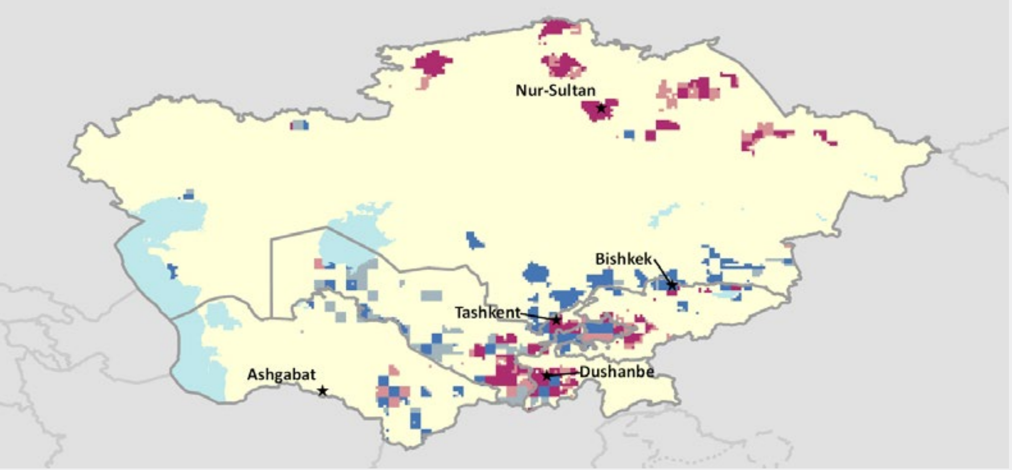
Climate out-migration hotspots are expected along the southern border of Kazakhstan, pockets surrounding the Ferghana Valley in Uzbekistan and Tajikistan, and the area around Bishkek, reflecting projected decreases in water availability and crop productivity. Smaller pockets of eastern Turkmenistan and southern Uzbekistan along the Amu Darya River are also projected to be climate out-migration hotspots for the same reasons. Climate out-migration would further decrease projected declines in population densities in these areas.

Figure 2.34: Hotspots projected to have high levels of climate in-migration and climate out-migration in Central Asia, 2030 and 2050

a. 2030



b. 2050



IN-MIGRATION

■ High certainty in high levels of climate in-migration

▨ Moderate certainty in high levels of climate in-migration

OUT-MIGRATION

■ High certainty in high levels of climate out-migration

▨ Moderate certainty in high levels of climate out-migration

Note: High certainty reflects agreement across all three scenarios modeled, and moderate certainty reflects agreement across two scenarios. In- and outmigration hotspots are thus areas in which at least two scenarios concur on density changes in the top 10th percentile of the density distribution, which in Central Asia represents an increased population density in 2050 of about 1.12 to 1.73 people per km^2, depending on the scenario. For decreased population density, it is about minus -0.85 to minus -1.44 people per km^2.

These projections do not take into account potential impacts from glacial melt, which could initially increase, but subsequently decrease water flows in the subregion's major rivers. Such impacts could drive migration to other areas.

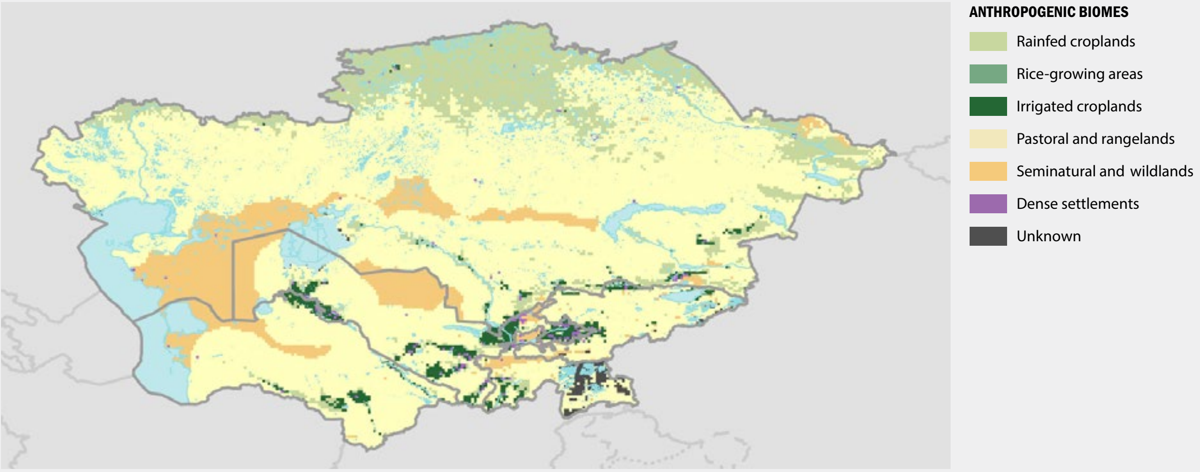
Some of the climate in- and out-migration hotspots by 2050 run along national borders. Although the model does not explicitly include cross-border movements as a result of climate change impacts (only the continuance of transboundary movements based on historical precedent), climate change could amplify or inhibit cross-border movements, depending on the contexts that drive individuals to migrate.

Trends in livelihood zones

The distribution of livelihood zones is presented in Figure 2.35 for the baseline year of 2015, following the anthropogenic biome classes defined by Ellis et al. (2010).[61] A very large area of the subregion is included in the pastoral/rangelands and seminatural and wildlands categories (essentially arid lands). Rainfed croplands dominate the northern areas, and irrigated croplands are mostly located in the southern mountain areas, where dense settlements are also visible.

Figure 2.36 shows the projected net change in the number of climate migrants by 2050 for each livelihood zone, as defined above. It is important to recognize that this represents migration into or out of the zones and does not imply changes in the livelihoods of those who migrate. Projections for net climate migration for rainfed croplands by 2050 across the three scenarios are consistent with expected climate in-migration hotspots, particularly in the northern areas of Kazakhstan. Negative net climate migration is projected for irrigated croplands (for the pessimistic reference and more climate-friendly scenarios) and for seminatural and wildlands (for the pessimistic reference and more inclusive development scenarios). The former coincides with climate out-migration hotspots projected particularly in eastern Turkmenistan and southern Uzbekistan along the Amu Darya River.

Figure 2.35: Livelihood zones in Central Asia, by anthropogenic biome, 2015



Source: Ellis et al. (2010).

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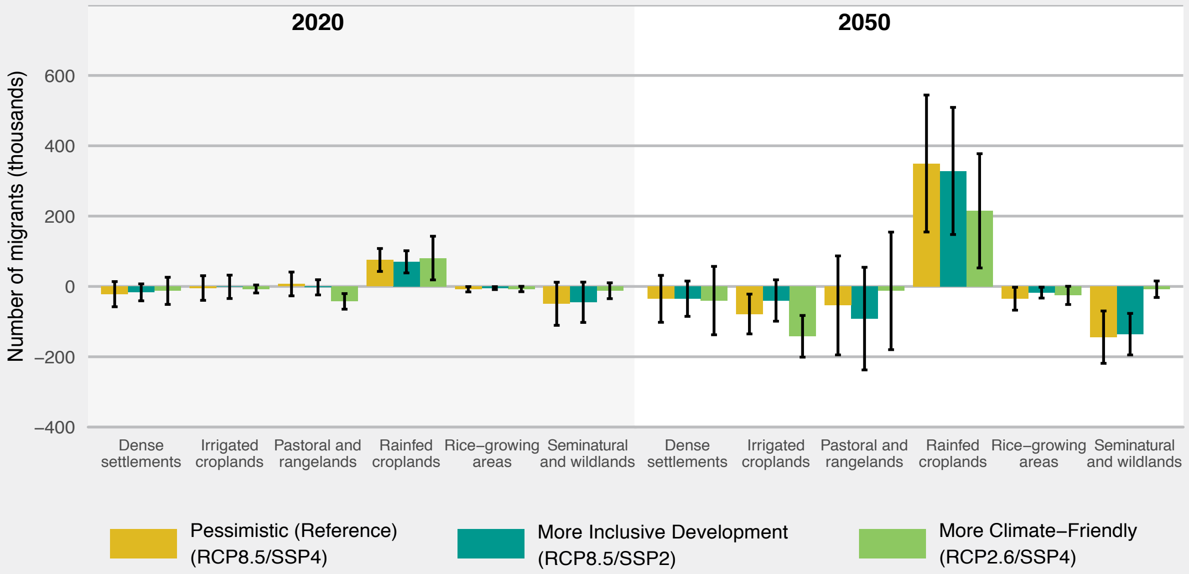
[61] The livelihoods zones used in the Groundswell reports represent an aggregation of anthropogenic biome classes in Ellis et al. (2010) into areas with relatively coherent livelihood characteristics. Note that although it is known that zones will shift with climate change, no projections of those shifts are available, so for the modeling presented in this report, the distribution of zones is assumed to remain static through 2050.

Figure 2.36: Projected net climate migration in and out of livelihood zones in Central Asia in three scenarios, 2020–2050



Note: Whiskers show 95th percentile confidence intervals for climate migrants.

Trends in urban areas

From a baseline of 34.5 million in 2010, the urban population in Central Asia is projected to increase to 58.8 million to 63.3 million by 2050 (under SSP2 and SSP4, respectively) and the spatial extent of urban areas is projected to expand as well (Figure 2.37). Climate migration projections for these areas (Figure 2.38) indicate positive net migration at first in the pessimistic reference and more inclusive development scenarios, but declining towards zero by 2050. Negative trends are projected across the time period to 2050 in the more climate-friendly scenario. Across the three scenarios, the numbers are small compared with the projected 2050 urban population for the region. In addition, uncertainty is high, as shown by the confidence intervals, which range from negative to positive values.[62]

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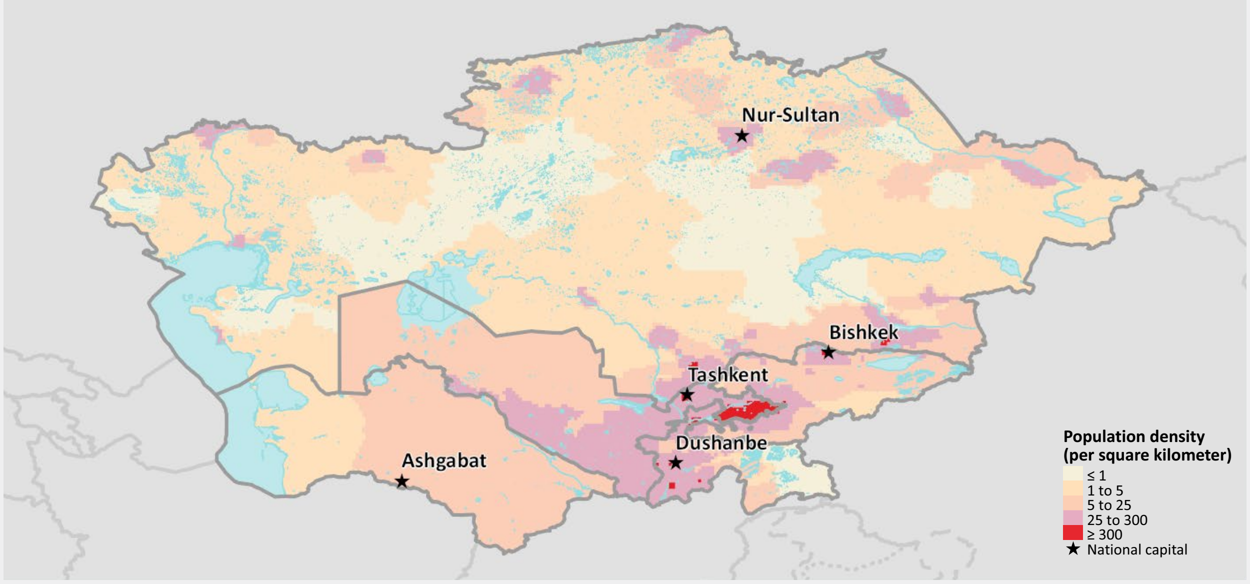
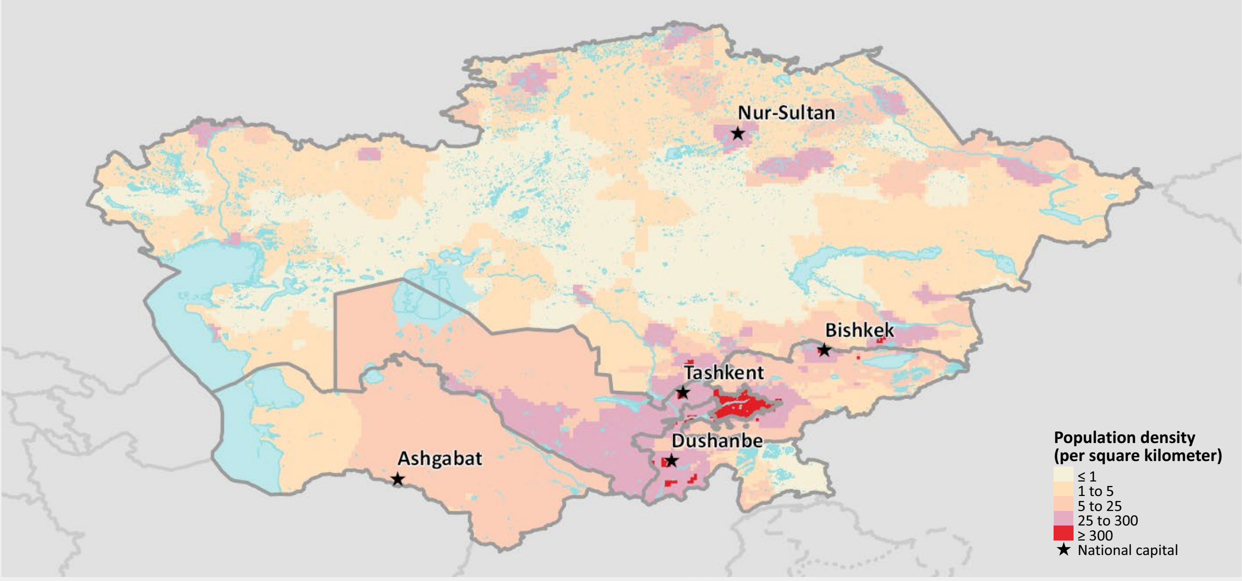
[62] Generally, the smaller the area, the larger the confidence intervals, because of the impact of extreme values in small areas on the spread.

Figure 2.37: Baseline and projected population density in urban areas of Central Asia, 2010 and 2050

a. 2010

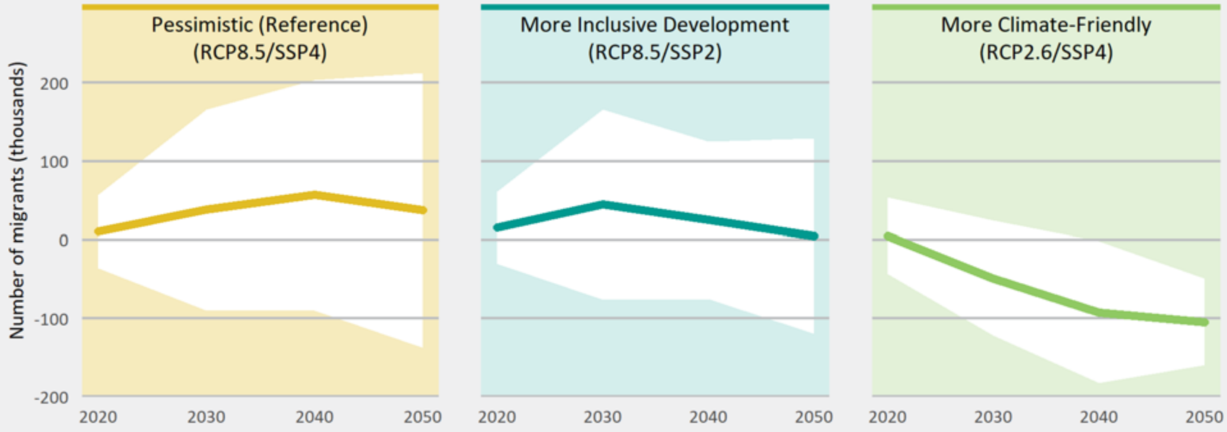


b. 2050



Note: An "urban" area is defined as an area with a population density of at least 300 people per km^2. The map for 2050 shows all areas in which any one of the three scenarios has populations of such density. It thus represents plausible urbanization outcomes, rather its more likely spread.

Figure 2.38: Projected net climate migration in and out of urban areas in Central Asia in three scenarios, 2020–2050



Note: Dark lines represent the average runs for each scenario. The white areas around the central trend line represent the confidence intervals, which reflect the degree of agreement among the four model runs used to provide estimates for each scenario. Narrower confidence intervals indicate greater agreement among the model runs for each scenario. The confidence intervals get larger with each successive time interval, due both to momentum that builds over time for each model run, and to increasing divergence among models as the climate change signal increases.

Photo Credit: World Bank

2.4 PROJECTED CLIMATE MIGRATION FOR THE REGIONS OF FOCUS

Climate migration results are presented at an aggregated level for each focus region. The modeling results were not analyzed as closely as the results for the three subregions examined in the preceding sections. Rather, the main objective was to assess the scale of climate migration across these regions to 2050 to get a better sense of broader regional trends.

For East Asia and the Pacific, aggregated results are included from Southeast Asia (including the Lower Mekong) as well as China and Mongolia.

For Eastern Europe and Central Asia, aggregated results are depicted for Central Asia, the Caucasus, Eastern Europe, and Turkey. For this region, as explained in Appendix B, certain countries were not modeled—the Russian Federation, Belarus, Moldova, and Ukraine—because the climate sensitivity of past changes in population distribution in these temperate, higher-latitude countries is low.[63] For the same reason, and because they are high-income countries, Poland and Croatia, in Eastern Europe, were also not modeled.

For the Middle East and North Africa, as also explained in Appendix B, a decision was taken not to model climate migration in the countries of the Mashreq subregion, due to the high degrees of uncertainty in baseline populations (2010) as a result of ongoing conflicts and refugee flows to neighboring countries. Climate migration projections are therefore presented for the North Africa subregion only. Environmental and climate-related mobility dynamics in countries of the Mashreq subregion are covered in a qualitative case study in Chapter 4.

Small Island Developing States (SIDS) were too small to model successfully, given the resolution of the ISIMIP inputs, also as explained in Appendix B. Therefore, regional results for East Asia and the Pacific presented in this section, and for Latin America, South Asia, and Sub-Saharan Africa, presented in the following section, do not include results from SIDS. Environmental and climate-related mobility dynamics in SIDS and current policy frameworks at this intersection are covered in a qualitative case study in Chapter 5.

Table 2.5 shows aggregate projections for total climate migration for the three new regions of focus: Middle East and North Africa, East Asia and the Pacific, and Eastern Europe and Central Asia. Across all three regions, the largest projections of climate migrants are in the pessimistic reference scenario, and the lowest in the more climate-friendly scenario.

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[63] Belarus was modeled as a test case, and it was found that climate factors had very low predictive power in terms of past movements.

Table 2.5: Projected numbers and shares of internal climate migrants by 2050 for the three regions of focus: Middle East and North Africa, East Asia and the Pacific, and Eastern Europe and Central Asia

	Scenario					
Region	**Pessimistic reference**		**More inclusive development**		**More climate-friendly**	
Middle East and North Africa (North Africa only)						
Average number of internal climate migrants by 2050 (million)	**13.0**		**9.9**		**4.5**	
Minimum (left) and Maximum (right) (million)	6.6	19.3	5.8	13.9	2.9	6.1
Internal climate migrants as percent of population	**6.05**		**4.22**		**2.10**	
Minimum (left) and Maximum (right)	3.08	9.02	2.50	5.94	1.36	2.84
East Asia (excluding Lower Mekong)						
Average number of internal climate migrants by 2050 (million)	**29.9**		**23.2**		**16.9**	
Minimum (left) and Maximum (right) (million)	19.9	39.9	15.4	31.1	6.2	27.6
Internal climate migrants as percent of population	**1.78**		**1.32**		**1.01**	
Minimum (left) and Maximum (right)	1.19	2.38	0.87	1.77	0.37	1.65
Lower Mekong						
Average number of internal climate migrants by 2050 (million)	**6.3**		**4.1**		**3.3**	
Minimum (left) and Maximum (right) (million)	4.1	8.5	2.7	5.4	2.3	4.2
Internal climate migrants as percent of population	**2.68**		**1.61**		**1.38**	
Minimum (left) and Maximum (right)	1.76	3.60	1.07	2.14	0.98	1.78
Eastern Europe						
Average number of internal climate migrants by 2050 (million)	**1.3**		**1.1**		**1.0**	
Minimum (left) and Maximum (right) (million)	1.0	1.5	0.9	1.3	0.9	1.2
Internal climate migrants as percent of population	**0.84**		**0.69**		**0.68**	
Minimum (left) and Maximum (right)	0.67	1.00	0.56	0.81	0.57	0.79
Central Asia						
Average number of internal climate migrants by 2050 (million)	**2.4**		**1.9**		**1.7**	
Minimum (left) and Maximum (right) (million)	1.1	3.6	1.0	2.8	0.9	2.4
Internal climate migrants as percent of population	**3.45**		**2.55**		**2.39**	
Minimum (left) and Maximum (right)	1.64	5.25	1.30	3.79	1.33	3.46

Note: The scenarios are based on combinations of two Shared Socioeconomic Pathways—SSP2 (moderate development) and SSP4 (unequal development)—and two Representative Concentration Pathways—RCP 2.6 (low emissions) and RCP 8.5 (high emissions) that drive climate change impacts on water availability and crop productivity as well as sea-level rise augmented by storm surge.

2.5 PROJECTED CLIMATE MIGRATION TO 2050 ACROSS SIX REGIONS

The projections of climate migration presented here are aggregated for all six World Bank regions modeled across both Groundswell reports. Together with the subregional and country-level analyses of projected climate change impacts, population dynamics, and development contexts presented in this and subsequent chapters, this global perspective on the scale and trend of climate migration to 2050 can contribute to a deeper understanding of the issue and inform better planning.

Table 2.6 shows aggregate projections for total climate migration for the six regions covered. Here again, common trends emerge regarding the scale, magnitude, and direction of climate migration to 2050:

- Internal climate migration is set to increase in all three scenarios across all six regions. This indicates that the upward trajectory of climate migration is set to play out across the globe. It will affect all geographies—hitting the poorest and most vulnerable regions the hardest. In all regions, the pessimistic reference scenario projects the highest climate migration levels and the more climate-friendly scenario has the lowest climate migration levels.

- In the pessimistic reference scenario, which reflects high emissions and unequal development pathways, the number of climate migrants could reach 216.1 million by 2050; the ensemble average is 170.3 million; the minimum is 124.6 million. Sub-Saharan Africa could see as many as 85.7 million climate migrants (4.2 percent of the total population); East Asia and the Pacific, 48.4 million (2.5 percent of the total population); South Asia, 40.5 million (1.8 percent of the total population); North Africa, 19.3 million (9.0 percent of the total population); Latin America, 17.1 million (2.6 percent of the total population); and Eastern Europe and Central Asia, 5.1 million (2.3 percent of the total population). This represents 2.95 percent of the total projected population by 2050 across these six regions.

- In the more inclusive development scenario, the number of climate migrants could be as much as 125.2 million lower than the high-end estimate in the pessimistic reference scenario—a reduction of almost 60 percent. The decreases per region are projected to be up to 43.6 fewer climate migrants in sub-Saharan Africa; 30.3 million fewer in East Asia and the Pacific; 22.4 million fewer in South Asia; 13.5 million fewer in North Africa; 12.2 million fewer in Latin America; and 3.2 million fewer in Eastern Europe and Central Asia. The more moderate development trajectory in this scenario means slower population growth in low-income countries, as well as less economic inequality, slower urbanization, higher GDP, and more education. This reduction relative to the pessimistic reference scenario is particularly evident in low- and middle-income countries, especially those with rapid demographic growth and large young populations, such as in Sub-Saharan Africa.

- The fewest internal climate migrants are projected in the more climate-friendly scenario, where across all regions, the number could be cut by up to 80 percent by 2050 (based on the low end of the more climate-friendly and high end of the pessimistic reference scenarios). The decreases per region are projected to be up to 68.3 million fewer climate migrants in Sub-Saharan Africa; 39.9 million fewer in East Asia and the Pacific; 29.1 million fewer in South Asia; 16.4 million fewer in North Africa; 14.9 million fewer in Latin America; and 3.3 million fewer in Eastern Europe and Central Asia. This means that sharply reducing global greenhouse gas emissions could make a major difference in alleviating impacts on rural livelihoods and urban systems and thus enable people to stay where they live—especially if couple with appropriate adaptation measures. they receive adequate support in adapting to unavoidable climate change impacts.

Regional differences across scenarios highlight how contextualizing and understanding climate migration within specific climate, demographic, and development contexts will be critical for effective planning:

- Sub-Saharan Africa is projected to have the largest number of climate migrants, with an ensemble average of 71.1 million in the pessimistic reference scenario by 2050, representing 3.5 percent of the region's total population. Sub-Saharan Africa is highly vulnerable to climate change impacts, especially in already fragile drylands and along exposed coastlines. Agriculture, which is almost all rainfed in the region, also accounts for a large share of employment. In the more inclusive development scenario, the ensemble average of climate migrants is cut by a quarter (17.7 million), while in the more climate-friendly scenario, it is cut by 60 percent (42.8 million). Along with global climate action, sustained development gains and efforts to ease pressure on vulnerable livelihood systems will be crucial for the region.

- In the pessimistic reference scenario, the East Asia and Pacific region is projected to have 36.2 million climate migrants by 2050 (1.9 percent of the total population; this is the ensemble average). In the more inclusive development scenario, the ensemble average of climate migrants drops by almost a quarter (down 8.9 million), while in the more climate-friendly scenario, it is cut by almost 45 percent (down 16 million). China is projected to be a major contributor to regional climate migration across all scenarios, mainly due to the size of the country's population. Beyond this, countries in the region are highly urban, with diversified economies. The projected scale of climate migration reflects vulnerability to impacts related to sea-level rise, augmented by storm surges, in densely populated low-lying coastal regions that host key livelihood systems and urban centers, particularly in Vietnam. Shifts in water availability and crop productivity also contribute to the relative attractiveness of agricultural livelihood zones, including in Thailand, Myanmar, and Cambodia. Reducing climate change impacts on population centers and vulnerable livelihoods through lower global emissions trajectories, along with integrated spatial planning, will be important for sustainable and resilient development in the region.


Photo Credit: World Bank

- In the pessimistic reference scenario, South Asia is projected to have 35.7 million climate migrants by 2050 (1.6 percent of the total population; this is the ensemble average). This reflects the region's high vulnerability to climate change impacts, particularly in coastal and deltaic areas facing sea-level rise and storm surges. Bangladesh drives the numbers in the region, with a projected 13.3 million climate migrants in the pessimistic reference scenario, or 37 percent of the region's projected climate migrants. Indeed, in Bangladesh, climate migration could outpace other internal migrations by 2050. In the more inclusive development scenario, the ensemble average of climate migrants in the region overall is cut by 40 percent (down 14.6 million) in comparison, while in the more climate-friendly scenario, it is cut by over 50 percent (down 18.8 million). Here too, sustained development gains and lessening climate change impacts on highly densely populated vulnerable areas will be crucial.

- North Africa is projected to have the largest proportion of climate migrants relative to total population, at 13.0 million on average in the pessimistic reference scenario by 2050, representing 6.1 percent of the total population. Severe water scarcity and impacts associated with sea-level rise in densely populated coastal areas and the Nile Delta explain these projected trends. In the more inclusive development scenario, the number of climate migrants is cut by almost a quarter (3.1 million) in comparison, while in the more climate-friendly scenario, it is cut by over 65 percent (8.5 million). More than in any other region modeled, the difference between the more climate-friendly scenario and pessimistic reference scenario is very stark, highlighting the critical role that lower global emissions pathways could play on lessening the burden of climate change impacts on key resources, livelihood systems, and urban centers in the region.

- In the pessimistic reference scenario, Latin America is projected to see 10.7 million climate migrants by 2050 (1.6 percent of the total population; this is the ensemble average). In the more inclusive development scenario, the number of climate migrants is similar, 10.6 million (1.5 percent of the total population), while in the more climate-friendly scenario, it is cut by 45 percent (down 4.9 million). The region includes several upper-middle-income countries with diversified economies and highly urban populations that have already experienced their demographic transitions. Stronger economies can mean higher adaptive capacity and financial resources to target the most vulnerable areas and groups. However, the role of lower global emissions trajectories in lessening climate change impacts on vulnerable areas and livelihood systems, particularly where these coincide with pockets of poverty, will remain critical.

- Eastern Europe and Central Asia are projected to have 3.7 million climate migrants by 2050, though as a proportion of the total population, the region is comparable to others (1.7 percent; this is the ensemble average). In the more inclusive development and more-climate friendly scenarios, the scale of climate migration is reduced by almost 20 percent and by over a quarter, with 3.0 million and 2.7 million climate migrants, respectively. Overall, countries in the region have lower dependency on agriculture, particularly in terms of employment, so potential shifts in water availability and crop productivity may have more muted effects on migration. Several areas may also see more favorable conditions for agriculture, including new areas (e.g. northern Kazakhstan) and some that are already important corridors of agricultural production, such as the Ferghana Valley. The favorability of these conditions will need to be considered in conjunction with the potential longer-term impacts on water resources resulting from glacial melt, particularly in Central Asia. In addition, shifting development trajectories from an agricultural base to an industrial base along with changes within the agriculture sector from subsistence to higher value crops will also influence these dynamics. Finally, it is also important to note that mobility in the region have been heavily influenced by the breakup of the former Soviet Union and associated push and pull factors, potentially over and above those of environmental impacts on livelihoods.

Table 2.6: Projected numbers and shares of internal climate migrants by 2050 for the six regions modeled in the Groundswell reports

	Scenario					
Region	Pessimistic reference		More inclusive development		More climate-friendly	
Sub-Saharan Africa						
Average number of internal climate migrants by 2050 (million)	**71.1**		**53.4**		**28.3**	
Minimum (left) and Maximum (right) (million)	56.5	85.7	42.1	64.8	17.4	39.3
Internal climate migrants as percent of population	**3.49**		**3.01**		**1.39**	
Minimum (left) and Maximum (right)	2.78	4.21	2.37	3.65	0.85	1.93
East Asia and the Pacific						
Average number of internal climate migrants by 2050 (million)	**36.2**		**27.3**		**20.2**	
Minimum (left) and Maximum (right) (million)	24.1	48.4	18.1	36.5	8.5	31.8
Internal climate migrants as percent of population	**1.89**		**1.36**		**1.06**	
Minimum (left) and Maximum (right)	1.26	2.53	0.90	1.81	0.45	1.67
South Asia						
Average number of internal climate migrants by 2050 (million)	**35.7**		**21.1**		**16.9**	
Minimum (left) and Maximum (right) (million)	30.9	40.5	18.1	24.1	11.4	22.4
Internal climate migrants as percent of population	**1.56**		**0.89**		**0.74**	
Minimum (left) and Maximum (right)	1.35	1.77	0.76	1.02	0.50	0.98
North Africa						
Average number of internal climate migrants by 2050 (million)	**13.0**		**9.9**		**4.5**	
Minimum (left) and Maximum (right) (million)	6.6	19.3	5.8	13.9	2.9	6.1
Internal climate migrants as percent of population	**6.05**		**4.22**		**2.10**	
Minimum (left) and Maximum (right)	3.08	9.02	2.50	5.94	1.36	2.84
Latin America						
Average number of internal climate migrants by 2050 (million)	**10.7**		**10.6**		**5.8**	
Minimum (left) and Maximum (right) (million)	4.3	17.1	4.9	16.2	2.2	9.4
Internal climate migrants as percent of population	**1.61**		**1.50**		**0.88**	
Minimum (left) and Maximum (right)	0.65	2.56	0.70	2.31	0.33	1.42
Eastern Europe and Central Asia						
Average number of internal climate migrants by 2050 (million)	**3.7**		**3.0**		**2.7**	
Minimum (left) and Maximum (right) (million)	2.2	5.1	1.9	4.1	1.8	3.6
Internal climate migrants as percent of population	**1.65**		**1.28**		**1.21**	
Minimum (left) and Maximum (right)	0.97	2.33	0.80	1.75	0.80	1.63
Total across the six regions						
Average number of internal climate migrants by 2050 (million)	**170.3**		**125.2**		**78.4**	
Minimum (left) and Maximum (right) (million)	124.6	216.1	90.9	159.7	44.2	112.6
Internal climate migrants as percent of population	**2.32**		**1.71**		**1.07**	
Minimum (left) and Maximum (right)	1.70	2.95	1.24	2.18	0.60	1.54

Note: The scenarios are based on combinations of two Shared Socioeconomic Pathways—SSP2 (moderate development) and SSP4 (unequal development)—and two Representative Concentration Pathways—RCP 2.6 (low emissions) and RCP 8.5 (high emissions) that drive climate change impacts on water availability and crop productivity as well as sea-level rise augmented by storm surge.

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Chapter 3

Country Perspectives: Climate Migration in Morocco, Vietnam, and the Kyrgyz Republic

This chapter expands on the regional analysis in Chapter 2, delving deeper into three countries in the regions of focus: Morocco, Vietnam, and the Kyrgyz Republic. These profiles place projections of the scale, trends, and spatial patterns of internal climate migration in each country's socio-economic and demographic characteristics, mobility patterns, urbanization trends, climatic conditions, and natural systems.

Overall Findings

- **Climate migration is projected to increase by 2050 in all three countries and across scenarios—most significantly in the pessimistic reference scenario, less in the more inclusive development scenario, and least in the more climate-friendly scenario. Clear hotspots of climate in- and out-migration also emerge by 2050 in all three countries, linked to changes in water availability, crop productivity, and sea-level rise. This aligns with the trends found at the regional level. Table 3.1 summarizes the country-level findings.**
- **The country and regional results highlight the need for decision-makers to view climate migration as a cross-cutting issue to be integrated into development policies and spatial planning.**

Table 3.1: Key climate migration results for Morocco, Vietnam, and the Kyrgyz Republic

Result	Morocco	Vietnam	Kyrgyz Republic
Population in 2050*	Projected to remain relatively stable at 37.1 million in SSP2 and decline slightly, to 34.8 million, in SSP4 (from 36.5 million in 2019)	Projected to remain relatively stable at 96.6 million in SSP4 and grow to 104.4 million in SSP2 (from 96.5 million in 2019)	Projected to remain relatively stable at 6.4 million in SSP2 and decline slightly to 5.7 million in SSP4 (from 6.4 in 2019)
Projected number of climate migrants by 2050, pessimistic scenario (average)	1.9 million (5.4 percent of total population)	3.1 million (3.1 percent of total population)	0.2 million (3.9 percent of total population)
Climate in-migration hotspots	Coastal cities, including Agadir, Rabat, and Tangier Around Fès, Tétouan and as far east as Bou Arfa	Hanoi and Red River Delta Coastal central region, including Bin Dinh, Quang Ngai and Quang Tri provinces	Ferghana Valley, including Osh and Jalal-Abad Smaller areas north of Lake Issyk-Kul and to the south of Bishkek
Climate out-migration hotspots	Central foothills including around Marrakech West and southwest coast including around Casablanca and Safi	Mekong Delta and Ho Chi Minh City	Bishkek and surroundings North of Lake Issyk-Kul, including Karakol Southwest and central region near Lake Son-Kul
Climate migration in/out of livelihood zones**	In-migration: pastoral and rangelands with small net gain Out-migration: rainfed croplands with small negative net change	Out-migration: dense settlements Wide confidence intervals for other livelihood zones	In-migration: pastoral and rangelands with small positive net gain Out-migration: dense settlements and irrigated croplands, with small negative net change

Note: SSP2= moderate development; SSP4 = unequal development.
* Under SSP4, middle-income countries see attenuated population growth, and, as in the case of for Morocco and the Kyrgyz Republic, even declines, while in low-income countries, there is rapid population growth.
** In general, the projections display large confidence intervals across livelihood zones, ranging from positive to negative depending on the category.

3.1 CLIMATE MIGRATION PROJECTIONS FOR MOROCCO

Key Findings

- **Climate migration is projected to increase by 2050 in all three scenarios modeled. The number of climate migrants is largest in the pessimistic reference scenario, averaging 1.9 million (5.4 percent of the total population). In the more inclusive development scenario, the projection is 1.5 million (4.0 percent of the total population), and in the more climate-friendly scenario, it is 0.5 million (1.3 percent of the total population). These results highlight the need for concrete climate action and more inclusive development to address the drivers of climate migration.**

- **Climate change impacts may alter patterns of mobility, with implications for planning across Morocco. In the two high-emission scenarios (pessimistic reference and more inclusive development), by 2050, nearly 21 percent and 52 percent of all internal migrants could be climate migrants, respectively. In the more climate-friendly scenario, climate migrants would make up about 10 percent of all internal migrants.**

- **Climate in-migration hotspots by 2050 are projected in the southwest near Agadir, around Rabat, and the Tingitana Peninsula, including Tangiers. Smaller climate in-migration hotspots are also projected in certain urban areas inland and along the eastern coast, and in the arid east and southeast. Movement to these areas is driven mainly by projected increases in crop productivity, with water availability conditions expected to remain stable or only slightly decrease.**

- **Climate out-migration hotspots are projected in the central foothills, including around Marrakech, and on the west and southwest coast around Casablanca and Safi, and south of Agadir to Tiznit. Consistent declines in water availability and either small declines or no changes in the crop productivity drive this movement. Climate-out migration would thus slow population growth in these areas.**

3.1.1 Country Context

Morocco, a lower-middle income economy, had relatively strong GDP growth prior to the COVID-19 pandemic, averaging about 4 percent since 2000, but with considerable fluctuations—from a high of 7.6 percent in 2006, to a low of 1.1 percent in 2016, and 2.5 percent in 2019.[64] The pandemic, combined with a drought that reduced agricultural output, plunged Morocco into its first recession in a quarter-century, shrinking GDP by about 7 percent year-over-year (World Bank 2021b).[65] The government adopted a number of measures to mitigate the impact of these shocks and has initiated an ambitious reform process, which could increase potential growth in the medium and long term. In 2021, GDP is projected to grow by 4.2 percent, but significant economic risks remain. Figure 3.1 shows the country's different regions and elevation zones.

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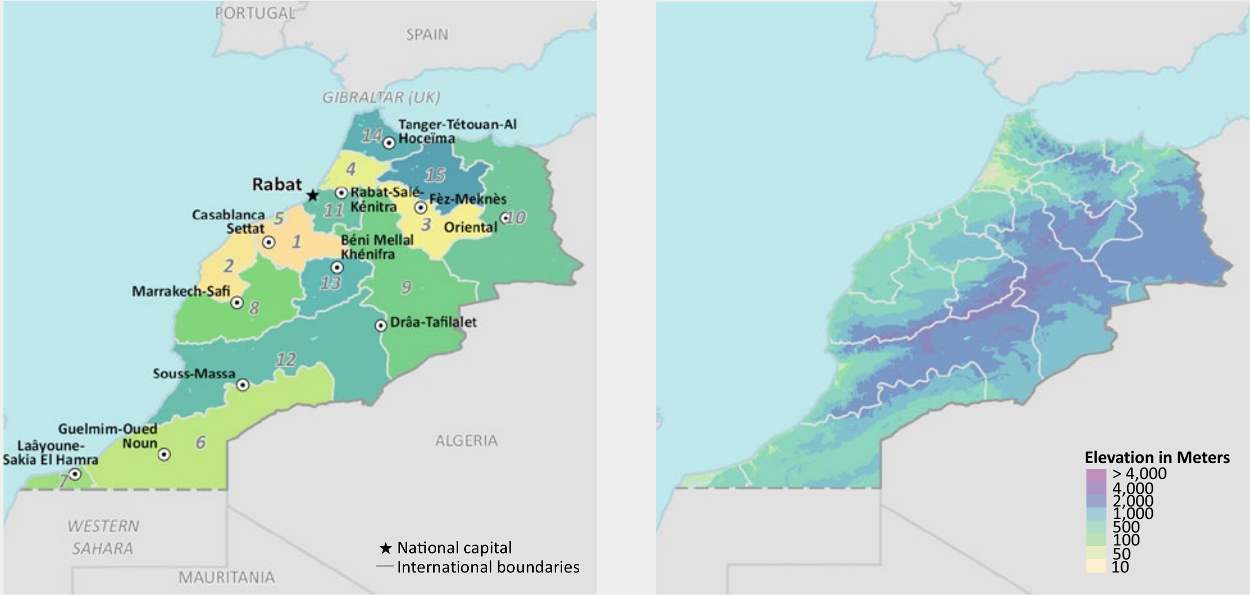
[64] See World Bank data for GDP growth (annual %): https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?locations=MA.

[65] See World Bank overview for Morocco: https://www.worldbank.org/en/country/morocco/overview (accessed May 25, 2021).

Figure 3.1: Administrative boundaries and elevation in Morocco



1. Chaouia - Ouardigha
2. Doukkala - Abda
3. Fès - Boulemane
4. Gharb - Chrarda - Béni Hssen
5. Grand Casablanca
6. Guelmim - Es-Semara
7. Laâyoune - Boujdour - Sakia El Hamra
8. Marrakech - Tensift - Al Haouz
9. Meknès - Tafilalet
10. Oriental
11. Rabat - Salé - Zemmour - Zaer
12. Souss - Massa - Draâ
13. Tadla - Azilal
14. Tanger - Tétouan
15. Taza - Al Hoceima - Taounate

Morocco has a diverse economy, with the service sector generating more than half of GDP since 2000 and employing a growing share of the workforce: 44 percent as of 2019.[66] Tourism is a key economic sector, with international tourism receipts amounting to US$10.0 billion, or 22.7 percent of exports in 2019.[67] Industry has also grown, accounting for 25 percent of GDP and 23 percent of employment as of 2019.[68] However, agriculture—long the country's largest employer—still accounts for a third of total employment, even though the sector's contribution to GDP has shrunk to 12 percent as of 2019.[69] Exports are important to the economy, including industrial products such as cars and insulated wire, mixed mineral and chemical fertilizers, some textiles, agricultural products, and fish products, among others.[70] Despite important recent investments in renewable energy, Morocco still depends heavily on imported oil, gas, and coal (IEA 2019). Table 3.2 provides a snapshot of development and climate risk indicators for Morocco.

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[66] See World Bank data for services, value added (% of GDP): https://data.worldbank.org/indicator/NV.SRV.TOTL.ZS?locations=MA, and employment in services (% of total employment), based on modeled International Labour Organization (ILO) estimates: https://data.worldbank.org/indicator/SL.SRV.EMPL.ZS?locations=MA.

[67] See World Bank data for international tourism, receipts (% of total exports): https://data.worldbank.org/indicator/ST.INT.RCPT.XP.ZS?locations=MA, and international tourism, receipts (current US$): https://data.worldbank.org/indicator/ST.INT.RCPT.CD?locations=MA.

[68] See World Bank data for industry (including construction), value added (% of GDP): https://data.worldbank.org/indicator/NV.IND.TOTL.ZS?locations=MA and employment in industry (% of total employment), based on modeled ILO estimates: https://data.worldbank.org/indicator/SL.IND.EMPL.ZS?locations=MA.

[69] See employment in agriculture (% of total employment), based on modeled ILO estimates: https://data.worldbank.org/indicator/SL.AGR.EMPL.ZS?locations=MA, and agriculture, forestry, and fishing, value added (% of GDP): https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?locations=MA.

[70] See OEC visualization of Morocco's exports, imports, and trade partners: https://oec.world/en/profile/country/mar.

Table 3.2: Demographic, socioeconomic, and climate risk indicators for Morocco

Development Indicators	
Population	
Population (millions)	36.5
Annual population growth (%)	1.2
Population in 2050 under SSP2 (millions)*	37.1
Population in 2050 under SSP4 (millions)*	34.8
Urban share of population (%)	63.0
Employment in agriculture (% of total employment)	33.3
GDP	
GDP (current US$ billions)	119.7
Annual GDP growth (%)	2.5
GDP per capita (current US$)	3,204
Value added of agriculture (% GDP)	12.2
Value added of services (% GDP)	50.9
Value added of industry (% GDP)	25.3
Poverty	
Poverty headcount ratio at $1.90 a day (2011 PPP) (% of population) (2013)	0.9
Poverty headcount ratio at $3.20 a day (2011 PPP) (% of population) (2013)	7.3
Climate and disaster risk indexes	
ND GAIN Index**	
Rank	70
Score	52.0
World Risk Index (2020)***	
Rank	103
Score	5.8

Sources: All 2019 data from World Bank Open Data (http://databank.worldbank.org), except where indicated.
* SSP population projections produced for this report
** ND-GAIN (https://gain.nd.edu/our-work/country-index/rankings/)
*** Bündnis Entwicklung Hilft (https://weltrisikobericht.de/english/)

Economic growth has helped to greatly improve living conditions. As of 2017, 100 percent of Moroccans had access to electricity, up from 70 percent in 2000; 70 percent had access to safely managed water, up from 55 percent in 2000; and 39 percent used safely managed sanitation services, up from 32 percent in 2000.[71] Recent poverty data are not available, but between 2000 and 2013, extreme poverty (people living on less than $1.90 per day) dropped from 5.8 to 0.9 percent,[72] and the share of people living below the national poverty line dropped from 15.3 to 4.8 percent.[73] Consumption by the bottom two quintiles of the population grew in that period, suggesting a real increase in shared prosperity (Angel-Urdinola, El Kadiri, and Pallares-Miralles 2015; World Bank and Morocco High Commission for Planning 2017).

However, important challenges remain. There is significant inequality: Morocco's most recent Gini coefficient, 39.5 in 2013, is one of highest in the Middle East and North Africa region.[74] There is also an urban-rural poverty gap. Urban poverty rates declined from 7.6 to 1.6 percent between 2001 and 2014, decreasing faster than rural poverty rates, which went from 25.1 to 9.5 percent (World Bank and Morocco

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[71] See the United Nations Global SDG Database: https://unstats.un.org/sdgs/indicators/database/.

[72] See World Bank data for poverty headcount ratio at $1.90 a day (2011 PPP) (% of population): https://data.worldbank.org/indicator/SI.POV.DDAY?locations=MA.

[73] See World Bank data for poverty headcount ratio at national poverty lines (% of population): https://data.worldbank.org/indicator/SI.POV.NAHC?locations=MA.

[74] The Gini index measures the extent to which the distribution of income (or, in some cases, consumption expenditure) among individuals or households within an economy deviates from a perfectly equal distribution. A Gini index of 0 represents perfect equality, while an index of 100 implies perfect inequality. See World Bank data: https://data.worldbank.org/indicator/SI.POV.GINI?locations=MA.

High Commission for Planning 2017). As of 2014, rural areas were home to 40 percent of the total population, but 79.4 percent of the poor. Important pockets of entrenched poverty remain in cities, which continue to have high rates of unemployment despite generating 75 percent of the Moroccan GDP (Angel-Urdinola, El Kadiri, and Pallares-Miralles 2015). A growing share of Moroccans see themselves as poor, even if their incomes do not reflect it: 45.1 percent in 2014, up from 41.8 percent in 2007 (World Bank and Morocco High Commission for Planning 2017). This perception is greatest among rural households (54.3 percent), women (55.3 percent) and young people under age 25 (57.6 percent).

Morocco has a relatively young population, with an estimated median age of 29.5 years in 2020 (UN DESA 2019b). Although that is up from 22.7 years in 2000, and the share of youth (ages 15–29) has declined, from 29.1 percent in 2000, to 24.0 percent in 2020, the country can still be considered to be experiencing a "youth bulge". By 2050, however, the median age is projected to be 38.2 (see Figure 3.2). Employing young workers has been a challenge for Morocco (Ferreira 2014; Angel-Urdinola, El Kadiri, and Pallares-Miralles 2015). The youth unemployment rate in Morocco was 22.3 percent in 2019, almost 2.5 times the total unemployment rate of 9.0 percent.[75]

Morocco's female labor force participation rate is one of the lowest in the world: 23.4 percent in 2019, down from a peak of 28.3 percent in 2006, and compared with 74.9 percent for men.[76] It is even lower than it was two decades ago—despite higher GDP per capita, lower fertility rates, and better access to education (Lopez-Acevedo et al. 2021). A 2015 World Bank analysis noted that 82 percent of girls dropped out of school and did not join the labor force, due to family reasons or discouragement (Angel-Urdinola, El Kadiri, and Pallares-Miralles 2015). Of the nearly 2.7 million Moroccans aged 15–24 in 2015 who were not in school, in training, or in the workforce, 94 percent were female.

Population growth, meanwhile, which slowed dramatically in the 1980s and 1990s, has held steady since then, fluctuating between 1.1 and 1.4 percent per year from 1996 to 2019; the growth rate was 1.2 percent in 2019.[77] Morocco's birth rate in 2015–2020, 19.1 per 1,000 people, is down significantly from 27.4 in 1990–1995 and well below the North African average of 25.4, though higher than Tunisia's or Libya's. Life expectancy at birth, meanwhile, has risen steadily, from 66 years in 1990–1995, to 76 in 2015–2020. The population is expected to remain relatively stable, from an estimated 36.5 million in 2019, to between 34.8 million by 2050 under SSP4 and 37.1 million under SSP2.[78]

Patterns of migration are well established in Morocco. Internal migration has fueled urban growth, for instance, especially along the Rabat–Casablanca corridor (de Haas 2007). Rural-urban migration has been significant since independence in the 1960s, and by 2004 about 1.4 million people—4.7 percent of the population—were internal migrants (Bernard, Bell, and Cooper 2018). Migrants are drawn mainly by job opportunities, including in large-scale road and infrastructure projects, tourism, and services, but there is also a "culture of migration" in rural and oasis areas that identifies leaving home with success (de Haas 2001). International out-migration, mainly to Europe, is also deeply rooted (see Box 3.1).

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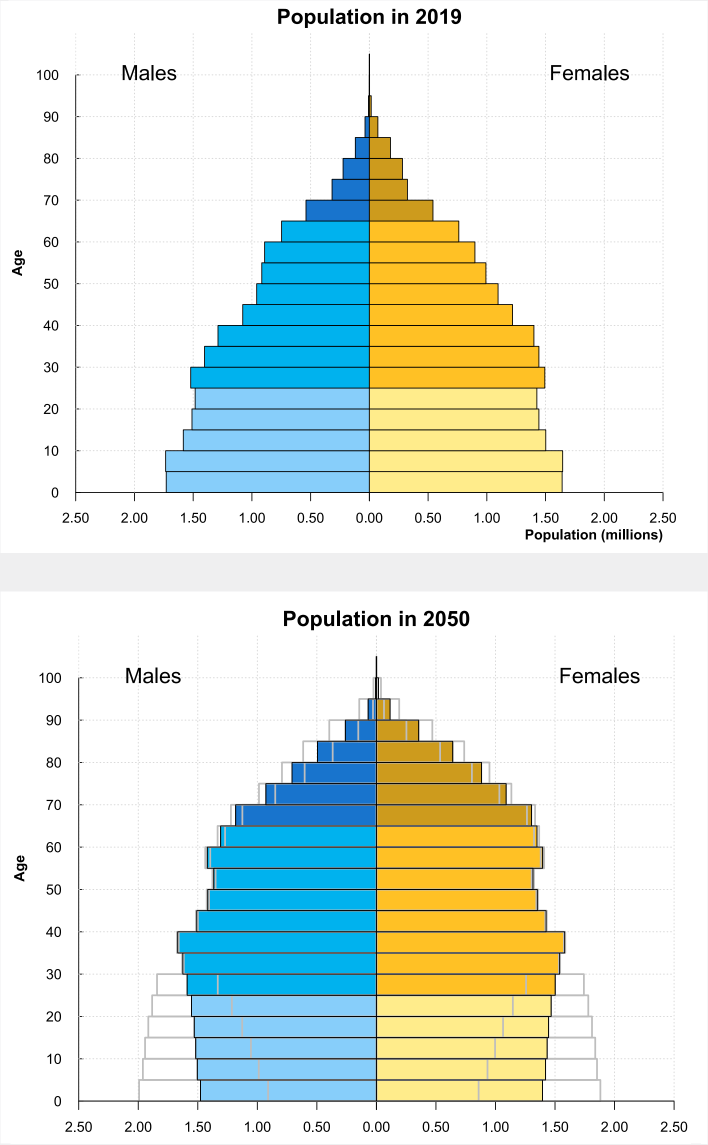
[75] See World Bank data for unemployment, youth total (% of total labor force ages 15–24), from modeled ILO estimates: https://data.worldbank.org/indicator/SL.UEM.1524.ZS?locations=MA and unemployment, total (% of total labor force), based on modeled ILO estimates: https://data.worldbank.org/indicator/SL.UEM.TOTL.ZS?locations=MA.

[76] See World Bank data for labor force participation rate, female (% of female population ages 15–64), from modeled ILO estimates: https://data.worldbank.org/indicator/SL.TLF.ACTI.FE.ZS?locations=MA and labor force participation rate, male (% of male population ages 15–64), from modeled ILO estimates: https://data.worldbank.org/indicator/SL.TLF.ACTI.MA.ZS?locations=MA.

[77] See World Bank data for population growth (annual %): https://data.worldbank.org/indicator/SP.POP.GROW?locations=MA.

[78] These SSP population scenarios use data from World Population Prospects 2010 for the baseline; see https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=10#v2 and further details in Riahi et al. (2017). Under SSP4, middle-income countries see attenuated population growth, and, as in the case of Morocco, even declines, in contrast to rapid population growth in low-income countries.

Figure 3.2: Morocco population pyramids, 2019 and 2050



Source: UN DESA (2019b).

Note: Medium-variant data are shown as colored bars, and uncertainty is shown in gray for 95 percent prediction intervals.


Photo Credit: World Bank

Box 3.1: International migration dynamics in Morocco

International migration has led to a large and increasingly diverse Moroccan diaspora. As of 2019, over 3.1 million Moroccans were living abroad (UN DESA 2019a), the vast majority in Europe, with France, Spain, and Italy as the top destinations, followed by Belgium and the Netherlands. They include highly educated professionals, women, executives, technicians, and other skilled workers (Berriane and Aderghal 2008).

Transfers of capital, skills, and knowledge (scientific, technical, and institutional) by migrants can contribute to both their home and destination communities' innovation and development. Moroccans abroad sent an estimated US$6.7 billion in remittances in 2019, equivalent to about 5.6 percent of Morocco's GDP.[a] Remittances have helped agricultural households buy individual motor pumps, land, agricultural equipment, fruit trees, seeds, and fertilizers (de Haas 2001). Migrants returning home also help introduce new techniques or cropping patterns, enabling local adoption over time (Dadush 2015). There are several ongoing diaspora engagement initiatives for Morocco, including "Mobilization Program Skills", "MDM Invest", the UN "Transfer of Knowledge through Expatriate Nationals (TOKTEN), and "Innovation Morocco", among others (Dadush 2015; Boukharouaa et al. 2014).

Finally, while Morocco is only a minor destination for international migrants, it is an important transit point for African migrants heading to Europe (de Haas 2014; De Bel-Air 2016; Sow, Marmer, and Scheffran 2016; Tangermann and Bennani 2016). In particular, it has attracted large numbers of irregular migrants from Sub-Saharan Africa, who settle in Moroccan cities while awaiting passage to Europe, experiencing multiple challenges in the absence of protective legal and social mechanisms (Sow, Marmer, and Scheffran 2016).

[a] See World Bank data for personal remittances, received (current US$): https://data.worldbank.org/indicator/BX.TRF.PWKR.CD.DT?locations=MA and (% of GDP): https://data.worldbank.org/indicator/BX.TRF.PWKR.DT.GD.ZS?locations=MA.

3.1.2 Climate Trends

Morocco's climate varies with its topography, which includes the Rif Mountains in the north, the Atlas Mountains in the center, plateaus in the east, plains and coast in the west, and the Sahara Desert in the south (World Bank 2021a). The Atlas Mountains run through the center of Morocco, forming a natural divide between the Mediterranean northern coastal zone and the southern interior regions.

Most of Morocco, particularly along the coast, experiences a typical Mediterranean climate, with mild, wet winters and hot, dry summers (World Bank 2021a). The south is much drier and receives approximately 100 millimeters of rainfall on average each year. Mean annual precipitation across the country is 318.8 millimeters, with the rainy season extending from November to March and extremely low precipitation occurring between June and August. In the summer, temperatures along the coast range from 18°C to 28°C and can reach up to 35°C in the interior. In the winter, temperatures along the coast range from 8°C to 17°C and can drop below 0°C in the interior mountain areas. Mean annual temperature for Morocco is 17.5°C, with average monthly temperatures ranging between 9.4°C (December, January) and 26°C (July, August).

Climate data for Morocco shows that the country has experienced considerable warming trends since the 1960s, with mean annual temperature increasing 0.9°C since the 1960s and observed average increases of 0.2°C per decade, exceeding the global average (World Bank 2021a). There is seasonal variability, but increases have been most pronounced from April to June and from September to November. The frequency of hot days has significantly increased across all seasons. Precipitation trends are also highly variable, but the past several decades have seen more erratic rainfall and an overall decline in precipitation. Additionally, seasonal rainfall patterns have shifted to longer and more intense rain events in October and November, but with substantial reductions in rainfall during the rest of the year. The country has also experienced more frequent and intense extreme events overall, including flooding, droughts, and heat waves.

These trends are expected to continue, with Morocco set to become hotter and drier in the future. Mean annual temperature is projected to increase by 1.5°C to 3.5°C by mid-century and possibly by more than 5°C by end of the century (World Bank 2021a). Warming rates are projected to be faster in the country's interior. For precipitation, projections indicate further reductions in average annual rainfall across the country particularly under high emissions scenarios.

The Inter-Sectoral Impact Model Intercomparison Project (ISIMIP) water availability and crop productivity model results for Morocco used in this report broadly confirm these projected trends (see Appendix A.4 for further details, including maps):

- ISIMIP water models show declining water availability on the order of 30–90 percent by 2050. Declines are proportionally larger in the already arid south and southeast (in absolute terms, where rainfall levels are already very low, the changes would not be as significant). Only under the LPJmL RCP2.6 scenario using the Hadley model does the analysis show some increases projected along the coast from Essaouira to Agadir (see Figure A.13 in Appendix A.4).

- Water availability would drop even more sharply from 2050 to 2100, by 50–90 percent, with far higher impacts in the high-emissions RCP8.5 scenario. In the RCP2.6 scenario, however, areas in the north of Morocco could see modest increases under the Hadley model (Figure A.14).

- ISIMIP crop productivity model results show less pronounced changes by 2050, with a mix of slight increases and decreases in the northwestern portion of the country (Figure A.15), where cropping is prevalent (no results are presented for non-cropped areas).

- In the 2050–2100 period, the model results for crop productivity are more consistently negative, especially in RCP8.5, where productivity declines are generally between 30–50 percent (Figure A.16).

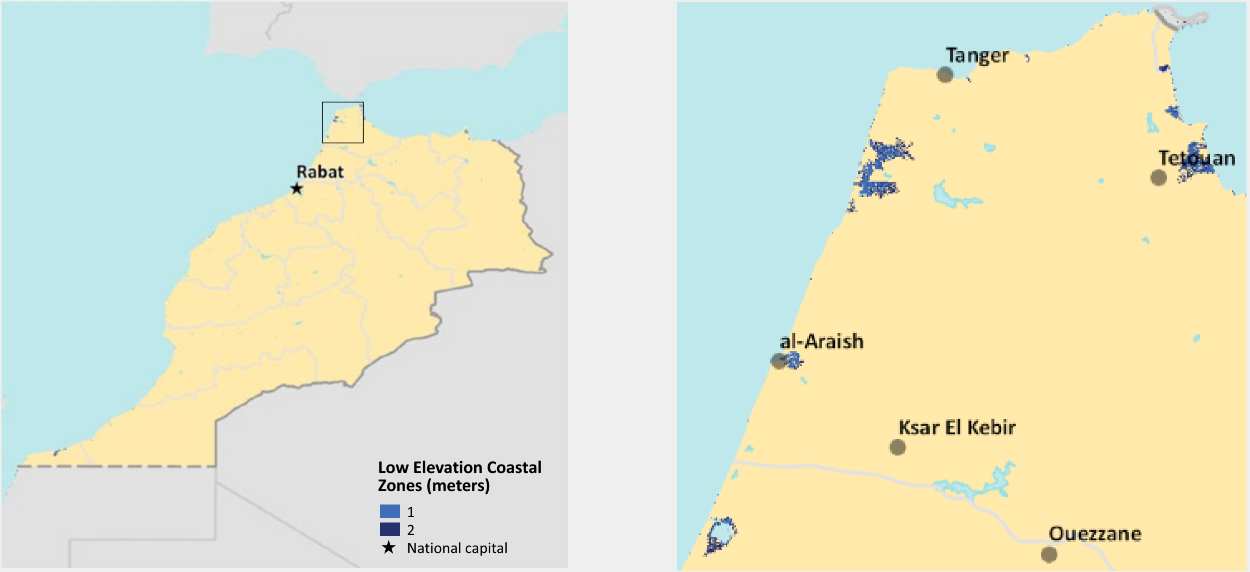
Morocco's already scarce water resources are under increasing pressure from climate change. Droughts are recurrent and becoming more frequent and more severe (Verner et al. 2018). Official drought declarations, triggering government emergency relief, were made in the years 1992–1995, 1998–2001, 2005, 2007, and 2015–2016. Water supply in rural areas and rainfed agriculture are particularly affected. Extended droughts in the Middle Atlas Mountains, in the Oum Er-Rbia watershed, have severely affected water availability (Ouatiki et al. 2019). Increased temperatures could also result in reduced snowpack in the Atlas Mountains, further impacting water reserves and storage in the long run (World Bank 2021a).

The combined effects of climate change could drastically alter Morocco's landscape. Two major biomes in Northern Morocco—the temperate conifer forest and temperate sclerophyll woodlands—are projected to shrink, replaced by an increase in desert, tropical xerophytic shrubland, or tropical grassland (World Bank 2013). Some models show the temperate conifer forest entirely disappearing by the end of the century. These shifts are consistent with the projected northward migration of the subtropical desert high climate system and the northward migration of the Sahara margin.

The coast of Morocco is exposed to high seas and surf action and is vulnerable to accelerated sea-level rise in areas of concentrated economic, touristic, and ecological value (Brown, Kebede, and Nicholls 2011). Morocco has a long coastline, but much of it rises quickly in elevation (Figure 3.1). Low-lying land at risk of further flooding due to sea-level rise includes the Nador lagoon, the delta of the Moulouya River, and the low-lying coastal plains of Oued Nekkor and Oued Laou. The areas of highest sea-level rise exposure are on the Tingitana Peninsula (including the coast near Tétouan, al-Araish, and Asilah) and in low-lying areas near the southern border (Figure 3.3). These distinct pockets of land could see some levels of inundation and potential habitability losses by 2050.

Overall, the Intergovernmental Panel on Climate Change (IPCC) *Fifth Assessment Report* found median sea-level rise projections for the Middle East and North Africa region of about 0.35 meters under RCP2.6 and 0.6 meters under RCP8.5 by 2080–2099, relative to 1986–2005 levels. The projected upper bound is about 0.6 meters under RCP2.6 and 1 meter under RCP8.5 (Waha et al. 2017). Combined sea-level rise and storm surge could affect coastal hotels and industries that are situated behind dune complexes. Up to 1.8 million people could be affected by a half-meter sea-level rise, with up to US$5.5 billion in economic impacts in the absence of adaptation (Brown, Kebede, and Nicholls 2011).

Figure 3.3: Land area inundated by 1-meter and 2-meter combined sea-level rise and storm surge for all of Morocco (left) and for the Tingitana Peninsula (right), by 2050



3.1.3 Projected Climate Migration Trends

Projected numbers of climate migrants

Analysis for this report shows climate migration increasing to 2050 across all three scenarios, but with considerable differences as follows (Figure 3.4 and Table 3.3):

- Pessimistic reference scenario: 1.9 million climate migrants (with a range of 1.1 to 2.7 million);
- More inclusive development scenario: 1.5 million climate migrants (with a range of 0.9 to 2.1 million);
- More climate-friendly scenario: 0.5 million climate migrants (with a range of 0.3 to 0.7 million).

The highest estimate of climate migrants, 2.7 million in the pessimistic reference scenario (95th percentile of the distribution of model runs), would represent 7.7 percent of the total projected population in 2050. The lowest estimate, 300,000, in the more climate-friendly scenario, would be about 0.8 percent of the total projected population in 2050.[79]

The number of climate migrants increases faster in the pessimistic reference and more inclusive development scenarios, which share the high-emissions pathway, than in the more climate-friendly scenario. This reflects the more pronounced climate change impacts in these scenarios, as shown in the ISIMIP water availability and crop productivity projections (Appendix A.4). Climate change impacts on both rural livelihoods and urban systems, especially with regard to water availability, are less severe in a low-emissions scenario, and would significantly affect the rate of climate migration.

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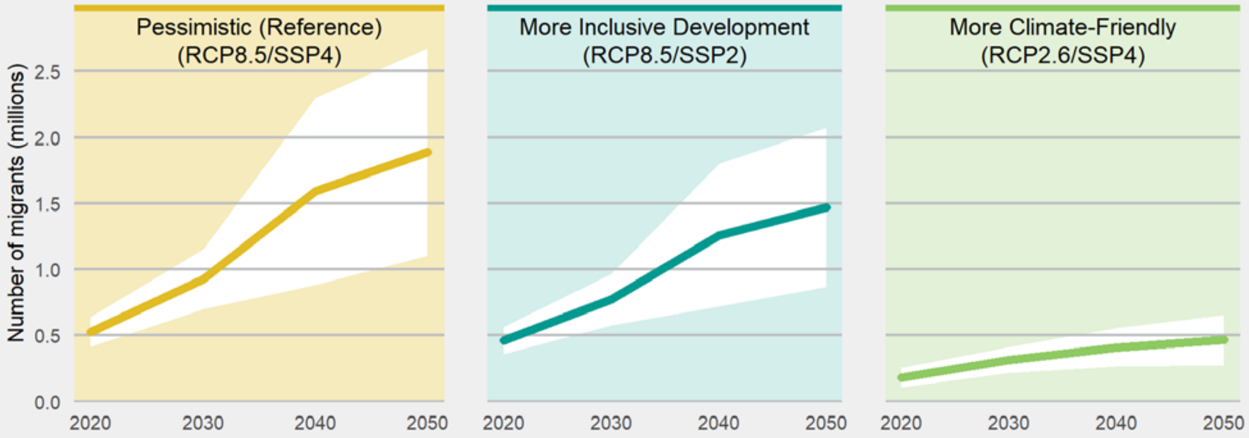
[79] The spread across model runs is also significantly narrower in the more climate-friendly scenario, a function of the greater certainty resulting from more consistent climate change impacts across the RCP2.6 model runs.

Figure 3.4: Projected number of internal climate migrants in Morocco in three scenarios, 2020–2050



Climate migrants as a percentage of the total population

Year	2020	2030	2040	2050	2020	2030	2040	2050	2020	2030	2040	2050
%	1.5	2.6	4.5	5.4	1.3	2.1	3.4	4.0	0.5	0.9	1.1	1.3

Note: Dark lines represent the average runs for each scenario. The white areas around the central trend line represent the confidence intervals, which reflect the degree of agreement among the four model runs used to provide each estimate for each scenario. Narrower confidence intervals indicate greater agreement among the model runs for each scenario. The confidence intervals get larger with each successive time interval owing to momentum that builds over time for each model run and to increasing divergence among models as the climate change signal increases.

Table 3.3: Projected number and share of internal climate migrants in Morocco in three scenarios, 2050

	Scenario					
Result	Pessimistic/ Reference		More inclusive development		More climate-friendly	
Number of internal climate migrants by 2050 (million)	**1.9**		**1.5**		**0.5**	
5th (left) and 95th (right) percentile (million)	1.1	2.7	0.9	2.1	0.3	0.7
Internal climate migrants as percent of population	**5.4%**		**4.0%**		**1.3%**	
5th (left) and 95th (right) percentile	3.7%	7.7%	2.3%	5.6%	0.8%	1.9%

The model results also show that climate migrants could make up an important share of Morocco's total internal migrants by 2050. The number of other internal migrants is projected to rise in the coming decades, to 2 million, on average, in 2050 under SSP2 (moderate development), or 4 million, on average, under SSP4 (unequal development), as shown in Figure 3.5. In the pessimistic reference scenario, which combines SSP4 with the high-emissions pathway, RCP8.5, climate migrants are projected to make up 21 percent of all internal migrants by 2050, while in the more inclusive development scenario, which combines SSP2 with RCP8.5, the share would be 52 percent.[80] In the more climate-friendly scenario, which combines SSP2 with the low-emissions pathway, RCP2.6, climate migrants would represent about 10 percent of all internal migrants by 2050.

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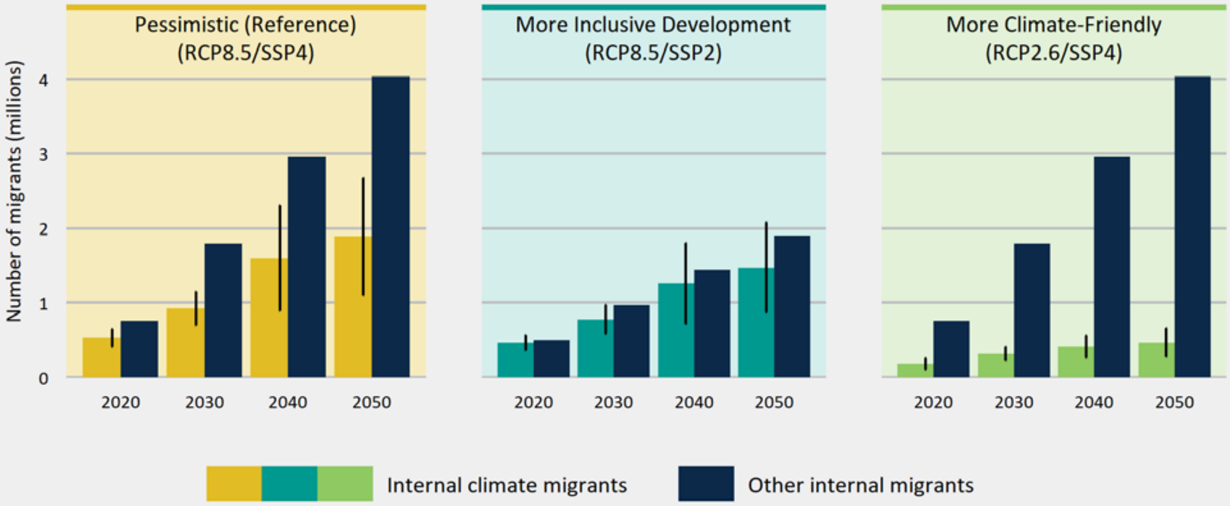
[80] Another important reason for this is that under SSP2, which represents a more equitable development pathway, urbanization slows and education disparities between rural and urban areas narrow, resulting in less other internal migration overall.

Figure 3.5: Projected number of climate and other internal migrants in Morocco in three scenarios, 2020–2050



Note: The whiskers on the climate migrant bars represent the 95th percentile confidence interval for the four model runs for each scenario. There are no confidence intervals for other internal migrants, because only a single development trajectory is used.

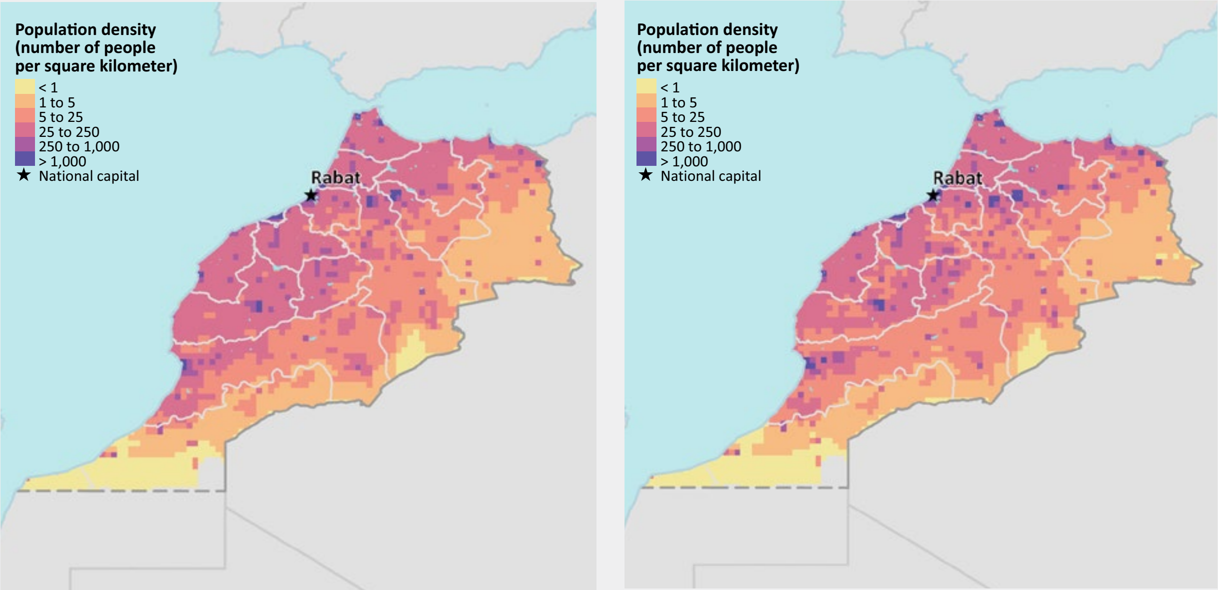
Projected spatial patterns of climate migration

The majority of Morocco's population lives west of the Atlas Mountains, and 63 percent live in urban areas on or near the coast (Figure 3.6). Casablanca is the commercial hub and largest city, with 3.7 million residents as of 2018, while Rabat, the capital, is the second-largest city, with 1.8 million residents (UN DESA 2018a). Though Fès was the only other Moroccan city with more than 1 million people as of 2015, by 2025, six urban agglomerations are projected to exceed that level (UN DESA 2018b). Overall, the urban population grew by an estimated 2.1 percent per year in 2015–2020 and is projected to grow by 1.9 percent annually in 2020–2025. Population density is lower in the mountain and arid areas to the east and south, with patches of relatively higher density indicating urban areas (for example, Zagora in the Souss-Massa-Draâ region) or oases (for example Erfoud in the Meknès-Tafilalet region).

These patterns of population distribution are expected to remain relatively unchanged to 2050 (Figure 3.6). In the pessimistic reference scenario, the largest projected increases in population density would be in urban areas (Figure 3.7), notably the zone close to Agadir on the southwest coast, the Rabat-Casablanca corridor, and Marrakech, Fès, and Meknès in the foothills of the Atlas Mountains. Outside urban areas, the southeast of the Oriental region could see a moderate increase in density to 2050, but from a small baseline. Large relative declines, also from low baselines, are projected in the more arid southern regions.

Areas projected to be climate in-migration hotspots include the southwest near Agadir, around Rabat, and the Tingitana Peninsula, including Tangiers (Figure 3.8). Smaller climate in-migration hotspots are also visible in certain urban areas inland and along the eastern coast, and in the arid east and southeast. The steep topography of coastal cities such as Rabat and Tangiers would reduce the impacts of sea-level rise (Figure 3.1 and Figure 3.3), and better climatic conditions may also increase the cities' relative attractiveness. Specifically, movement to these areas is driven mainly by projected increases in crop productivity, as shown by the ISIMIP crop models, while water availability conditions are expected to remain stable or only slightly decrease (Appendix A.4). The rural areas around Agadir and Tangiers are a mix of irrigated and rainfed croplands, and around Rabat, they are mostly rainfed croplands that will see increases in crop productivity under most models, while the arid east and southeast are mainly pastoral and rangeland areas. Increasing population densities in semiarid to arid areas will require strong adaptation interventions to ensure sustainability.

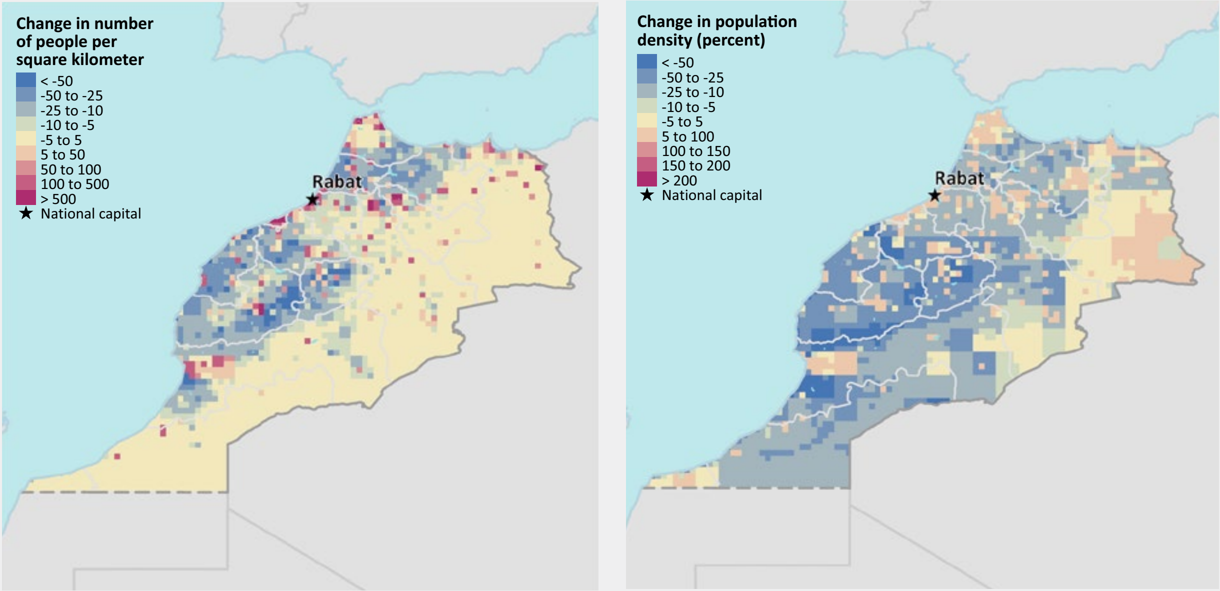
Figure 3.6: Baseline population density, 2010, and projected population density in the pessimistic reference scenario, 2050, Morocco



a. 2010

b. 2050

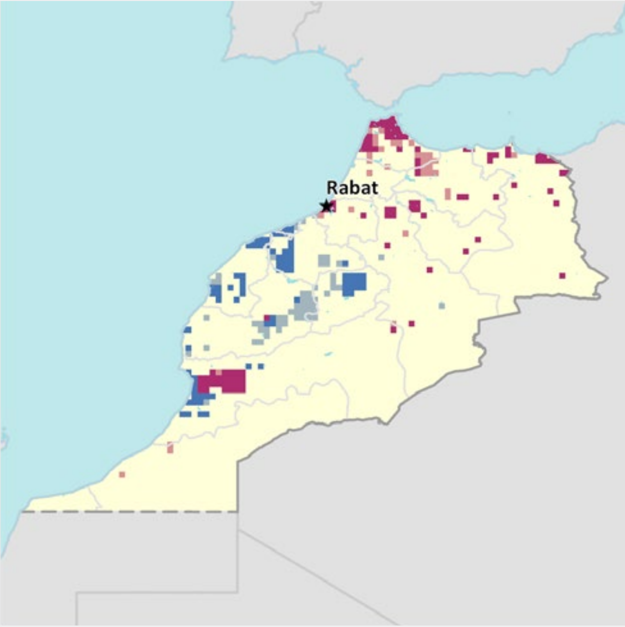
Figure 3.7: Absolute and percentage change in population density in Morocco in the pessimistic reference scenario, 2010–2050



a. Change in population density

b. Percentage change in population density

Figure 3.8: Hotspots projected to have high levels of climate in-migration and climate out-migration in Morocco, 2050



IN-MIGRATION

🟪 High certainty in high levels of climate in-migration

🟥 Moderate certainty in high levels of climate in-migration

OUT-MIGRATION

🟦 High certainty in high levels of climate out-migration

▨ Moderate certainty in high levels of climate out-migration

Note: High certainty reflects agreement across all three scenarios modeled, and moderate certainty reflects agreement across two scenarios. In- and out-migration hotspots are thus areas in which at least two scenarios concur on density changes in the top 10th percentile of the density distribution, which in Morocco represents an increased population density in 2050 of about 1 to 14 people per km^2, depending on the scenario. For decreased population density, it is about minus –3 to minus –14 people per km^2.

Climate out-migration hotspots are concentrated in the central foothills, including around Marrakech, and on the west and southwest coast around Casablanca, Safi, and south of Agadir to Tiznit. Rural areas in these regions have mainly rainfed agriculture, and the ISIMIP models show consistent declines in water availability and either small declines or no changes in the crop productivity. As in the climate in-migration hotspots, impacts from sea-level rise are less of a factor in these climate out-migration hotspots, mainly due to topography. Overall, climate out-migration would thus have a dampening effect on population growth in these areas.

Trends in livelihood zones

Morocco has three main livelihood zones: rainfed croplands, pastoral and rangelands, and seminatural and wildlands. Irrigated croplands are scattered within the areas of rainfed croplands, including to the north of Rabat and to the east of Marrakech. The distribution of livelihood zones is presented in Figure 3.9 for the baseline year of 2015, following the anthropogenic biome classes defined by Ellis et al. (2010).[81] Figure 3.10 shows the projected net change in the number of climate migrants by 2050 for each livelihood zone, as defined above. It is important to recognize that this represents migration into or out of the zones and does imply changes in the livelihoods of those who migrate. Across Morocco, pastoral and rangelands would see

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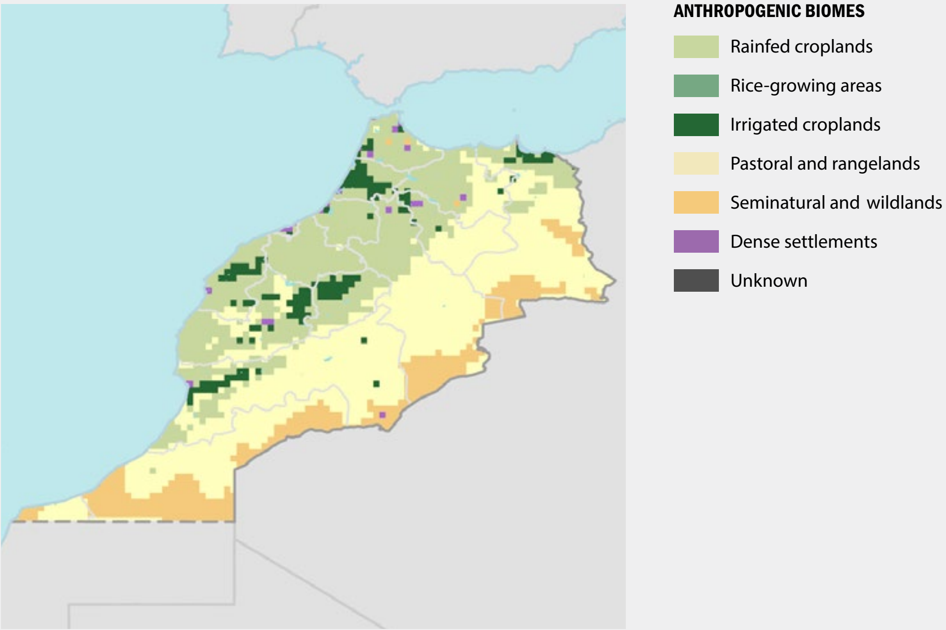
81. The livelihoods zones used in the *Groundswell* reports represent an aggregation of anthropogenic biome classes in Ellis et al. (2010) into areas with relatively coherent livelihood characteristics. Note that although it is known that zones will shift with climate change, no projections of those shifts are available, so for the modeling presented in this report, the distribution of zones is assumed to remain static through 2050.

small positive net climate migration, potentially exceeding 200,000 people in the high-emissions scenarios. Rainfed croplands would see small negative net climate migration by 2050 overall, though the uncertainty ranges show both negative and positive values. This indicates some divergence in the climate change impact model combinations underlying each scenario, both for projected water availability and crop productivity.

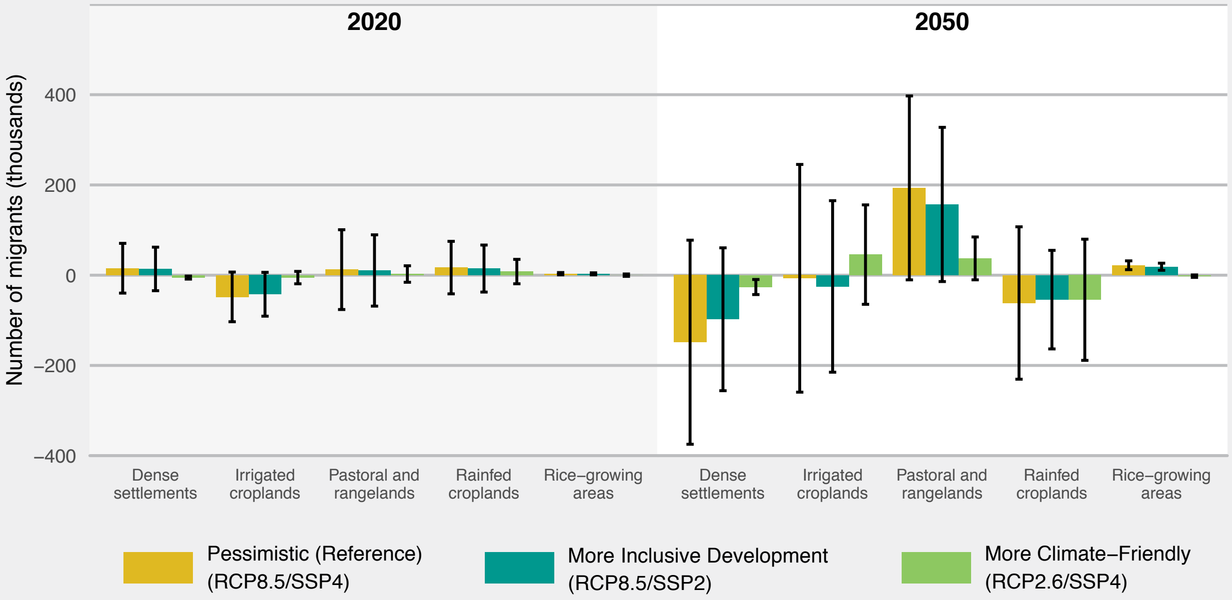
Figure 3.9: Livelihood zones in Morocco, by anthropogenic biome, 2015



Source: Ellis et al. (2010)

Photo Credit: Juan Ignacio Tapia

Figure 3.10: Projected net climate migration in and out of livelihood zones in Morocco in three scenarios, 2020–2050



Note: Whiskers show 95th percentile confidence intervals for climate migrants.

3.1.4 Consultations on Modeling Results

The modeling results were shared with stakeholders in Morocco through virtual consultations in March and April 2021. The workshops included representatives from government ministries, departments, and agencies, academia, civil society, and international organizations. Along with providing feedback on the modeling results, participants were asked to reflect on historical and current migration patterns, including in the context of climate change, and potential policy directions. They agreed that the issues raised by the modeling were relevant and provided additional insights, particularly in the context of territorial development.

Participants reflected on the importance of policies, plans, and strategies to increase resilience to climate change, which could shape future migration dynamics and the relative attractiveness of locations. They pointed to Morocco’s medium- to long-term efforts to develop water resources, foster sustainable rural and urban development, build the resilience of key sectors, diversify livelihoods, and promote circular economy approaches. For example, in Agadir, a major coastal city and area of both agricultural and touristic importance, efforts to ensure adequate water supply and access have been paired with measures to make irrigation more efficient and foster sustainable agriculture.

Participants also highlighted ongoing efforts on water conservation, recycling and reuse, desalination, and efficient irrigation, as well as the development of water regulations and standards, particularly to meet the needs of major coastal cities and key sectors. They emphasized that close and ongoing engagement with multiple stakeholders and targeted awareness-building of the economic implications of climate change could increase the impact of policies and strategies.

Participants also reflected on migration trends, socio-economic drivers of migration, and issues related to climate change and mobility. Rural-urban migration has historically been important in Morocco. In recent years, Morocco's rural areas have also seen structural changes in terms of share of rural population, main employment sectors, and new economic opportunities. Historically, the mid-Atlas region has seen in-migration from the Sahara, which has resulted in overall population growth, while recently, people have migrated out of the region in search of jobs, mainly to urban areas. Coastal cities such as Casablanca and Mohammedia are vulnerable to sea-level rise, while these cities have historically been attractive in-migration areas. Mohammedia in particular plays an important role in the country's energy sector and has developed urban resilience strategies.

Participants also said it is important to further unpack environmental drivers of mobility in local contexts, especially ecosystem changes and shocks. For example, Morocco's oases are highly vulnerable to environmental and climatic changes and have historically seen high out-migration after extreme events such as fires. Agriculture in the Mediterranean region already faces water resource constraints and is highly vulnerable to climate change, so it was noted that droughts could be particularly potent drivers of migration. Furthermore, groundwater was noted as a key resource, and the importance of assessing Morocco's future water availability was highlighted as critical.

3.1.5 What Do These Results Mean for Morocco's Development Future?

1. **With climate migration set to rise over the next three decades, representing up to 8 percent of the total population in the pessimistic reference scenario, it is important for Morocco to anticipate interconnected drivers of mobility and ensure that migration can be a positive adaptation strategy.**

Internal migration is important part of historical mobility patterns in Morocco, but climate change impacts may drive a growing share of that migration. The literature has found direct and indirect links between mobility in Morocco and both sudden- and slow-onset climate events (Tangermann and Chazalnoel 2016). Hamza el al. (2009) concluded that in two oasis villages in the Middle Draâ Valley of southern Morocco, environmental degradation was a major factor for either past or intended migration, with lack of access to services and opportunities also being major contributing factors. In addition, the Internal Displacement Monitoring Centre (IDMC) estimates the risk of future internal displacements from sudden-onset hazards in Morocco at nearly 32,400 per year, with about 60 percent due to floods.[82]

Though climate change impacts may drive mobility, migrants themselves may not make that direct linkage. Household surveys in Morocco (M. C. Nguyen and Wodon 2014) showed that even when a quarter of households had been affected by weather shocks, respondents did not directly identify droughts, floods, desertification, or rising sea levels as major reasons for migration. Instead, they cited low farm revenue, lack of agricultural employment, and better opportunities elsewhere, even when those factors were linked to climate change. Still, the probability of both temporary and permanent migration has been found to increase when the household had been affected by adverse weather shocks or their consequences (World Bank 2014a).

Morocco is a global leader on the climate and mobility agendas. In 2018, Morocco hosted the Intergovernmental Conference to Adopt the Global Compact for Safe, Orderly and Regular Migration in Marrakech. It now has an opportunity to show continued leadership on both mobility and climate action by proactively addressing projected climate migration, and developing context-specific and durable solutions in concert with local actors.

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[82] The rest would be due mainly to earthquakes, with a minor risk of tsunamis. See the IDMC profile page for Morocco: http://www.internal-displacement.org/countries/morocco (accessed May 23, 2021).

2. **With a third of Moroccans still employed in agriculture, adaptation is crucial given projected declines in water availability and crop productivity especially in the second half of the century. Measures will need ensure that people are able to adapt in place, with viable and diversified livelihood options.**

Climate change, particularly as it affects water supplies, poses serious threats to agriculture, most notably in rainfed croplands—which is why modeling for this report shows potential climate out-migration hotspots in several of those areas. About 16.8 percent of land in Morocco is considered arable.[83] Crops grown across Morocco include cereals, commercial plantation crops (almonds, grapes, citrus, olives, dates), industrial crops (cotton, sugar beets and cane, oilseeds), forage, vegetables, and pulses (Verner et al. 2018). Farming in the north is diversified, including orchards, annual crops, cereals, and vegetables, while in central Morocco, mostly cereals are grown, integrated with subsistence livestock production; in the south, there are oases and greenhouses. Rapid value chain assessment results suggest that every 10 percent loss of crop yields nationally would reduce direct jobs by about 13,000. Reduced water availability could also limit farm activities, forcing farm workers to find other sources of employment, potentially leading to migration (World Bank 2017).

Despite recent progress in the expansion of irrigation systems, agricultural productivity remains vulnerable to recurrent droughts, especially for smallholder farmers and in areas under rainfed agriculture. About 70 percent of Morocco's farms are smaller than 5 hectares (Verner et al. 2018). Small family farms, averaging just 1.6 hectares, generally produce low-value commodities with rainfed production systems and little modern technology. In contrast, about 4 percent of farms are 20 hectares or larger. These commercial farms cover only 4.6 percent of agricultural land, but contribute 50 percent of agricultural GDP, often growing high-value export crops with irrigation systems; they also employ about half the rural labor force.

Climate projections suggest that conditions for growing important crops for Morocco could become unsuitable in parts of the country (Drine 2011), especially for barley (World Bank 2013). Echoing the findings for this report, past studies have projected that yields for a variety of crops could decrease to mid-century and beyond (Giannakopoulos et al. 2009; Schilling et al. 2012). Climate change could bring more difficult growing conditions for fragile mountainous areas, oasis ecosystems, and argan trees.

Animal husbandry and pastoralist transhumanism are important for rural livelihoods as well. Though only 18 percent of farmers depend entirely on livestock, it provides a significant financial reserve for most small farmers (Verner et al. 2018). As a result of both anthropogenic and climate factors, the rangelands that now make up 82 percent of the country's arid land face increased desertification, which, in turn, could negatively impact feedstock levels (Kingdom of Morocco 2016). Drought could also reduce livestock production by reducing forage availability, and, in extreme cases, leave animals without drinking water. Results for this report project small positive net climate migration into pastoral and rangeland areas that will need adaption measures to ensure livelihood viability.

Many people who rely on livestock production are nomadic (about 25,000, according to the 2014 census), concentrated in the eastern and southern regions (Kingdom of Morocco 2016), some of which could become climate out-migration hotspots. About 25 percent of sheep and goats in Morocco are kept in some type of mobile system (Tangermann and Bennani 2016). While demographic and socio-economic gaps between nomads and the general population have decreased, there are still more to be done. The general trend is towards more sedentary and commercial forms of pastoralism, which could eventually change and increase vulnerability to both the sudden shocks and the slow-onset consequences of climate change (Freier, Finckh, and Schneider 2014).

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[83] See World Bank data on arable land (% of land area): https://data.worldbank.org/indicator/AG.LND.ARBL.ZS?locations=MA.

3. **Climate change is projected to place further stress on Morocco's rural and urban water supplies, even as demand grows due to demographic and economic expansions. Improved water resource development; efficiency gains, including in irrigation; and integrated water resource management can help mitigate water scarcity and increase economic and social resilience.**

As noted earlier, Morocco is already one of the most water-scarce countries in the world. Water availability per capita has declined to below the water poverty level of 1,000 cubic meters per person per year: from about 2,600 in 1960 to about 700 in 2016 (Kingdom of Morocco 2016). By 2025, an estimated 35 percent of Moroccans are expected to fall below the extreme scarcity threshold of 500 cubic meters per person per year (UN DESA 2015). By 2050 this situation could extend to the entire population (World Bank 2017).

With climate change, conventional water resources may no longer be enough to meet household and economic needs. Reduced snowpack in the Atlas Mountains, due to a combination of warming and reduced precipitation, combined with more rapid springtime melting, is expected to reduce supplies of seasonal meltwater for lowland areas (García-Ruiz et al. 2011). Water sector vulnerability could also be affected by increasing costs related to the aging and deteriorating quality of surface and underground resources. Competing uses from rapid urban development also pose challenges to the agricultural sector by decreasing available freshwater for irrigation (Michel-Kerjan et al. 2014).

Improvement of water use efficiency, desalination of sea and brackish water, treatment and reuse of wastewater, and rainwater harvesting already feature prominently in the national water strategy. Morocco is committed to integrated water resources management under its national Water Sector Development Strategy and its Water Law 36-15 from 2016. It aims to save 2.5 billion cubic meters per year through water demand and efficiency management—95 percent through improved irrigation systems, 5 percent through improved potable water networks. Through supply management and development, Morocco aims to secure another 2.6 billion cubic meters per year—65 percent through the construction of 60 large dams and 1,000 small- and mid-sized dams by 2030, 20 percent through desalinization, 11 percent through reuse of treated water, and 4 percent through rainwater capture (World Bank 2017). The government is also making efforts to conserve underground aquifers. Efficient irrigation plays a key role in Morocco's Water Sector Development Strategy as well (World Bank 2021a). A National Irrigation Water Saving Program aims to establish drip irrigation over 555,000 hectares, saving approximately 1.4 billion cubic meters per year. The government is also working on the extension of irrigation to new agricultural areas over 260,000 hectares.

4. **Climate in-migration hotspots coincide with major coastal urban centers, including Agadir, Rabat, and Tangiers, as well as smaller cities in the Tingitana Peninsula and along the eastern coast. Expanding coastal cities will need to undertake climate-resilient and inclusive urban planning that accounts for climate risks—including sea-level rise, storm surge, and flooding—and their impacts on key economic sectors and urban infrastructure.**

Some of Morocco's largest cities are already vulnerable to floods, including from storm surges, swelled rivers, and flash floods—the latter have led to some of Morocco's biggest natural disasters. Between 2000 and 2020, Morocco experienced 17 major flood events.[84] Urban flooding due to extreme weather events poses an important economic risk to Rabat and Casablanca (Grant 2011), testing citywide absorption and drainage capacities. Casablanca could be 1.5 times more vulnerable to urban flooding by 2100 (Balica, Wright, and van der Meulen 2012), while sea-level rise and increasingly intense precipitation could make 40–50 kilometers of coast vulnerable to erosion (Grant 2011).

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[84] Data from the EM-DAT database: https://public.emdat.be (accessed June 6, 2021).

Potential economic losses for the 2010–2030 period due to natural hazards and impacts of climate change in Casablanca have been projected at US$1.4 billion, or 7 percent of the GDP of Greater Casablanca (World Bank 2011a). In 2008, flash floods caused by torrential rains caused a number of deaths in northern Morocco, including Tangiers, which also suffered economic losses to its industrial zone (Michel-Kerjan et al. 2014). One study found that sea-level rise in the Bay of Tangier could greatly increase the area at risk from storm surge in Tangiers, with potential affected areas including port infrastructure, water diversion canals, the industrial zone, railways, roads, and densely populated areas (Snoussi et al. 2009).

Moroccans living in cities' poorest areas are particularly vulnerable to climate change impacts due to lacking or deficient basic services and, in some cases, the location of informal settlements in high-risk areas. As of 2018, an estimated 9.2 percent of Morocco's urban population lived in slums.[85] In Casablanca, for instance, slum-dwellers typically live in dilapidated housing and lack paved roads, running water, (legal) electricity, and other public amenities (Bogaert 2011). Slums and structures built with cheaper or inferior materials are particularly vulnerable to flooding (World Bank 2011a). A number of slums in Casablanca are in low-lying areas and encroach on areas legally protected for water catchment. This could be an even graver issue if climate change drives an increase in low-income migrants into such informal settlements.

Morocco's tourism sector may also be affected by climate change impacts on coastal areas. One study found that almost all sandy beaches and nearly 85 percent of tourism infrastructure in the Bay of Tangier could be lost to an 0.86-meter sea-level rise by 2100 (Snoussi et al. 2009). Other studies in Morocco have shown that climate change impacts on water supply and demand are likely to increase competition for water between tourism and other uses, which may affect the economic performance of specific tourism services (Tekken, Costa, and Kropp 2013; Tekken and Kropp 2012).

Climate change may also affect the viability of fisheries and aquaculture, which are important sources of livelihoods. The maritime fisheries sector contributes up to 2.3 percent of Morocco's GDP, directly or indirectly employs 660,000 people, and helps sustain 3 million (Kingdom of Morocco 2016). Through its fisheries strategy, Halieutis, Morocco increased the contribution of the sector to GDP eightfold between 2009 and 2019, while nearly doubling its contribution to exports, and creating almost 30,000 jobs (Maritime News 2019). The government has identified fisheries as one of the sectors that are most vulnerable to climate change, due to impacts on "upwelling" zones (which are very nutrient-rich and have a high fish density) and warming marine waters (Kingdom of Morocco 2016; World Bank 2013). Ocean and coastal ecosystems are already fragile due to human activity, including overexploitation of fisheries. Already, mating periods are shifting, some species are migrating or disappearing, and the number of days amenable to fishing is dropping due to increases in flooding and storms. Aquaculture, in turn, can be affected by the increased incidence of disease and reduced availability of freshwater (FAO 2018). Sea-level rise and extreme weather events can also affect the sector's coastal infrastructure (World Bank Group 2013).

5. **Given the potential escalation of climate change impacts beyond 2050, Morocco would need to continue pursuing economic transformation toward low-carbon and resilient development pathways. National strategies across key sectors are in place that can help create an enabling environment aligned with the more inclusive and more-climate friendly scenarios in this report and shape future migration dynamics.**

Looking out to the end of the century, further declines in water availability and crop productivity, as suggested by the ISIMIP models used in this report, may exacerbate impacts on climate-vulnerable sectors and populations. Water availability is projected to decline across most of the country in the high-emissions scenarios, with declines of 50–90 percent over much of the country by the end of the century (Appendix A.4). Crop productivity is also more severely impacted under the high-emissions scenarios by the end of the century.

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[85] See World Bank data for population living in slums (% of urban population): https://data.worldbank.org/indicator/EN.POP.SLUM.UR.ZS?locations=MA.

Morocco is already taking action to reap "triple wins" by adapting its agriculture and fisheries to climate change and creating new economic opportunities. In February 2020, the Morocco Green Generation 2020–2030 Strategy was launched, an extension of the Green Morocco Plan (Plan Maroc Vert), the national agricultural strategy launched in 2008 (ADA 2020).[86] Morocco has been investing to enhance agricultural productivity, together with measures to improve the sector's water resource management, reduce its fossil fuel consumption, move away from the production of low-value staple crops towards higher-value horticulture exports, and introduce soil carbon management techniques such as direct seeding. The government is also investing in the sustainability of fish stocks to secure the durability of this critical economic sector, along with the development of sustainable aquaculture. This is in combination with efforts to preserve coastal and mountainous areas that are central to the future development of the tourism sector (World Bank 2014a).

The Green Morocco Plan has reaped important results that build resilience, such as a fourfold increase in the area equipped with drip irrigation systems, from 128,000 ha in 2008 to 542,000 ha in 2018.[87] The Green Generation 2020–2030 Strategy aims to build on these by accelerating the transition towards a more climate-resilient agriculture sector, while also offering a people-centered strategy that focuses on job creation, increasing economic opportunities in the country's disadvantaged rural areas, and building human capital to facilitate higher productivity employment and labor mobility.

Morocco has also set increasingly ambitious greenhouse gas emission reductions goals and has emerged as a regional leader on renewable energy. In its updated Nationally Determined Contribution (NDC), Morocco committed to reducing its emissions by 18.3 percent by 2030 relative to a 2010 baseline reference scenario, with the possibility of a reduction of 45.5 percent conditional on receiving international support (Kingdom of Morocco 2021). The country also aims to have 52 percent of its installed electricity generation capacity come from renewable sources by 2030, and it has set additional targets for energy efficiency and energy use in the built environment. The ambitious Noor Solar Plan aims to support the achievement of this objective through large scale solar power projects at various locations, including Ouarzazate and Midelt with solar thermal, photovoltaic and concentrated solar power (Senhaji 2016). Morocco is also one of the first countries in Africa to use green bonds to fund renewable energy projects and has developed guidelines on certifying and issuing bonds as resources for clean energy facilities (NDC Partnership 2018). In addition, Morocco is implementing a number of policy reforms to meet national climate change priorities. For instance, it has removed subsidies on petroleum products to encourage more efficient use of energy and to free up resources to invest in the transition to a green economy (Gass and Echeverría 2017).

Morocco has also taken steps to implement the adaptation- and resilience-related components of its first NDC. For instance, through the World Bank-supported Disaster Risk Management Development Policy Loan with Deferred Drawdown Option for Catastrophe Risks (Cat DDO), the country is strengthening its capacity to manage the financial impact of natural disasters and climate-related shocks, while also upgrading its institutional framework for disaster risk management.[88] This includes reforms to the Solidarity Fund against Catastrophic Events that provides compensation to the uninsured, such as the poor and most vulnerable, to cover losses caused by extreme events, including flooding. In its updated NDC, submitted in June 2021, Morocco's adaptation priorities are aligned with the 2020–2030 National Strategic Plan for Adaptation, with objectives for key sectors including meteorology, agriculture, water, fisheries and aquaculture, forestry, vulnerable ecosystems, territorial and urban development, and health (Kingdom of Morocco 2021).

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[86] See also the "Foundations" web page for the Green Morocco Plan: https://www.ada.gov.ma/en/foundations (accessed May 23, 2021).

[87] See "Main Achievements of the Green Morocco Plan": https://www.ada.gov.ma/en/main-achievements-green-morocco-plan (accessed May 23, 2021).

[88] See project press release: https://www.worldbank.org/en/news/press-release/2019/12/11/upgrading-moroccos-disaster-risk-management-strategy.

3.2 CLIMATE MIGRATION PROJECTIONS FOR VIETNAM

Key Findings

- **Climate migration is projected to increase by 2050 in all three scenarios modeled. The number of climate migrants is largest in the pessimistic reference scenario, averaging 3.1 million people (3.1 percent of the total population). In the more inclusive development scenario, the projection is 1.9 million (1.9 percent of the total population), and in the more climate-friendly scenario, it is 1.5 million (1.5 percent of the total population). Sustained development gains through low-carbon, resilient and inclusive development pathways will help reduce the scale of climate migration.**

- **By 2050, in the pessimistic reference scenario, about 26 percent of all internal migrants could be climate migrants—and in the more inclusive development scenario, also with a high-emissions pathway, 36 percent. In the more climate-friendly scenario, it would be about 14 percent. Climate change impacts may alter patterns of mobility, with implications for development planning in Vietnam.**

- **Hanoi and the Red River Delta are projected to be the largest hotspots for climate in-migration by 2050; there are also smaller in-migration hotspots in the coastal central region, including Bin Dinh, Quang Ngai and Quang Tri provinces. These areas are projected to see improvements in water availability to 2050 and, on average, in crop productivity. Though the Red River Delta faces impacts from sea-level rise, they are largely confined to the mouth of the river, with better conditions prevailing further inland.**

- **The largest climate out-migration hotspots by 2050 are projected to be the Mekong Delta and around Ho Chi Minh City, Vietnam's most populous city. Sea-level rise augmented by storm surge is the main driver of migration from the Mekong Delta, as the low-elevation coastal zone is already subject to inundation and associated impacts. Ho Chi Minh City and its environs are projected to see declines in water availability. Even with climate out-migration, these areas will still support a large number of people. High population densities in both climate in and out-migration hotspots that are highly vulnerable to sea-level rise and storm surge will require strong proactive adaptation measures and planning.**

3.2.1 Country Context

Vietnam has made remarkable advances in development over the last decades. Economic and political reforms under Đôi Môi in the 1980s, have spurred rapid economic growth, transforming what was then one of the world's poorest nations into a lower middle-income country.[89] GDP growth has been steady since 2000, averaging about 6–7 percent, with some fluctuation—from a high of 7.5 percent in 2006, to a low of 5.2 percent in 2012.[90] Robust domestic demand and export-oriented manufacturing contributed to a GDP growth rate of 7.0 percent in 2019, one of the fastest growth rates in Southeast Asia.

However, despite a highly effective COVID-19 response that has gained global recognition (World Bank 2021c; Malhotra 2020; T. V. Nguyen et al. 2021), given Vietnam's deep integration with the global economy, a dampening of growth was unavoidable. Instead of the 6.5 percent growth projected prior to the pandemic, Vietnam's economy grew by 2.9 percent in 2020—but growth is projected to rebound to 6.5 percent in 2021 and 7.2 percent in 2022 (IMF 2021; 2019). Figure 3.11 shows the country's different regions and elevation zones.

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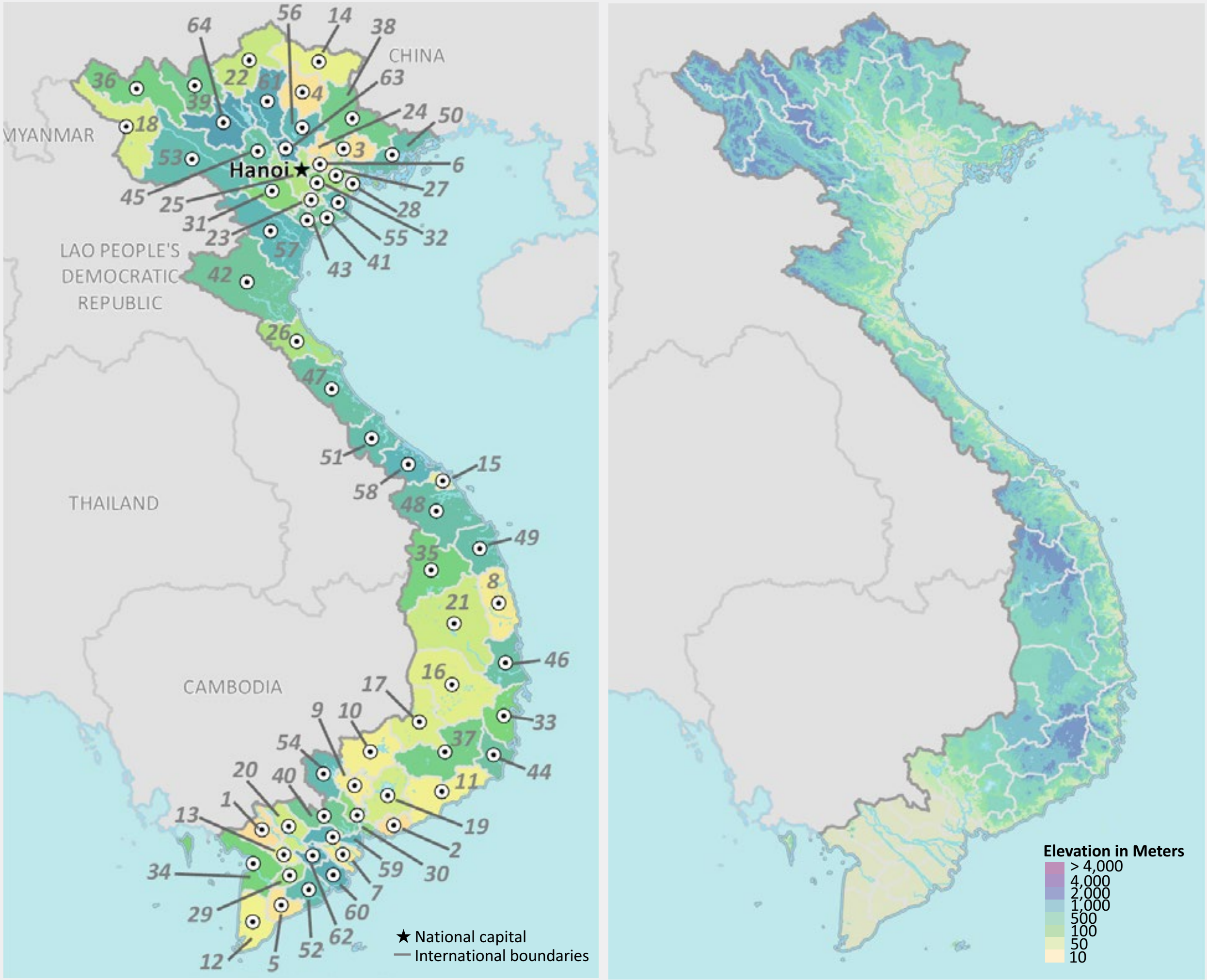
[89] See World Bank country overview: https://www.worldbank.org/en/country/vietnam/overview.

[90] See World Bank data for GDP growth (annual %): https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?locations=VN.

Figure 3.11: Administrative boundaries and elevation, Vietnam



1. An Giang
2. Ba Ria-Vung Tau
3. Bac Giang
4. Bac Kan
5. Bac Lieu
6. Bac Ninh
7. Ben Tre
8. Binh Dinh
9. Binh Duong
10. Binh Phuoc
11. Binh Thuan
12. Ca Mau
13. Can Tho city
14. Cao Bang
15. Da Nang City
16. Dak Lak
17. Dak Nong
18. Dien Bien
19. Dong Nai
20. Dong Thap
21. Gia Lai
22. Ha Giang
23. Ha Nam
24. Ha Noi City
25. Ha Tay
26. Ha Tinh
27. Hai Duong
28. Hai Phong City
29. Hau Giang
30. Ho Chi Minh City
31. Hoa Binh
32. Hung Yen
33. Khanh Hoa
34. Kien Giang
35. Kon Tum
36. Lai Chau
37. Lam Dong
38. Lang Son
39. Lao Cai
40. Long An
41. Nam Dinh
42. Nghe An
43. Ninh Binh
44. Ninh Thuan
45. Phu Tho
46. Phu Yen
47. Quang Binh
48. Quang Nam
49. Quang Ngai
50. Quang Ninh
51. Quang Tri
52. Soc Trang
53. Son La
54. Tay Ninh
55. Thai Binh
56. Thai Nguyen
57. Thanh Hoa
58. Thua Thien - Hue
59. Tien Giang
60. Tra Vinh
61. Tuyen Quang
62. Vinh Long
63. Vinh Phuc
64. Yen Bai

Vietnam's manufacturing and service sectors have grown rapidly in recent years, adding jobs in electronics and textiles production, construction, hospitality, and retail, among others (Cunningham and Pimhidzai 2018). In 2019, the service sector produced 41.6 percent of Vietnam's GDP, and manufacturing, 16.4 percent.[91] The relative contribution of agriculture, forestry, and fishing to the country's economy has thus declined, but they remain key sources of livelihoods. As of 2019, the three combined produced 13.9 percent of GDP,[92] and agriculture provided an estimated 37.2 percent of the country's employment.[93] Fisheries and aquaculture are also vital parts of Vietnam's economy and livelihoods, typically contributing around 6–7 percent of GDP and a similar proportion of employment.[94] Aquaculture alone employs more than 1.6 million people full-time (T. U. Nguyen 2018), and seafood production overall has been growing fast, reaching 3.9 million tons of catch in 2020 and 4.6 million tons farmed, with exports valued at a combined US$8.4 billion (Ministry of Agriculture and Rural Development 2021a).

Though electronics and other manufactured products are now Vietnam's top exports, agricultural goods, both raw and processed, are very important as well.[95] Vietnam is among the top exporters of cashews, pepper, coffee, and rice, and an important supplier of fish and shellfish. The government has set a goal of reaching US$50–51 billion in agricultural, forestry, and fishery exports by 2025, and US$60-62 billion by 2030 (Ministry of Agriculture and Rural Development 2021b; see also TTXVN 2021). Table 3.4 provides a snapshot of development and climate risk indicators for Vietnam.

Photo Credit: Toomas Tartes

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91. See World Bank data for services, value added (% of GDP): https://data.worldbank.org/indicator/NV.SRV.TOTL.ZS?locations=VN and manufacturing, value added (% of GDP): https://data.worldbank.org/indicator/NV.IND.MANF.ZS?locations=VN.
92. See World Bank data for agriculture, forestry, and fishing, value added (% of GDP): https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?locations=VN.
93. See World Bank data for employment in agriculture (% of total employment, modeled ILO estimate: https://data.worldbank.org/indicator/SL.AGR.EMPL.ZS?locations=VN.
94. See country page and climate risk profile for Vietnam on the World Bank Climate Change Knowledge Portal: https://climateknowledgeportal.worldbank.org/country/vietnam.
95. See OEC country profile for Vietnam: https://oec.world/en/profile/country/vnm as well as profiles for individual export categories.

Table 3.4: Demographic, socioeconomic and climate risks indicators for Vietnam

Development Indicators	
Population	
Population (millions)	96.5
Annual population growth (percent)	1.0
Population in 2050 under SSP2 (millions)*	104.4
Population in 2050 under SSP4 (millions)*	96.6
Urban share of population (percent)	36.7
Employment in agriculture (percent of total employment)	37.2
GDP	
GDP (current US$ billions)	261.9
Annual GDP growth (percent)	7.0
GDP per capita (current US$)	2,715
Value added of agriculture (percent GDP)	14.0
Value added of services (percent GDP)	41.6
Value added of industry (percent GDP)	34.5
Poverty	
Poverty headcount ratio at $1.90 a day (2011 PPP) (percent of population)	1.8
Poverty headcount ratio at $3.20 a day (2011 PPP) (percent of population)	6.6
Climate and disaster risk indexes	
ND GAIN Index**	
Rank	102
Score	46.6
World Risk Index (2020)***	
Rank	43
Score	10.3

Sources: All 2019 data from World Bank Open Data (http://databank.worldbank.org), except where indicated.
* SSP population projections produced for this report
** ND-GAIN (https://gain.nd.edu/our-work/country-index/rankings/)
*** Bündnis Entwicklung Hilft (https://weltrisikobericht.de/english/)

Vietnam has leveraged its strong economic growth to significantly reduce poverty. The share of people living on less than US$1.90 per day declined from 37 percent of the population in 2002, to 1.8 percent in 2018,[96] and the share living on less than US$3.20 per day, from 70.1 percent, to 6.6 percent.[97] Inequality has held relatively steady; in 2018, Vietnam's Gini index was 35.7.[98]

Despite this progress, there are notable disparities, both among regions, and between the majority and ethnic minorities. The vast majority of Vietnam's remaining poor are ethnic minorities.[99] As of 2016, close to 45 percent of ethnic minorities still lived in poverty, making up 73 percent of the poor despite being only 15 percent of the total population (Pimhidzai 2018). Poverty rates are also significantly higher in the Midlands and Northern Mountains and in the Central Highlands, where ethnic minorities are concentrated, than in the rest of the country. Targeted government efforts have sought to narrow those gaps in recent years. Still, inequality has increased in parts of the country, especially in the Central Highlands and the Mekong Delta.

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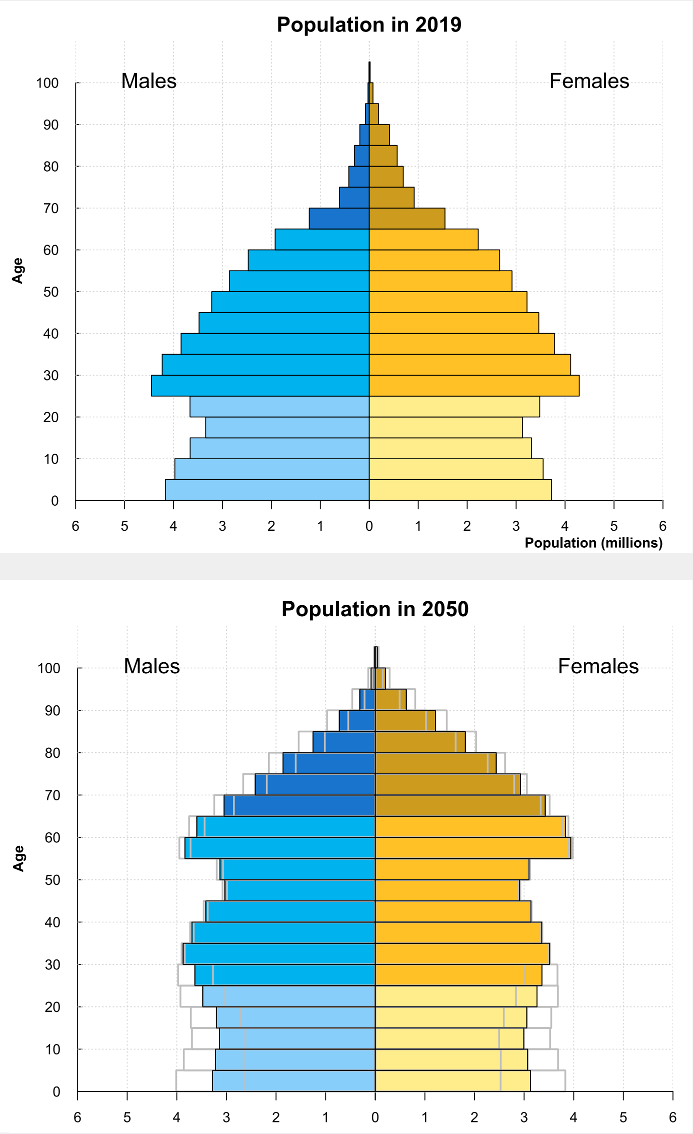
[96] See World Bank data for poverty headcount ratio at $1.90 a day (2011 PPP), % of population: https://data.worldbank.org/indicator/SI.POV.DDAY?locations=VN.

[97] See World Bank data for poverty headcount ratio at $3.20 a day (2011 PPP), % of population: https://data.worldbank.org/indicator/SI.POV.LMIC?locations=VN.

[98] The Gini index measures the extent to which the distribution of income (or, in some cases, consumption expenditure) among individuals or households within an economy deviates from a perfectly equal distribution. A Gini index of 0 represents perfect equality, while an index of 100 implies perfect inequality. See World Bank data: https://data.worldbank.org/indicator/SI.POV.GINI?locations=VN.

[99] See World Bank country overview: https://www.worldbank.org/en/country/vietnam/overview.

Figure 3.12: Vietnam population pyramids, 2019 and 2050



Source: UN DESA (2019b).
Note: Medium-variant data are shown as colored bars, and uncertainty is shown in gray for 95 percent prediction intervals.

Vietnam's development trajectory has been shaped by several factors, including a significant demographic dividend—its labor force is young and growing—as well as investments in productive and inclusive infrastructure, and effective basic health care and education (Eckardt et al. 2016; Vanham 2018; Eckardt, Demombynes, and Chandrasekharan Behr 2016; Binh et al. 2014). Vietnam's female labor force participation rate in 2019—79.6 percent, compared with 86.5 percent for men[100]—has been maintained at these levels for more than two decades (Banerji et al. 2018).

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[100] See data for labor force participation rate, female (% of female population ages 15–65), modeled ILO estimate: https://data.worldbank.org/indicator/SL.TLF.ACTI.FE.ZS?locations=VN and male: https://data.worldbank.org/indicator/SL.TLF.ACTI.MA.ZS?locations=VN.

Vietnam is experiencing rapid demographic and social changes. Its population reached 96.5 million in 2019, up from 54.3 million in 1980 (UN DESA 2019b); 55.1 percent is of prime working age (25–64).[101] The population is aging, however; the median age was 24.2 in 2000, but 32.5 in 2020, and it is projected to rise to 41.2 by 2050. Life expectancy at birth is now 76 years, more than two years above the regional average, and up from 68 in 1980–1985; it is projected to rise to 79 by 2045–2050. The fertility rate in 2015–2020 was 2.06 children per woman, however, just slightly below replacement level, and it is expected to further decline to 1.9 children per woman by 2050.

Overall, the annual population growth rate was about 1 percent for 2015–2020, and it is projected to drop to 0.8 percent in 2020–2025 and reach 0.1 percent by 2045–2050 (UN DESA 2019b). Given this, projections to 2050 used for this report indicate that the population will remain relatively stable, with an estimated 96.6 million under SSP4 and 104.4 million under SSP2.[102] Vietnam's population pyramids in Figure 3.12 show two clear breaks: a decline at age 65 and older cohorts, particularly for men, related to the Vietnam War, and another decline at age 25, with smaller cohorts entering the population at younger ages, likely related to the reduction of fertility and selective migration. As younger cohorts become smaller and aging accelerates, Vietnam's demographic dividend window—the period of low dependency ratios—is closing (Eckardt et al. 2016).

Vietnam has experienced strong urbanization, driven by growth in the manufacturing and services sectors. Though almost 63 percent of the population was still rural as of 2020, the urban population grew by around 3 percent per year in 2015–2020, while the rural population grew by only 0.1 percent per year (UN DESA 2018b).[103] In 1990, the country had 13.3 million urban residents; as of 2020, it had an estimated 36.7 million, and the urban share of the population is projected to surpass 50 percent by 2040. Table 3.5 shows Vietnam's most populous cities. The Southeast and the Red River Delta, which include Ho Chi Minh City (population over 8.5 million) and Hanoi (population over 4.5 million), respectively, are the country's most urbanized regions (World Bank 2020b). They have also been at the forefront of Vietnam's economic transformation, together accounting for about 80 percent of industrial and service jobs, production, and profits, and attracting large numbers of migrants in search of economic opportunities.

Table 3.5: Most populous cities in Vietnam, 2020 and 2030 (in thousands)

Urban Agglomeration	2020	2030
Thành Pho Ho Chí Minh (Ho Chi Minh City)	8, 602	11,054
Hà Noi	4, 678	6,362
Can Tho	1, 618	2,294
Hai Phòng	1, 300	1,698
Da Nang	1, 125	1,449

Source: UN DESA (2018b).

Internal and external migration patterns are well established in Vietnam. Rural–urban migration trends can be traced back to before the Doi-Moi reforms (Thao and Agergaard 2012). Vietnam's internal and international mobility have increased over the last decades, boosted by economic growth, diversification of the economy, lower migration costs related to information and transportation availability, and some relaxation of the household registration system (see Box 3.2 for further details on international migration).

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[101] For a helpful summary of the UN DESA (2019b)data cited here, see this World Population Prospects 2020 country profile for Vietnam: https://population.un.org/wpp/Graphs/1_Demographic%20Profiles/Viet%20Nam.pdf.

[102] These SSP population scenarios use data from World Population Prospects 2010 for the baseline; see https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=10#v2 and further details in Riahi et al. (2017). Under SSP4, middle income countries see attenuated population growth as is the case for Vietnam, in contrast to rapid population growth in low income countries.

[103] Projected population growth rates for 2020–2025 are 2.7 percent per year for urban areas and 0.3 percent per year for rural areas (UN DESA 2018b).

Box 3.2: International migration dynamics in Vietnam

Vietnam has experienced net out-migration for many years (K. Miller 2015). Economic growth has resulted in increasing international labor emigration, particularly after the Đôi Môi reforms. Significant flows of skilled and high-education labor migration occur from Vietnam to wealthier Asian countries, especially Malaysia, Singapore, Japan, the Republic of Korea, and China and Taiwan (Anh, Leonardelli, and Dipierri 2016). Government programs have played an important role in expanding markets and securing worker protections.

The 2012 Vietnam Household Living Standards Survey of 2012 found that about 9 percent of all migrants had moved abroad (Coxhead, Cuong, and Vu 2015). The United States and Australia are key destinations (IOM 2019b), including for students, who are also drawn to China (Anh, Leonardelli, and Dipierri 2016; Ishizuka 2013). Remittances from international migrants represented about 6 percent of GDP in 2019.[a]

Immigration to Vietnam is also increasing, including unskilled workers from China, particularly in the construction sector (V. C. Nguyen 2013). The Vietnamese government enacted a new immigration law in 2015 to limit labor immigration (K. Miller 2015).

[a] See World Bank data for personal remittances, received (% of GDP): https://data.worldbank.org/indicator/BX.TRF.PWKR.DT.GD.ZS?locations=VN.

Most migration in Vietnam today is internal, from rural to urban areas, concentrated in a few destinations, such as Hanoi and Ho Chi Minh City (Coxhead, Cuong, and Vu 2015). Higher and more reliable incomes in urban areas create pull factors for rural households as compare to rice farming and small-scale aquaculture. Some migrants move to rural areas in search of work, particularly where agricultural land is being converted to industrial parks in Northern Vietnam (Fox et al. 2018). Current rural-to-urban migration trends can benefit cities by meeting growing labor demand, and rural areas by alleviating poverty and land constraints on agricultural livelihoods (Anh, Leonardelli, and Dipierri 2016).

Regardless of destination, young adults are the likeliest to migrate, as are people with higher levels of education (along with their household); members of ethnic minorities are less likely to move (Coxhead, Cuong, and Vu 2015). Women have been migrating more since the 1990s, mostly to work in light manufacturing (mainly garment production), health care, and social services; male migrants typically work in manufacturing, construction, or transportation (UNESCO et al. 2018; Thao and Agergaard 2012).

Migration often involves a single person moving to an urban area and sending money back home (Betcherman, Haque, and Marschke 2021). Remittances help improve the financial situation of receiving households (Liu and Dang 2019), and investing remittances in farms can offset the impact of losing farm workers to out-migration (Huy and Nonneman 2016). However, remittances may also increase inequality at the community level between receiving and non-receiving households.

The nature of rural-urban migration is also evolving. Recent trends indicate that rural-urban migration in the Mekong Delta is gradually being replaced by short-distance mobility linked to job opportunities in neighboring towns and villages and to improved transport connections (Coxhead, Cuong, and Vu 2015). This lowers the cost of living and enables workers to save more than if they lived in large cities. People living in increasingly connected areas around Ho Chi Minh City and Hanoi are thus less likely to migrate than people in other regions, commuting instead. Studies also suggest that migrants from these regions do return home, and that remittance flows have become multidirectional (Luong 2018).

3.2.2 Climate Trends

Vietnam has a varied climate, with warm to temperate weather in the north and a tropical climate in the south (World Bank and ADB 2021b; see also McSweeney et al. 2010). Rainfall patterns closely follow the monsoon—the northern and southern regions experience heavy rain in May through October, while the central regions see heavy rainfall from September to January. Seasonal variations are more pronounced in the north, with temperatures ranging from 15 to 20°C in the winter to and from 22 to 27.5°C in the summer. In the south, temperatures are typically between 26 and 27°C in the winter and 28 to 29°C in the summer. El Niño influences monsoonal circulation and drives shifts in rainfall and temperature patterns that vary spatially at the subnational level.

Historical trends indicate that Vietnam's mean annual temperature has been steadily increasing, particularly in southern Vietnam and the Central Highlands (World Bank and ADB 2021b). Since 1960, mean annual temperature has increased by 0.5–0.7°C, with a rate of warming estimated at 0.26°C per decade in the period 1971–2010, almost twice the rate of global warming over the same period. Greater warming has been identified in winter months than in summer months. The frequency of hot days and nights has increased significantly since 1960 in every season, and the annual frequency of cold days and nights has decreased significantly. Mean rainfall over Vietnam as a whole has not significantly changed since 1960, nor has the proportion of rainfall falling during heavy events. At the subnational level, there have also been some significant trends, including toward increased rainfall in the central regions and reduced rainfall in the northern and southern regions.

These trends are expected to continue in the future (World Bank and ADB 2021b). Under the highest-emissions pathway, RCP8.5, the mean annual temperature in Vietnam is projected to rise by 3.36°C by 2080–2100. Across all emissions scenarios and future time periods, annual maximum temperatures are projected to rise more than the mean temperature. The greatest temperature increases are projected in southern Vietnam, though there is uncertainty. There is also considerable uncertainty in projections of future precipitation ranges linked to El Niño. Overall, however, the trends indicate projected increases in annual precipitation across the country, typically in the range of 10–20 percent by 2045–2065. There may also be variations in extreme rainfall, with some increases projected in southern and central Vietnam and slight reductions projected elsewhere.

The ISIMIP water availability and crop productivity model results used in this report broadly conform to these projections (see Appendix A.5 for further details, including maps):

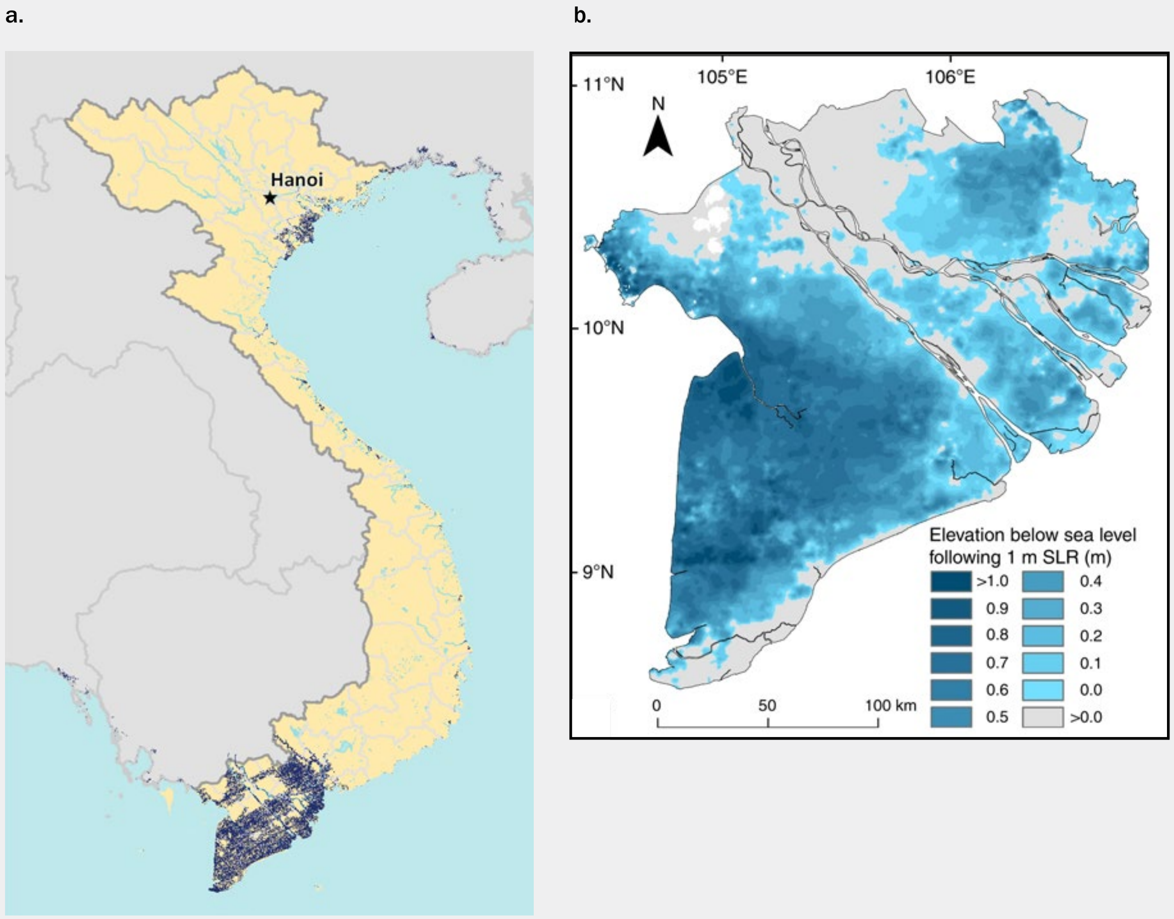
- Almost all ISIMIP model runs to 2050 reproduce the historical trend of increasing rainfall (and therefore water availability) in the central coastal region and drying in the north and southern mountainous regions (see Figure A.17 in Appendix A.5).

- Crop productivity changes are patchier (particularly under the GEPIC model), but generally the central areas will see slight declines, with more significant declines in the far north in some model runs (Figure A.19). Except in the GEPIC model under RCP8.5, the southern portion of the country, including the Mekong Delta, is projected to see increases in crop productivity. For rural areas, changes in crop productivity are the strongest predictors of changes in population distribution, but changes in water availability are also important (Table A.5). For urban areas, changes in crop productivity have less of an effect, but they still make an impact on population distribution where agriculture is practiced in urban areas.

- Looking ahead to the second half of the century, changes in water availability are not drastically different from changes projected to the 2050 (Figure A.18). Trends in crop productivity (both positive and negative) generally also remain stable or slightly increase in intensity, with the exception of the GEPIC model under RCP8.5, where northern Vietnam sees more significant declines, on the order of 30–70 percent (Figure A.20).

Rising sea levels are rendering Vietnam's 3,000-kilometer coastline and coastal lowlands increasingly vulnerable to inundation, salinization, erosion, and storm surges driven by tropical cyclones. The Mekong Delta has an average elevation of just 0.8 meters above sea level (Minderhoud et al. 2019). The Red River Delta rises more steeply, with an average elevation at Hai Phong and Nam Dinh of 3 meters and at Hanoi of 8 meters above sea level (Neumann et al. 2015). Projections of sea-level rise around Vietnam under different scenarios vary: a government review (Tran et al. 2016) found projections ranging from 0.18–0.56 meters by 2090.

Figure 3.13: a) Land area inundated by 1-meter and 2-meter combined sea-level rise and storm surge in Vietnam, using SRTM's Digital Elevation Model (DEM), 2050, and b) total area of the Mekong Delta plain projected to be below sea level with 1 meter of sea-level rise, using Topo DEM

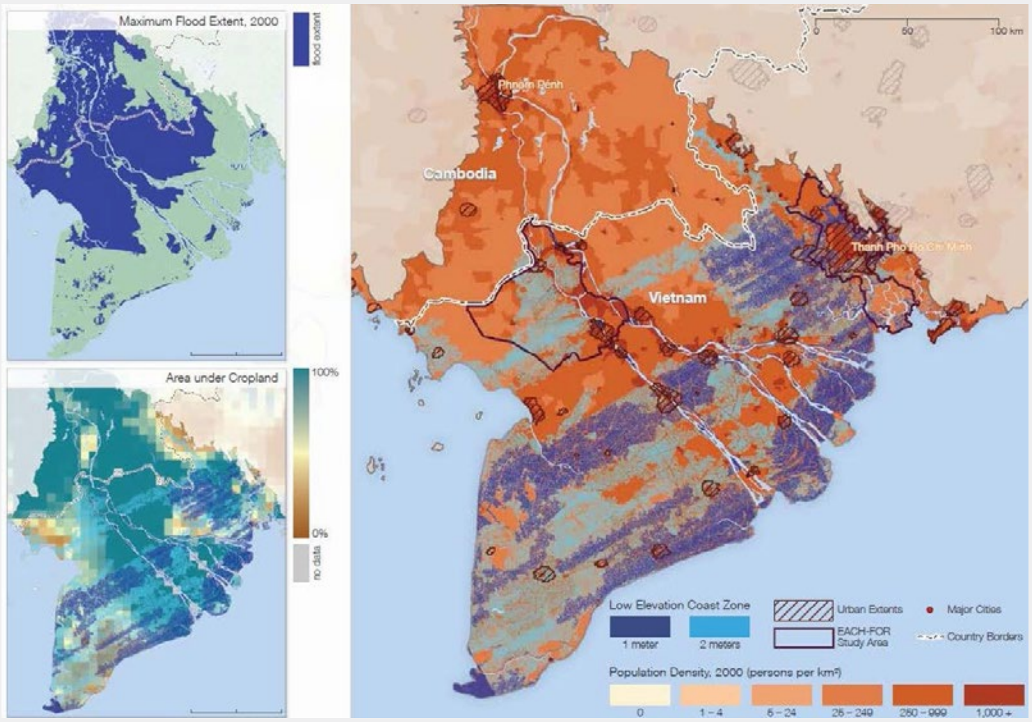


Source: Minderhoud et al. (2019).

In both the Mekong and Red River Deltas, efforts to control water resources in the face of natural flooding and tidal influences have shaped a large diversity of agricultural landscapes. The two deltas are important agricultural centers, concentrating a large majority of rice, fruit, and especially aquaculture production, including for export (GSO 2020; World Bank 2014b; Thao and Agergaard 2012). Flooding, salinization, and land subsidence all pose threats to low-lying coastal agriculture areas already, and deltaic erosion, especially on the Ca Mau Peninsula, also constitutes a threat to the habitability of land. A number of geographic and economic factors—such as natural sediment compaction and groundwater extraction—have contributed to increasing rates of coastal subsidence in the deltaic zone (Minderhoud et al. 2019).

Both deltas would be seriously affected by sea-level rise (see Figure 3.13). The Vietnamese government review cited above found that 0.5 meters of sea-level rise could potentially inundate 6.9 percent and 4.5 percent of the land area of the Red River and Mekong Deltas, respectively (Tran et al. 2016). An estimated 2.4 percent of Vietnam's GDP is at risk from permanent inundation in the Red River Delta region (World Bank and ADB 2021b). Other vulnerable central provinces, such as Quang Binh Province, could see 1.7 percent of their area inundated with 0.5 meters of sea-level rise (Tran et al. 2016). Recent work by Minderhoud et al. (2019) suggests that 12.3 million people (70 percent of the total population) would be affected by a 1-meter rise in sea-level (Figure 3.14).

Figure 3.14: Flooding, agriculture, and low-elevation coastal zone in the Mekong River Delta



Source: Warner et al. (2009)
Note: The map shows the areas affected by 1 or 2 meters of sea-level rise (dark and light blue, respectively) on a population density map with urban extents delineated. It also shows the regions of the EACH-FOR study areas (see O. Dun 2011). The upper left inset map shows the area flooded in 2000, when unusually widespread monsoon floods deluged nearly 800,000 km^2 in Cambodia, Vietnam, Thailand, and Laos. The lower left inset map shows the distribution of agricultural lands.

Rural livelihoods in coastal areas are already being affected by saline intrusion and land subsidence, resulting in forced land use changes, abandonment, and reduced yields, including in the Mekong Delta (World Bank and ADB 2021b). It has been estimated that a sea-level rise of 0.3 meters, which could occur as early as 2040 in pessimistic scenarios, could affect about 30,000 hectares of agricultural land—due both to inundation and saltwater intrusion—and reduce crop production in the Mekong Delta by about 12 percent (Vu, Yamada, and Ishidaira 2018; World Bank 2014b). Four of eight farming provinces in Vietnam —Tien Giang, Ben Tre, Tra Vinh and Soc Trang— could expect severe salinity intrusion as sea levels rise (Vu, Yamada, and Ishidaira 2018).

Vietnam is also highly exposed to extreme weather events, due to its location, geography, and the distribution of population and economic activities (Lukyanets et al. 2015). Storms, typhoons, and droughts have caused significant human, agricultural, and infrastructure losses. Vietnam is frequently struck by tropical cyclones, with a particularly high rate of landfall along its northern coast, which has suffered significantly in terms of people killed and affected as well as total damages (World Bank and ADB 2021b). EM-DAT, the International Disaster Database, shows that in 2016–2020, Vietnam experienced 8–12 disasters per year, the vast majority involving storms (mostly cyclones) and floods, with 59–323 lives lost per year, and combined costs of US$49 million to nearly US$3.2 trillion per year.[104] The single costliest was Typhoon Hato, in August 2017, with damages estimated at US$1.4 billion; the deadliest was Tropical Storm Linfa, in October 2020, which cost 243 lives.

The Vietnamese government's own estimates suggest the actual impacts of these disasters may be much greater, however. The Central Steering Committee for Natural Disaster Prevention and Control has estimated that in the past three decades, economic losses from natural disasters cost Vietnam an average of 1–1.5 percent of its GDP per year (Viet Nam News 2017). Losses are projected to rise dramatically

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[104] Authors' calculations based on data from EM-DAT: https://public.emdat.be.

over coming years as the value of both exposed assets and climate-related hazards increase. Vietnam's updated NDC cites damages averaging VND 14 trillion per year (about US$990 million, in 2010 values) from 1995 to 2017 and notes that "the increasing trend of loss and damage is inevitable" (Socialist Republic of Viet Nam 2020). A World Bank analysis estimated that about a third of Vietnam's population is already exposed to a one-in-25-years flood, and this could increase to 38 percent under RCP2.6 and 46 percent under RC8.5 by 2100 (Bangalore, Smith, and Veldkamp 2019).

3.2.3 Projected Climate Migration Trends

Analysis for this report shows climate migration increasing to 2050 across all three scenarios, but with large differences, as follows (Figure 3.15 and Table 3.6):

- Pessimistic reference scenario: 3.1 million climate migrants (with a range of 2.4 to 3.8 million);
- More inclusive development scenario: 1.9 million climate migrants (with a range of 1.6 to 2.3 million);
- More climate-friendly scenario: 1.5 million climate migrants (with a range of 1.0 to 1.9 million)

The highest estimate of climate migrants, 3.8 million in the pessimistic reference scenario (95th percentile of the distribution of model runs), would represent 3.9 percent of the total projected population in 2050. The lowest estimate, 1.0 million people in the more climate-friendly scenario, would be about 1.1 percent of the total projected population in 2050.[105]

The number of climate migrants increases faster in the pessimistic reference and more inclusive development scenarios, which share the high-emissions pathway, than in the more climate-friendly scenario. The upward trend also accelerates after 2030 in those scenarios, as climate change impacts intensify, particularly affecting crop productivity in the GEPIC model under RCP8.5 (Figures A.19 and A.20); no such acceleration is seen in the more climate-friendly scenario. Climate change impacts on both rural livelihoods and urban systems, especially with regard to sea-level rise and crop productivity, are less severe in a low-emissions scenario, and would significantly affect the rate of climate migration.

Table 3.6: Projected number and share of internal climate migrants in Vietnam in three scenarios, 2050

	Scenario					
Result	Pessimistic/ Reference		More inclusive development		More climate-friendly	
Number of internal climate migrants by 2050 (million)	**3.1**		**1.9**		**1.5**	
5th (left) and 95th (right) percentile (million)	2.4	3.8	1.6	2.3	1.0	1.9
Internal climate migrants as percent of population	**3.1%**		**1.9%**		**1.5%**	
5th (left) and 95th (right) percentile	2.4%	3.9%	1.5%	2.2%	1.1%	2.0%

The model results also show that climate migrants could make up an important share of Vietnam's total internal migrants by 2050 (Figure 3.16)—but again, with variations. The share is greatest in the more inclusive development scenario (rising to 36 percent), which shows far lower internal migration levels overall.[106] In both the pessimistic reference and more climate-friendly scenarios, which show overall internal migration rising more sharply under the SSP4 pathway, climate migrants make up 26 percent and 14 percent of the total by 2050, respectively, and those shares hold relatively steady over time.

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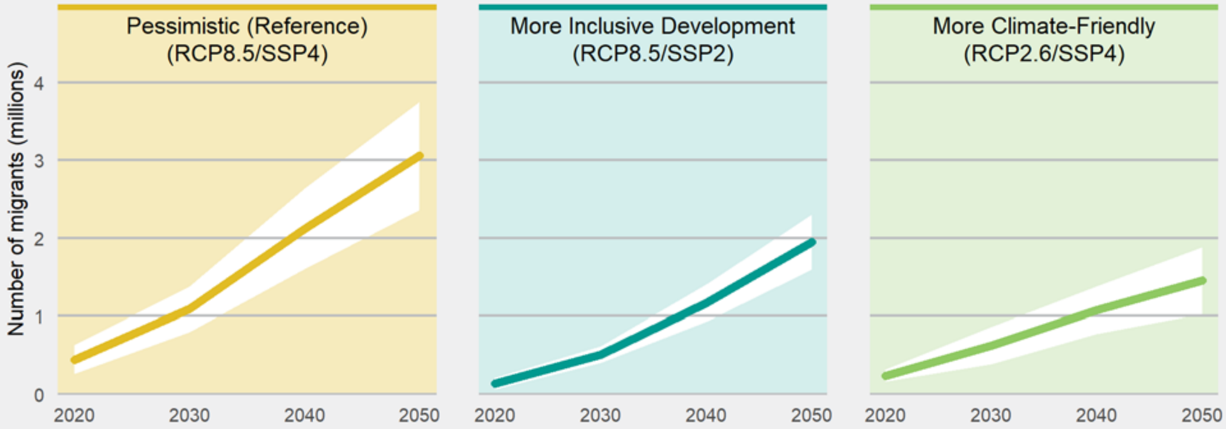
105. The spread across model runs is also significantly narrower in the more climate-friendly scenario, a function of the greater certainty in the projections due to more consistent climate impacts across the RCP2.6 model runs.

106. An important reason for this is that under SSP2, which represents a more equitable development pathway, urbanization slows and education disparities between rural and urban areas narrow, resulting in less other internal migration overall.

Figure 3.15: Projected number of internal climate migrants in Vietnam in three scenarios, 2020–2050

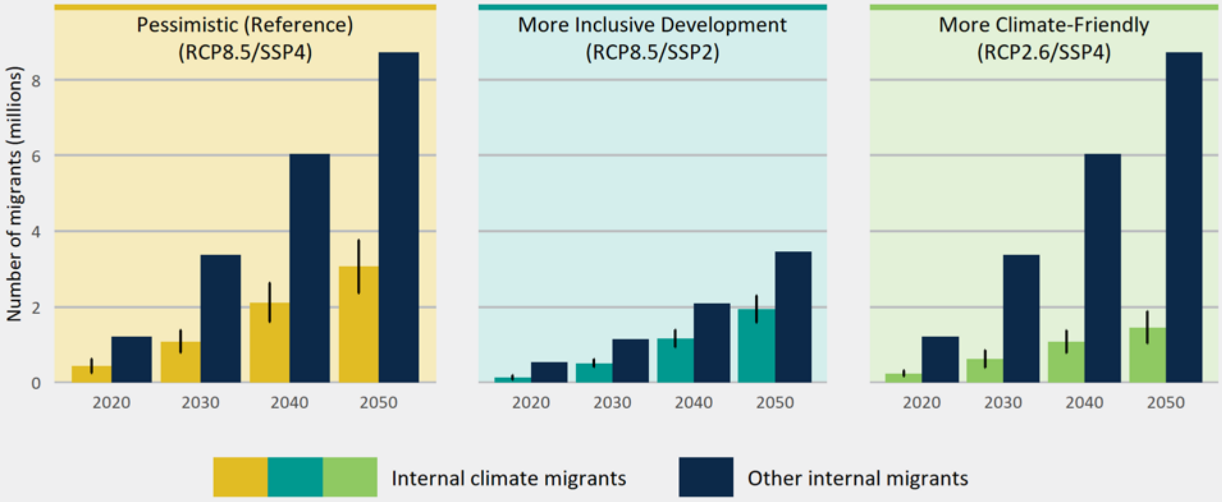


Climate migrants as a percentage of the total population

Year	2020	2030	2040	2050	2020	2030	2040	2050	2020	2030	2040	2050
%	0.5	1.1	2.1	3.1	0.1	0.5	1.1	1.9	0.2	0.6	1.1	1.5

Note: Dark lines represent the average runs for each scenario. The white areas around the central trend line represent the confidence intervals, which reflect the degree of agreement among the four model runs used to provide each estimate for each scenario. Narrower confidence intervals indicate greater agreement among the model runs for each scenario. The confidence intervals get larger with each successive time interval owing to momentum that builds over time for each model run and to increasing divergence among models as the climate change signal increases.

Figure 3.16: Projected number of climate and other internal migrants in Vietnam in three scenarios, 2020–2050



Note: The whiskers on the climate migrant bars represent the 95th percentile confidence interval for the four model runs for each scenario. There are no confidence intervals for other internal migrants, because only a single development trajectory is used.

Projected spatial patterns of climate migration

Overall, the population of Vietnam is concentrated in the regions surrounding Hanoi in the north, the Mekong Delta, and Ho Chi Minh City in the south, and in a narrow band along the coast. Areas of lower population densities are located in the west and west-central areas, in the highlands.

These patterns of population distribution are expected to remain relatively unchanged to 2050 (Figure 3.17). Densely populated areas are projected to become even denser by 2050, as people become even more concentrated in the largest cities and in parts of the Mekong Delta and the coast (Figure 3.18a). The more sparsely populated west and west-central areas, in the highlands, are expected to lose density. Some areas of the Mekong Delta are also projected to see relative declines in density, as people move out of low-lying areas close to the coast and towards slightly higher-elevation areas inland, which are expected to see population growth. In relative terms, the northwest region displays the largest declines in population density by 2050 (Figure 3.18b).

Figure 3.17: Baseline population density, 2010, and projected population density in the pessimistic reference scenario, 2050, Vietnam

a. 2010

b. 2050

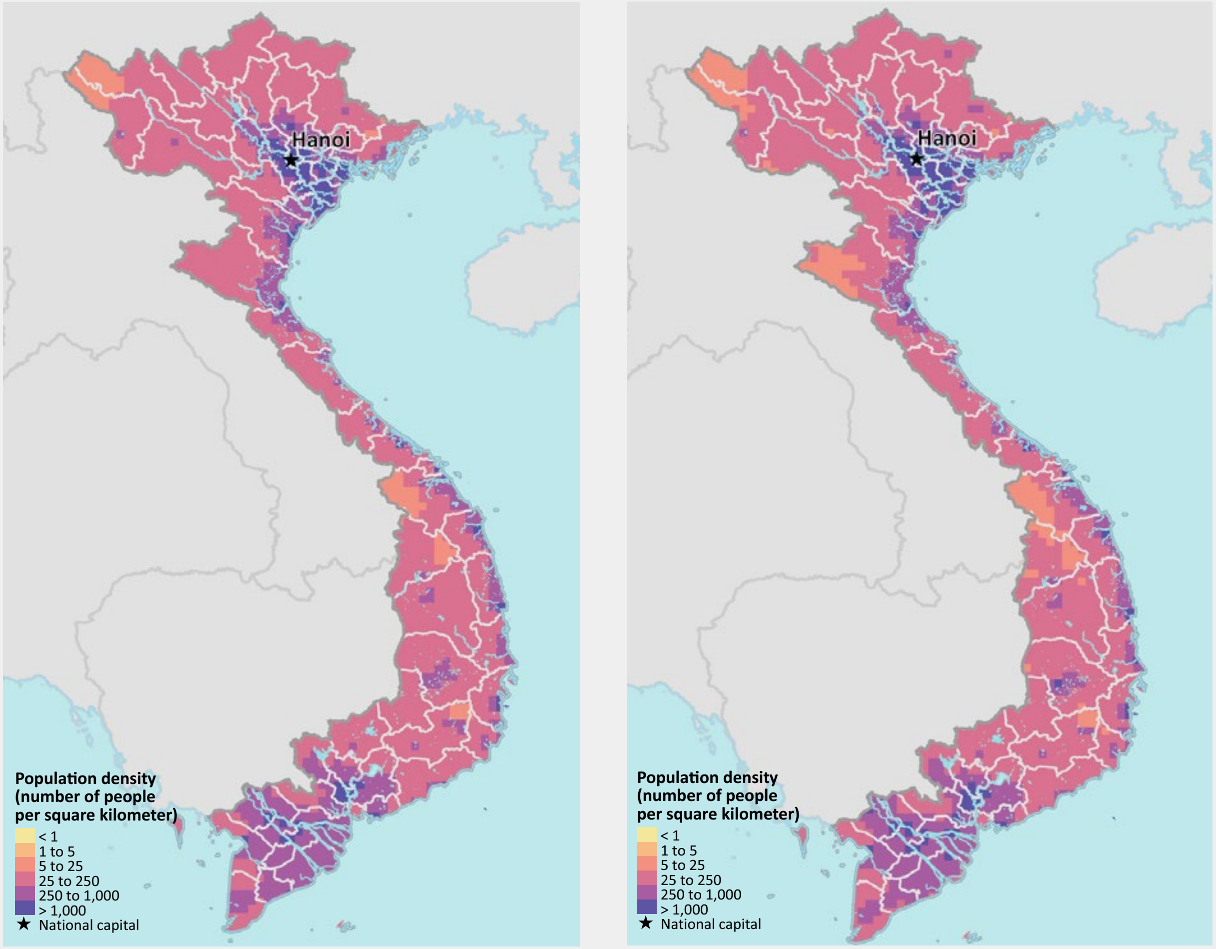
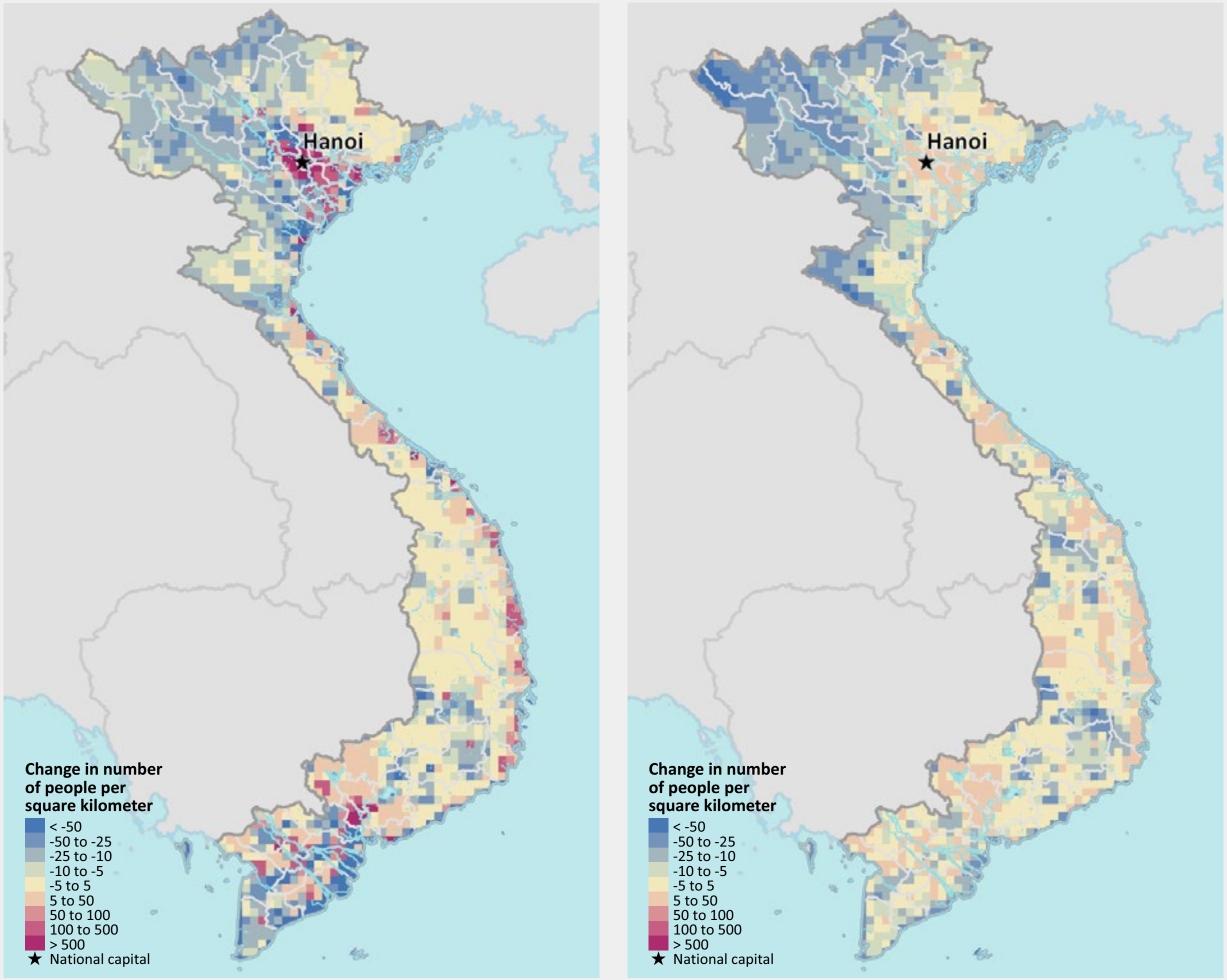


Figure 3.18: Absolute and percentage change in population density in Vietnam in the pessimistic reference scenario, 2010–2050



a. Change in population density

b. Percentage change in density

The analysis shows Hanoi and the Red River Delta as the largest climate in-migration hotspots (Figure 3.19). There are also smaller climate in-migration hotspots scattered in the coastal central region, including Bin Dinh, Quang Ngai, and Quang Tri provinces. These are areas where the ISIMIP model results show increased water availability, especially in the HADGEM2-ES global climate model (Appendix A.5). The climate in-migration hotspots also correspond to areas with, on average, better crop productivity outlooks to 2050, particularly in the Red River Delta, although ISIMIP model results for crop productivity diverge more across models. Impacts of sea-level rise, while projected to be pronounced in the Red River Delta (Figure 3.13), may be offset by better water availability and crop productivity, and by the fact that it is not as low-lying as the Mekong Delta. Rural areas of the Red River Delta and the central coast are primarily rice-growing areas. Notably, the results also suggest that migrants may be attracted to areas that are already vulnerable to tropical cyclones, which the report models do not take into account.

Ho Chi Minh City and the Mekong Delta are expected to be the largest climate out-migration hotspots by 2050. Sea-level rise augmented by storm surge is the main driver of migration from the Mekong Delta, as the low-elevation coastal zone is already subject to inundation and associated impacts. Ho Chi Minh City and its environs are projected to see declines in water availability across most model runs, and a few model runs show significant declines in crop productivity as well. Rural areas of the Mekong Delta are primarily rice-growing areas, mostly projected to see increases in water availability. Even with the dampening effect of climate out-migration, the Mekong Delta and Ho Chi Minh City will still support large numbers of people (Figure 3.17). High population densities in both climate in and out-migration hotspots that are highly vulnerable to sea-level rise and storm surge will require effective adaptive planning.

Figure 3.19: Hotspots projected to have high levels of climate in-migration and climate out-migration in Vietnam, 2050

IN-MIGRATION

🟥 High certainty in high levels of climate in-migration

▨ Moderate certainty in high levels of climate in-migration

OUT-MIGRATION

🟦 High certainty in high levels of climate out-migration

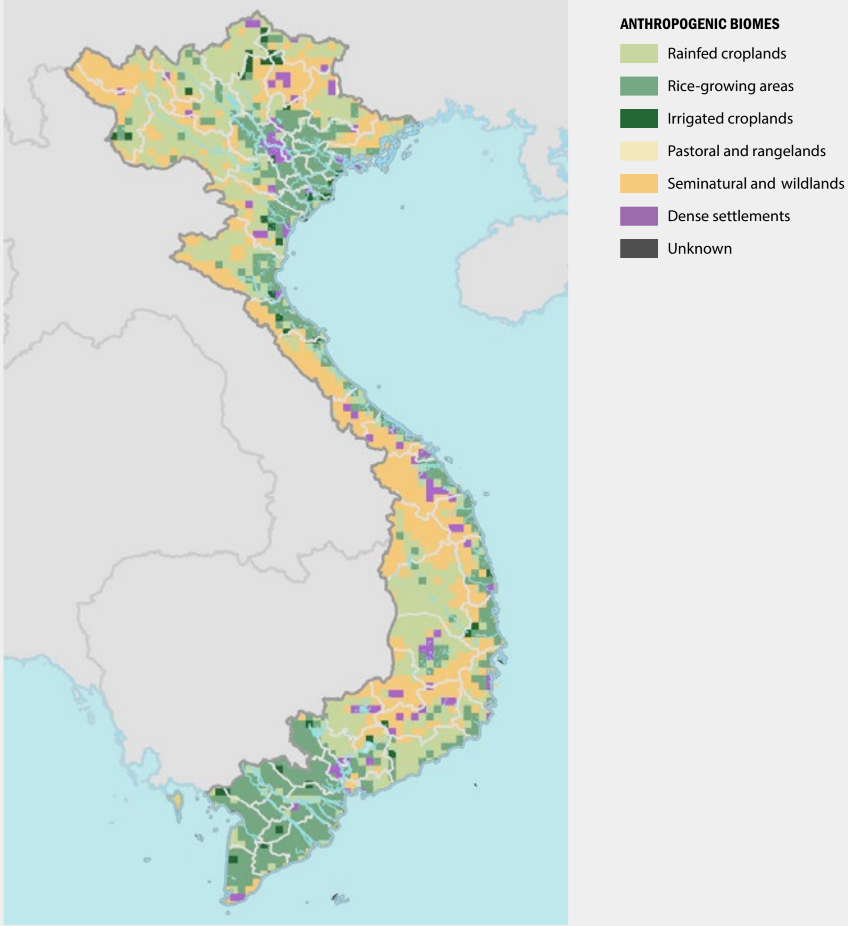
▨ Moderate certainty in high levels of climate out-migration

Note: High certainty reflects agreement across all three scenarios modeled, and moderate certainty reflects agreement across two scenarios. In- and out-migration hotspots are thus areas in which at least two scenarios concur on density changes in the top 10th percentile of the density distribution, which in Vietnam represents an increased population density in 2050 of about 16.6 to 44.2 people per km^2, depending on the scenario. For decreased population density, it is about minus–9.7 to minus–26.3 people per km^2.

Trends in livelihood zones

The distribution of livelihood zones is presented in Figure 3.20 for the baseline year of 2015, following the anthropogenic biome classes defined by Ellis et al. (2010).[107] Rice-growing areas (particularly in the Red River and Mekong Deltas), rainfed croplands, and seminatural and wildlands (located in the highlands) cover a large proportion of the country. There are also several dense settlements. Figure 3.21 shows the projected net change in the number of climate migrants by 2050 for each livelihood zone. It is important to recognize that this represents migration into or out of the zones and does not imply changes in the livelihoods of those who migrate. By 2050, dense settlements show negative climate out-migration across scenarios (driven largely by declines in Ho Chi Minh City), while wide confidence intervals for the rest of the livelihood zones make it difficult to identify a clear trend. This is in part because in rice-growing areas, for example, climate in-migration trends projected in the Red River Delta may be countered by climate out-migration trends expected in the Mekong Delta. In addition, wide confidence intervals also indicate some divergence in the climate impact projections underlying each scenario, for both water availability and crop productivity.

Figure 3.20: Livelihood zones in Vietnam, by anthropogenic biome, 2015



Source: Ellis et al. (2010).

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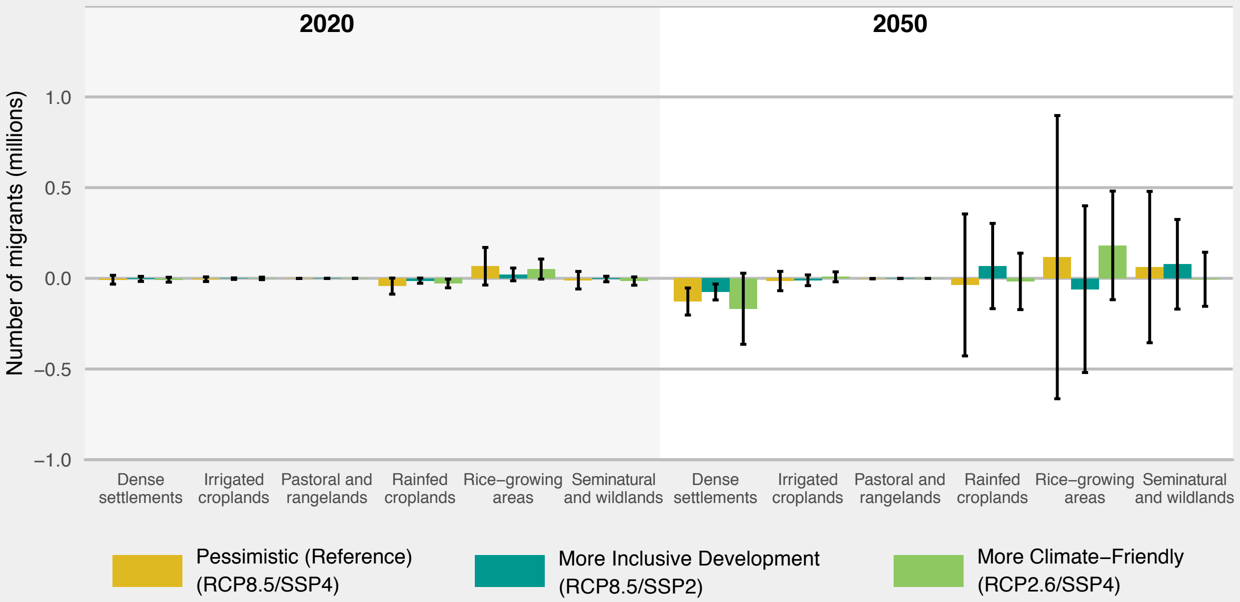
[107] The livelihoods zones used in the *Groundswell* reports represent an aggregation of anthropogenic biome classes in Ellis et al. (2010) into areas with relatively coherent livelihood characteristics. Note that although it is known that zones will shift with climate change, no projections of those shifts are available, so for the modeling presented in this report, the distribution of zones is assumed to remain static through 2050.

Figure 3.21: Projected net migration in and out of livelihood zones in Vietnam in three scenarios, 2020–2050



Note: Whiskers show 95th percentile confidence intervals for climate migrants.

3.2.4 Consultations on Modeling Results

A virtual workshop was held in May 2021 to share the modeling results with stakeholders in Vietnam and gather feedback. It included representatives from government ministries, departments, and agencies; academia; civil society organizations; and international organizations. Participants were asked to reflect on historical and current migration patterns in the country, including in the context of climate change, on the plausible future climate migration scenarios and hotspots presented in the report, and on potential policy responses. They agreed that the issues raised by the modeling were relevant and provided additional insights, particularly in the context of spatial development. They also noted the importance of embedding mobility more generally in regional planning as well as in national-level efforts.

Participants noted that historically, migration in Vietnam has been primarily from rural to urban areas, including to industrial zones in Ho Chi Minh City, or internationally, for economic and professional development opportunities. Migrants have also been drawn to the Mekong Delta and coastal zones, which have better economic conditions and infrastructure than mountainous inland regions. In the past 10 years, there has been some out-migration from the Mekong Delta, reducing the overall population. Without interventions to adapt to climate change and boost resilience, participants said, those patterns could be amplified. More investment is also needed to provide viable livelihood opportunities that enable people to stay.

Participants also noted the erosion, loss of land, saltwater intrusion, and reduced freshwater availability challenges that the Mekong Delta currently faces, and the potential impacts on jobs, income, and migration. They emphasized that it is crucial for spatial planning to focus on resilience interventions, jobs, high-value agriculture and aquaculture, sustainable water resource and coastal ecosystem management, and opportunities to increase public and private investments in transportation, logistics, and technology development.

Participants discussed Vietnam's evolving policies, strategies and plans aimed at building resilience to climate change and how these intersect with the country's development trajectory. In particular, the multi-sectoral Mekong Delta Master Plan 2021–2030, still being finalized, was highlighted as having the potential to influence population distribution in the Delta and surrounding areas. Among other strategic areas, the plan aims to promote regional development that takes into account climate risks and opportunities. It also seeks to integrate high-value, competitive, and climate-smart agricultural production, fisheries, and aquaculture with other sectors—including services, ecotourism, and processing industries—which could offer new livelihood opportunities.

The appeal of urban centers to migrants was also discussed. Cities offer economic and educational opportunities, but climate change is expected to bring new challenges. Heightened flood risks, extreme heat, and extreme weather events could disproportionately affect urban areas and need to be taken into account in urban planning. It was suggested that future analysis on internal climate migration in Vietnam could delve deeper into critical climate-related risks that could influence migration patterns into or out of cities.

3.2.5 What Do These Results Mean for Vietnam's Development Future?

1. **Environmental factors and extreme events are already well recognized drivers of internal mobility in Vietnam. With climate change impacts projected to intensify to mid-century and beyond, it is crucial for Vietnam to address climate-related drivers of mobility and prepare for potential climate migration.**

Environmental and climate-related mobility are already occurring in Vietnam and will add to well-established patterns of internal and external migration. With a large proportion of the Vietnamese population in low-elevation coastal zones, flooding is already, and will continue to be, an important driver of displacement and migration (F. Miller and Dun 2019; Koubi, Stoll, and Spilker 2016; O. Dun 2011). According to the Internal Displacement Monitoring Centre (IDMC), between 2008 and 2020, there were about 4.3 million displacements due to disasters in Vietnam, with large yearly variations: from a low of 9,600 in 2015, to highs of 1,040,000 in 2013 and 1,267,000 in 2020.[108] In the future, displacements due to disasters are expected to average more than 1 million per year.

As noted earlier, parts of the Mekong Delta have seen out-migration, as have the Northern Central and Southern Central coastal areas (UNESCO et al. 2018). These have the country's lowest income per capita, fewer livelihood opportunities, and high exposure to environmental stressors, including drought in the dry season and tropical storms and floods in the rainy season. These hazards are predicted to increase in intensity and frequency over the coming decades, suggesting increased out-migration from these regions (Anh, Leonardelli, and Dipierri 2016). Most migration driven by environmental change is expected to be internal, since poor subsistence farmers in rural areas would be disproportionately impacted and have limited resources with which to relocate (Koubi, Stoll, and Spilker 2016).

Exposure to environmental changes or hazards can have different implications for decisions to move, depending on local agricultural conditions, adaptation options, and possibilities for income diversification (Hoffmann et al. 2020). Complex non-linear relationships underlie the environment-migration nexus, and different forms of hazards have differential impacts on livelihoods and consequently can both amplify and suppress migration. Household-level survey research suggests that sudden-onset events with immediate impacts on safety and property, such as floods and typhoons, are likelier to contribute to decisions to migrate, while people are likelier to respond to slow-onset events, such as salinization, by adapting their lifestyles and livelihoods (Betcherman, Haque, and Marschke 2021; Koubi, Stoll, and Spilker 2016; Anh, Leonardelli, and Dipierri 2016). However, research in Thap Muoi District of Dong Thap Province in the northern delta area found that out-migration is an increasingly important strategy in response to multiple livelihood threats, including changing rainfall patterns and flood regimes, increased concentration of land ownership, and reduced labor demand due to mechanization (van der Geest, Nguyen, and Nguyen 2012).

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[108] See the IDMC profile page for Vietnam: https://www.internal-displacement.org/countries/viet-nam (accessed May 24, 2021).

By incorporating climate migration in planning, Vietnam has the opportunity to better manage its evolving landscape of migration and develop a number of new solutions. In this regard, the availability of comprehensive data and information integrating different forms and characteristics of migration, including environmental and climate-related migration, could aid long-term policy development. This could better inform sectoral plans and policies and help evaluate infrastructure and service needs in both sending and receiving areas, particularly in major metropolitan areas (World Bank 2020b).

2. **Early and concerted action is needed to prepare agricultural areas for climate change impacts, including low-lying areas in the Mekong and Red River Deltas facing sea-level rise and storm surge, as well as the Central Highlands and mountainous northeast and northwest.**

Climate change impacts have the potential to reshape the geography of agricultural production, necessitating adaptation measures. The modeling results suggest contrasting climate migration dynamics in the Mekong and Red River deltas by 2050. The Mekong Delta is expected to be an out-migration hotspot, but will continue to support a large number of people, who will need adaptive measures to ensure the viability of their livelihoods. In contrast, the Red River Delta is projected to be a climate in-migration hotspot. Planning there is crucial to accommodate growing numbers of people, especially in light of the increasing challenges posed by extreme weather events in Vietnam's coastal and deltaic areas.

Vietnam's updated Nationally Determined Contribution (NDC) identifies sea-level rise as a particularly serious threat to agriculture (Socialist Republic of Viet Nam 2020), noting that a 1-meter rise in sea-level could inundate nearly 39 percent of the Mekong Delta and 3 percent of the Red River Delta, significantly reducing rice cultivation areas. As soon as 2030, the agriculture sector's growth rate could slow by 5–15 percent, the NDC notes, and by 2050, by 5.8–13.5 percent. Along with inundation, increased saline intrusion is a key concern, as it is affecting freshwater supplies and reducing water quality. For generations, farmers have adapted to seasonal changes in salinity levels by cultivating different crops, for instance (M. T. Nguyen, Renaud, and Sebesvari 2019). However, pressures on livelihoods are increasing, and the industrialization of agriculture and aquaculture, especially in the Mekong Delta, has reduced the sustainability of small-scale farming and fishing (Betcherman, Haque, and Marschke 2021).

In the Mekong Delta, some salinity intrusion is natural, but sea-level rise would heighten impacts (Renaud and Kuenzer 2012). The Red River Delta is more protected from salinity intrusion, as it has a system of concrete sea and river dykes, sluicegates and pumping stations (Pham and Nguyen 2010). In Ca Mau Province, at the extreme southern tip of the Mekong Delta, saltwater has intruded into freshwater sources at an accelerated rate since the year 2000 (O. V. Dun 2012). Salinization is also linked to changing land use, particularly conversion of rice fields into salt-water monoculture shrimp farms. In the dry season of 2015–2016, which was characterized by a strong El Niño effect, saltwater intruded more than 90 kilometers inland and caused heavy crop losses and damages (GFDRR 2017; Joven and Cruz 2016).

Droughts are another growing concern. The Mekong Delta faced record-level droughts in 2020, in addition to severe droughts from 2015–2017 (USAID 2017). Rising temperatures and seasonal reductions in runoff threaten to reduce yields for rainfed and irrigated rice, by over 50 percent and 20 percent, respectively, by 2040, if high emissions continue (World Bank and ADB 2021b). The ISIMIP model results for crop productivity used in this report suggest decreases in the Red River Delta and increases in the Mekong Delta (except for the GEPIC model projecting declines). Studies suggest that adaptation measures such as changing planting dates may help mitigate these losses. In addition, the government has undertaken a progressive relaxation of restrictions on the use of paddy lands, with emphasis on diversification of rice-based farming systems and aquaculture production (Van Kien, Hoang Han, and Cramb 2020).

Agriculture in several other regions is vulnerable to climate change as well, including in the Central Highlands, where several cash crops are cultivated, such as tea, coffee, pepper, and rubber (World Bank and ADB 2021b). Coffee production could be affected by more intense droughts, higher temperatures, and increasing heat waves (T. N. Nguyen et al. 2017). In some scenarios, certain coffee-growing areas could become unsuitable for the crop (Bunn et al. 2015; World Bank and ADB 2021b).

In the northeast and northwest mountainous areas, meanwhile, most agriculture is for subsistence purposes, except in areas that can sustain forestry plantations and cash crops such as tea and rubber (T. N. Nguyen et al. 2017). Not only do these areas face climate change impacts, but their vulnerability is exacerbated by limited transportation infrastructure, poor market access, and limited irrigation systems. The mountains and the Central Highlands are also where ethnic minorities are concentrated, who—as discussed earlier—have particularly high poverty rates; social analyses have found them to also be particularly vulnerable to climate change (McElwee 2010). For instance, the 2015–2016 drought disproportionately affected ethnic minorities located in the drought-stricken provinces of the Central Highlands, as well as poor households in general, women, and girls (GFDRR 2017).

Maize, grown for animal feed and as a food staple when rice is in short supply, is an important source of income for many farmers. The outlook for maize production is poor due to its sensitivity to high temperatures (World Bank and ADB 2021b). GEPIC crop model runs used in this report suggest pronounced declines in crop productivity in this region under RCP8.5, and more modest declines under RCP2.6. LPJmL crop model runs show increases in productivity in the northeastern tip of Vietnam but slight declines in the northwest.

Several adapt-in-place measures are already being implemented in Vietnam's agriculture sector, both by individual farmers, and through government efforts (Van Kien, Hoang Han, and Cramb 2020). Autonomous adaptation measures include changes in sowing dates, switching to drought-tolerant crops, adoption of salinity-tolerant varieties of rice, adoption of new varieties for other crops, and switching to rice-fish rotations (World Bank 2010). Planned adaptations focus on increasing investment on research, development, and extension, with the goal of raising average crop yields and extending the area of irrigated land mainly for rice, maize, and coffee. In recent years, the government has also sought to diversify farming systems and promoted agro-ecological agriculture to boost the resilience of farmers in the Mekong Delta (Van Kien, Hoang Han, and Cramb 2020). Farmers in the Mekong Delta are increasingly engaged in aquaculture (such as shrimp and combined rice-shrimp farming) and grow different field crops instead of rice monocultures; this could improve food security and help adapt coastal livelihoods to climate change (Dang 2020).

Aquaculture and fisheries, meanwhile, especially in the Mekong Delta, are expected to be affected by higher temperatures, more frequent storms, flooding, sea-level rise, and saline intrusion (DuBois King 2015). As water temperatures rise, fish may move farther from the coast, potentially out of reach for small fishing boats. Aggressive storms can damage infrastructure, posing a greater challenge for artisanal fisherman and small-scale operations. Parts of the aquaculture sector, particularly catfish farming, already currently face uncertain economic prospects as a result of rising prices for feed and the costs of maintaining water quality. As temperatures rise, some fish species, including catfish, may grow faster, but also be more vulnerable to disease. There is some evidence that with adapted species and innovative management systems, rising temperatures and increased inundation during the wet season could improve aquaculture productivity (T. N. Nguyen et al. 2017). However, rising sea levels will continue to pose major challenges, with inundated ponds and lakes potentially suffering large stock losses.

Maintaining aquaculture productivity in a changing climate will require significant investments in research and development, including breeding new varieties adapted to higher temperatures and salinity (World Bank 2016). Adapting shrimp and catfish aquaculture to changing conditions in the Mekong Delta could prove very costly, so required investments should be weighed against the benefits as well as potential alternatives. Promoting livelihoods such as aquaculture may also increase households' exposure to flood risks, so other diversification options, such as business and trade, should be considered (McElwee et al. 2017).

Adapt-in-place approaches, particularly in the deltas, should also avoid further degradation of natural capital, given its role as a critical buffer to maintain the resilience of key rural livelihoods and ecosystems. In the Central Highlands, the majority of new rubber plantations have been established on natural forest land (T. N. Nguyen et al. 2017). Increased monoculture production has also made landscapes more vulnerable to climate change. A major expansion of shrimp aquaculture, meanwhile, has reduced paddy production, polluted water, depleted biodiversity, and destroyed nearly half of the Mekong Delta's mangroves. And while low-level dyke systems are helping control saltwater intrusion and early flooding and improve water management in the Mekong Delta, continued expansion of hard infrastructure to control water could destabilize the deltas' already-fragile ecology (Betcherman, Haque, and Marschke 2021) and exacerbate existing challenges (M. T. Nguyen, Renaud, and Sebesvari 2019). For instance, dam infrastructure in the upper reaches of the Mekong has reduced freshwater input and sediment transport, while increasing the siltation of tributaries and saltwater intrusion (de Sherbinin 2014).

Agricultural production that aligns with the natural and dynamically changing ecological conditions of the deltas could help maintain natural capital and keep adaptation options open and flexible for the future (M. T. Nguyen, Renaud, and Sebesvari 2019). There are also cross-sectoral opportunities to increase resilience, particularly at the water-energy-food nexus. Most notably, traditional rice production uses large amounts of water to inundate fields, which could be increasingly challenging as climate change makes water supplies less reliable. The flooded fields also emit large amounts of methane (Adhya et al. 2014; Torbick et al. 2017). Climate-smart techniques such as alternate wetting and drying can sharply reduce emissions and water demand, contributing to both mitigation and adaptation. Vietnam's updated NDC identifies that approach as one of several climate strategies being implemented in agriculture, including in rice cultivation, dairy and livestock production, and coffee cultivation (Socialist Republic of Viet Nam 2020). Understanding the particular vulnerabilities of each location can inform more effective sectoral planning as well as the implementation of comprehensive approaches such as integrated coastal zone management.

3. **Major coastal urban centers will require climate-resilient planning, but they have differentiated needs. Hanoi, which could see climate in-migration even as flooding and exposure to tropical cyclones continue to grow, may need to address increasing strains on urban infrastructure and key economic activities. Ho Chi Minh City, meanwhile, will need to balance climate out-migration with broader population growth trends, and strengthen investments in adaptive capacity.**

Sea-level rise, tropical cyclones, and floods pose major threats to urban areas, with Ho Chi Minh City, the Mekong Delta, and the Red River Delta facing particularly high risks. The combination of heavy rainfall and high water levels along rivers is the most important cause of flood to inland cities like Hanoi and Can Tho, whereas in coastal cities, such as Hai Phong, Nha Trang, and Ho Chi Minh City, flooding is caused by a combination of heavy rainfall, high water river levels, and sea-level rise augmented by storm surge (World Bank Group 2012). By 2030, nearly 70 million could be at risk from flooding, mainly in the deltas, including in Hanoi and Ho Chi Minh City (Rutten et al. 2014). Depending on how well it adapts, with 0.40 meters of sea-level rise, Ho Chi Minh City could face annual losses of 1–5 percent of its GDP, while Hai Phòng has the potential to lose 0.5–20 percent of its GDP (World Bank and ADB 2021b).

Ho Chi Minh City already experiences frequent floods due to intense rainfall and riverine flooding from the Saigon River and neighboring Mekong Delta, and climate change is expected to amplify those risks. Flooding may be further exacerbated by rapid development. With the population expected to exceed 12 million people by 2035 (Table 3.5), how resilient the city's growth will be to climate change impacts will depend on how urban planning, design, and policies address high-flood-risk areas and vulnerable populations, particularly poor and marginalized people (World Bank Group 2012). Within Ho Chi Minh City, slum areas are 10–20 percent more exposed to floods than the rest of the city, and climate change is expected to widen the gap (Bangalore, Smith, and Veldkamp 2019).

Hanoi, meanwhile, which is projected to be a climate in-migration hotspot, will need to ensure that its infrastructure is resilient to heightened flood and cyclone risks, and also ensure that it can provide adequate services for an expanded population. One study in two key districts (Long Bien and Gia Lam) in Hanoi found that by 2030, if nothing is done, the total area at risk of flooding could increase by 65 percent, and the areas exposed to deep flooding could double, with almost one-fifth of the districts' critical transport network vulnerable to flooding (World Bank 2020a). As in Ho Chi Minh City, development could increase flood risks, too, by covering a larger area with impervious surfaces. Holistic approaches to flood risk management are needed, incorporating both hard infrastructure and "soft" approaches, such as changes in land use planning and insurance instruments (McElwee et al. 2017).

Urban planning will have to consider the specific needs of migrants, who tend to lack access to public services, formal jobs, and housing (UNESCO et al. 2018). There are also formal institutional barriers, such as the *ho khau,* or household registration system, that can make it difficult for migrants to integrate into cities (Coxhead, Cuong, and Vu 2015; Fan et al. 2019). Policy development will also need to consider the role of climate migration in shaping the future of jobs in Vietnam, particularly in cities as key receiving areas. A recent study by Cunningham and Pimhidzai (2018) suggests a number of policy areas to facilitate the future transformation of the job market in Vietnam, from creating more good jobs in small and medium enterprises, knowledge-intensive sectors, and a modernized agro-food industry, to enhancing the quality of existing jobs in traditional sectors, to connecting qualified workers to the right jobs.

4. **Vietnam is already working to address climate change risks, and stepping up those efforts—including proactive, multisectoral planning and the adoption of transformative solutions—will be crucial to maintaining the country's robust development trajectory. With good preparation in both sending and receiving areas, climate migration can be a positive adaptation strategy for those who cannot effectively adapt in place.**

The Vietnamese government is keenly aware of threats posed by climate change and disasters, as outlined in its updated NDC (Socialist Republic of Viet Nam 2020). Flood mitigation in particular is recognized as a priority, with significant investments guided by the Second National Strategy and Action Plan for Disaster Mitigation and Management in Vietnam 2001–2020 and the Strategy on Flood Management and Mitigation. The Second National Strategy includes requirements for flood safety and security in residential areas, and there is a program to raise the foundations of houses. Major investments have been committed to upgrade national and provincial dyke systems, including for Ho Chi Minh City and Hanoi (van Ledden et al. 2020).

In coastal areas, along with protecting human settlements and agriculture, adaptation strategies need to address risks to other key economic sectors, such as tourism and industry, threatened by coastal erosion, flooding, and tropical cyclones (Rentschler et al. 2020). Major investments have been made in recent decades to restore coastal mangroves, with important successes, but also challenges (Hai et al. 2020; Tatarski 2020). The protection of the Mekong Delta is also being actively discussed through the development of the Mekong Delta Master Plan 2021–2030 and its vision to 2050. There is an opportunity to build strong institutions to promote regional coordination on the development and management of the Delta. Box 3.3 for delves deeper into approaches to resilient coastal development in Vietnam.

Vietnam is also trying to balance the ability of people to adapt in place when they can, with support for migration when needed (Evers and Pathirana 2018; Anh, Leonardelli, and Dipierri 2016). For example, the government provides technical assistance to build resilience in rural communities and livelihoods, but also has a number of resettlement programs (see Box 3.4 for further details). It is important that when people cannot stay where they are, movement is anticipated and facilitated, so it does not occur under distress conditions; this can also help ensure social cohesion. Without adequate planning, households may expend all their resources adapting to progressive environmental change, and when their livelihoods, especially those tied to agriculture, become untenable, find themselves stranded, as they no longer have sufficient means to migrate (Koubi et al. 2016).

Embedding climate action in medium- and long-term planning is crucial as well. Vietnam's earliest national policy on climate change is the 2008 National Target Program to Respond to Climate Change. This was followed by the 2011 National Climate Change Strategy and the 2012 Vietnam Green Growth Strategy, both of which set a number of emission reduction targets out to 2050 in key sectors including energy, industry and forestry (for an overview, see Le et al. 2019). Next came the National Action Plan on Climate Change and the Green Growth Action Plan, both for the period up to 2020. Vietnam's 2016–2020 Socio–Economic Development Plan put an unprecedented emphasis on climate resilience and promoting green and low-carbon development.

Most recently, the country's updated NDC laid out a comprehensive agenda for mitigation and adaptation, including an unconditional pledge to reduce emissions by 9 percent relative to business-as-usual levels by 2030 (up from 8 percent in its first NDC), rising to 27 percent with international support (Socialist Republic of Viet Nam 2020; see also NDC Partnership 2020). Along with specific strategies to build resilience, including in priority areas discussed above, the NDC outlined commitments to mainstream the NDC with socioeconomic development plans and strategies.

Targeted policy reforms, including those in the Climate Change and Green Growth Development Policy Financing supported by the World Bank,[109] seek to support Vietnam through a multidimensional approach including climate-resilient management of landscapes, the development of sustainable forest management plans, coordination of investments in the Integrated Regional Master Plan for the Mekong Delta to address multiprovincial issues compounded by climate change, and climate-responsive investments in the agriculture sector, among other areas. There is a further need to integrate climate change-induced migration and displacement in national strategies and plans.

Box 3.3: A resilience and dynamic coastal development strategy for Vietnam

Resilient Shores: Vietnam's Coastal Development Between Opportunity and Disaster Risk, a 2020 joint report by the World Bank and the government of Vietnam, outlines a strategy for resilient and dynamic coastal development (Rentschler et al. 2020). It starts with a systematic, multisectoral assessment of risks to Vietnam's coastal communities, infrastructure, public services, and economic sectors. It then takes stock of Vietnam's current measures to reduce and manage disaster risks in coastal regions, assessing their scope, effectiveness, and shortcomings. Finally, it introduces an integrated resilience framework with concrete risk reduction actions to help the government and coastal authorities formulate resilient district-level Socio-economic Development Plans, aiming to minimize or manage threats while boosting economic growth. The actions target five strategic areas:

- Strengthening data and decision-making tools by establishing openly accessible natural disaster databases, as well as asset management systems for critical infrastructure;

- Enforcing risk-informed coastal planning, through systematic planning to manage risks in high-risk and high-growth areas, and the implementation of integrated coastal zone management (ICZM);

- Strengthening the resilience of infrastructure systems and public services, ensuring systematic maintenance, upgrading key assets, especially in the most exposed and under-protected areas, and updating and enforcing existing safety standards and technical guidelines;

- Taking advantage of nature-based solutions, ensuring management and protection of the sandy coastline and developing a plan for restoring and protecting mangroves and coral reefs; and

- Improving preparedness, response, and recovery capacity, by improving early warning systems and communication channels, strengthening emergency planning and civil protection capacity, and establishing a national financial protection strategy.

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[109] See June 2020 World Bank press release, with a link to project documents: https://www.worldbank.org/en/news/press-release/2020/06/05/vietnam-new-credit-to-support-effective-policymaking-for-climate-action.

Box 3.4: Resettlement programs in Vietnam

Vietnam's "Living with the Flood" program, launched in 1996, resettled about 1 million people: 200,000 largely poor and landless households who were living in areas that are now permanently flooded (Danh and Mushtaq 2011). The program built more than 1,000 resettlement clusters along dykes away from the main stem of the Mekong, aiming to improve living conditions and stabilize livelihoods. The resettlement clusters are connected by roads that lead to towns and cities, increasing both circular and permanent migration that supplements rural income (de Sherbinin 2014).

Sampan boat dwellers in Central Vietnam (e.g. in the coastal lagoons of Thua Thien-Hue province) were resettled through another program that provided a plot of land, financial resources for building a house, and access to services, particularly education (Lindegaard 2018). The goal was to counter vulnerabilities associated with fishing-based livelihoods, limited access to education and health services, and poor living conditions further stressed by extreme storms and sea-level rise. While relocation has reduced physical vulnerability to natural disasters, some people have struggled to establish sustainable livelihoods and thus returned to sampans and back again, which has been with met with discontinued government funding, greater land scarcity in resettlement areas, and higher construction costs (UN Viet Nam 2014). Initiatives to establish adequate legal frameworks regarding land allocation and building associational ties with members of other communities are seen as pivotal elements to anchor the sustainability of new livelihoods (DaCosta and Turner 2007).

In general, even with benefits, relocation may not always reduce overall social vulnerabilities, and it can even create new ones by disrupting livelihoods and social networks, reducing access to public services (e.g. by increasing the distance from schools). It can also have a disproportionate effects on minorities and deepen rural debt through government loans associated with relocation (F. Miller and Dun 2019; UNESCO et al. 2018; Ty, Van Westen, and Zoomers 2013).

Photo Credit: Steve Le

3.3 CLIMATE MIGRATION PROJECTIONS FOR THE KYRGYZ REPUBLIC

Key Findings

- The scale of climate migration is projected to increase by 2050 in all three scenarios modeled. The number of climate migrants is largest in the pessimistic reference scenario, averaging 0.22 million (3.9 percent of the total population). In the more inclusive development scenario, the projection is 0.18 million (2.8 percent of the total population), and in the more climate-friendly scenario, it is 0.14 million (2.4 percent of the total population).

- By 2050, in the pessimistic reference scenario, about 26 percent of all internal migrants could be climate migrants—and in the more inclusive development scenario, which shares a high emissions pathway, 42 percent. In the more climate-friendly scenario, it would be about 19 percent. Climate change impacts, mainly on water availability, may become an increasingly important driver of internal migration, with implications for spatial planning.

- The largest in-migration hotspot by 2050 is projected close to the Ferghana Valley, including the cities of Osh and Jalal-Abad, driven mainly by increases in water availability. Climate out-migration hotspots are projected around Bishkek and along the northern border on Lake Issyk-Kul including Karakol, driven mainly by negative trends in water availability, which would slightly dampen projected population growth trends in these areas. Climate out-migration hotspots are also projected in areas of the southwest and central region near Lake Son-Kul. Understanding the differing vulnerabilities and attractiveness of hotspots, particularly in key agricultural livelihood systems and urban centers, can provide a stronger basis for proactive planning in both sending and receiving areas.

3.3.1 Country Context

The Kyrgyz Republic is a landlocked country in northeastern Central Asia, situated between two major mountain systems, the Tien Shan and the Pamir (Figure 3.22). Roughly 80 percent of the country's 198,000 square kilometer land area is in the Tien Shan mountain range, which extends through the country, running along the border with China in the east, bounding the Ferghana Valley in the west, and culminating in Peak Pobeda, at 7,439 meters above sea level. Seventy percent of the country's land surface is above 2,000 meters, and a majority of the population lives on the foothills of the mountains (World Bank 2011b). The population is predominantly rural, with mountain communities interspersed throughout the Tien Shan mountains.

The Kyrgyz Republic, a lower-middle income country, has a GNI per capita of US$1,140 in 2019.[110] Like other Central Asian countries, it experienced a sharp economic decline after the fall of the Soviet Union and the shift to a market economy (Schmidt and Sagynbekova 2008). Agrarian reforms in 1994–1996 eliminated state subsidies for crops, resulting in a shift from Soviet-era cooperatives or corporate farms to small individual private farms dependent on family labor (Atamanov and Van den Berg 2011). The agricultural sector had difficulty absorbing the rural labor force, resulting in a period of stagnation. Estimates suggest that almost one-sixth of the Kyrgyz Republic's inhabitants left the country between 1989 and 1999 (Schmidt and Sagynbekova 2008).

Over the last two decades, economic growth has been relatively robust. GDP has risen from US$1.4 billion in 2000 to US$8.5 billion in 2019,[111] but the country has seen periods of economic volatility (Figure 3.23 and Table 3.7). Growth has been disrupted by natural disasters, gold production shocks, and political instability (IMF 2016). With a relatively small GDP (about one-thirtieth of Kazakhstan's), the country is more vulnerable to shocks, with sudden changes in the direction of capital flows potentially inducing boom-bust cycles. These economic cycles may influence migration patterns; one study found a decline in internal migration and an increase in temporary international migration during economic slowdowns (Agadjanian and Gorina 2019). The Kyrgyz Republic is the third-most remittance-dependent country in the world, with remittances equivalent to 28.5 percent of GDP in 2019.[112] In 2020, with GDP contracting by an estimated 8 percent due to the COVID-19 crisis, remittances amounted to 29.4 percent of GDP (IMF 2021; Ratha, Kim, and Plaza 2021).

The country is rich in natural resources, including minerals, forests, and pastures, which present opportunities for economic diversification and employment growth in energy, agriculture, and tourism. The share of GDP coming from agriculture and forestry has declined rapidly since 1996, from 46.3 percent to just 12.1 percent in 2019.[113] The share of employment in those sectors has also dropped, from 52.9 percent in 2001, to a still-substantial 19.3 percent in 2019.[114] Further economic diversification could help buffer against external shocks and alleviate heavy dependence on gold exports.[115] The energy sector accounts for about 5.5 percent of GDP and 16 percent of industrial production and generates about 10 percent of national government revenues (UNECE 2020). Table 3.7 provides a snapshot of development and climate risk indicators for the Kyrgyz Republic.

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[110] See World Bank data on GNI per capita, Atlas method (current US$): https://data.worldbank.org/indicator/NY.GNP.PCAP.CD?locations=KG. Note that the threshold between low- and lower-middle income countries is US$1,036 per capita (Serajuddin and Hamadeh 2020).

[111] See World Bank data on GDP (current US$): https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=KG.

[112] See World Bank data for personal remittances, received (% of GDP): https://data.worldbank.org/indicator/BX.TRF.PWKR.DT.GD.ZS?locations=KG.

[113] See World Bank data on agriculture, forestry and fishing, value added (% of GDP): https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?locations=KG.

[114] See World Bank data on employment in agriculture (% of total employment), modeled ILO estimate: https://data.worldbank.org/indicator/SL.AGR.EMPL.ZS?locations=KG.

[115] See World Bank country overview: https://www.worldbank.org/en/country/kyrgyzrepublic/overview.

Figure 3.22: Administrative boundaries and elevation in the Kyrgyz Republic

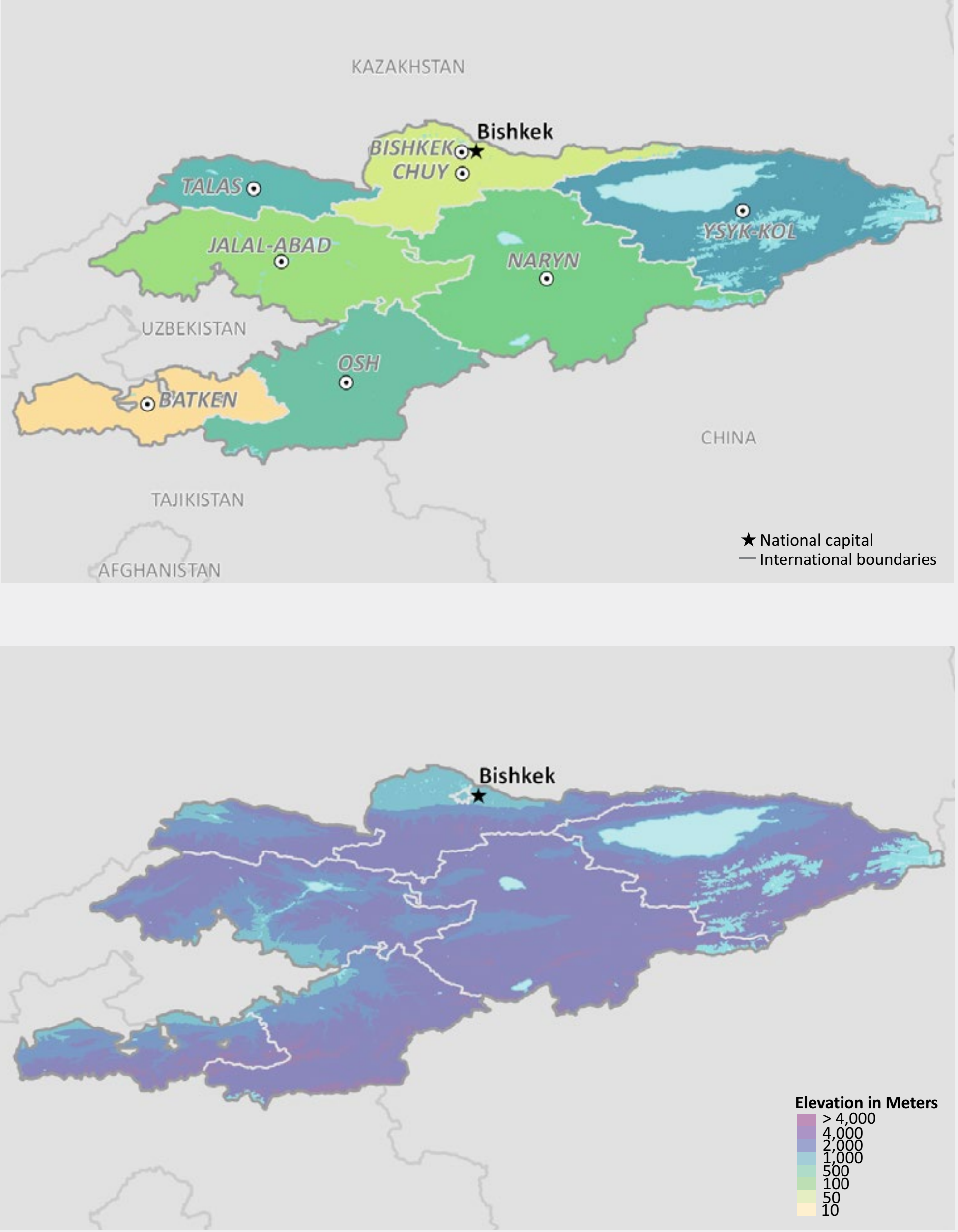
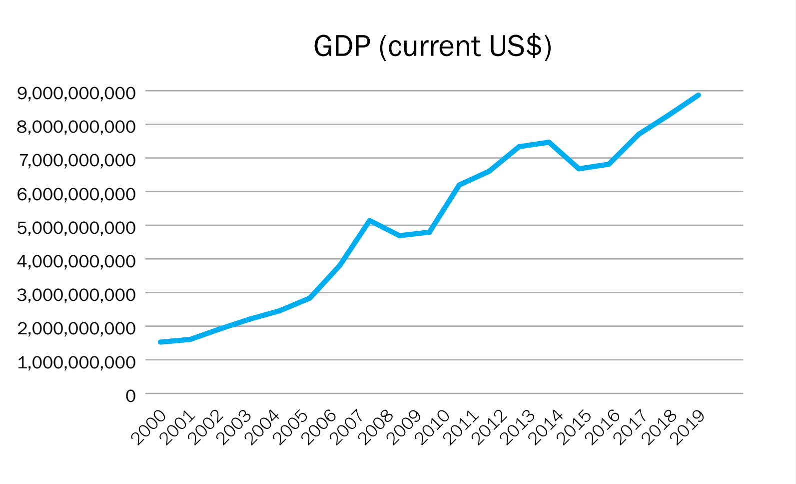
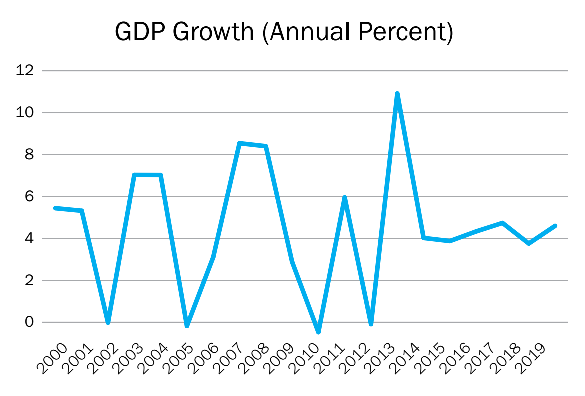


Figure 3.23: Economic performance in the Kyrgyz Republic, 2000–2019





Source: World Bank, World Development Indicators.[64]

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[64] See World Bank data on GDP (current US$): https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=KG and GDP growth (annual %): https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?locations=KG.

Table 3.7: Demographic, socioeconomic, and climate risk indicators for the Kyrgyz Republic

Development Indicators	
Population	
Population (millions)	6.5
Annual population growth (percent)	2.1
Population in 2050 under SSP2(millions)*	6.4
Population in 2050 under SSP4 (millions)*	5.7
Urban share of population (percent)	36.6
Employment in agriculture (percent of total employment)	19.3
GDP	
GDP (current US$ billions)	8.9
Annual GDP growth (percent)	4.6
GDP per capita (current US$)	1,374
Value added of agriculture (percent GDP)	11.7
Value added of services (percent GDP)	49.9
Value added of industry (percent GDP)	28.5
Poverty	
Poverty headcount ratio at $1.90 a day (2011 PPP) (percent of population)	0.6
Poverty headcount ratio at $3.20 a day (2011 PPP) (percent of population)	9.7
Climate and disaster risk indexes	
ND GAIN Index**	
Rank	65
Score	52.5
World Risk Index (2020)***	
Rank	78
Score	7.3

Sources: All 2019 data from World Bank Open Data (http://databank.worldbank.org) except where indicated.
* SSP population projections produced for this report
** ND-GAIN (https://gain.nd.edu/our-work/country-index/rankings/)
*** Bündnis Entwicklung Hilft (https://weltrisikobericht.de/english/)

Poverty remains relatively high, especially compared with regional peers. Though only 0.6 percent of the population as of 2019 lived in extreme poverty, 20.1 percent were below the national poverty line, and as of 2019, 52.6 percent of the population lived on less than $5.50 per day (2011 PPP), with strong seasonal fluctuations.[116] Poverty is concentrated in rural areas and mountainous areas, such as Talas and Naryn (Thieme 2014), and there are regional disparities, with the southern part of the country being more rural and having lower levels of human development. Over one-third of the rural population lives in poverty, and urban poverty has also increased from 23.8 percent in 2008 to 29.3 percent in 2015 (World Bank 2018b). The poverty gap between rural and urban areas has narrowed over time, but there is variation across regions (IMF 2016). The country was ranked No. 120 out of 189 countries on the latest Human Development Index (UNDP 2020). On the Human Capital Index, the Kyrgyz Republic's most recent score, in 2018, was 0.59, versus 0.79 for Kazakhstan.[117]

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[116] See World Bank data on poverty headcount ratio at $1.90 a day (2011 PPP, % of population): https://data.worldbank.org/indicator/SI.POV.DDAY?locations=KG, at national poverty lines (% of population): https://data.worldbank.org/indicator/SI.POV.NAHC?locations=KG, and poverty headcount ratio at $550 a day (2011 PPP, % of population): https://data.worldbank.org/indicator/SI.POV.UMIC?locations=KG.

[117] See World Bank data on Human Capital Index (scale 0–1): https://data.worldbank.org/indicator/HD.HCI.OVRL?locations=KG-KZ,

Photo Credit: Mick Truyts

Given the current levels of income inequality, unemployment is relatively high and concentrated among youth and women (IMF 2016). The youth unemployment rate was 14.8 percent in 2019, more than twice the overall unemployment rate of 6.7 percent.[118] Female labor force participation was at 44.1 percent in 2019, compared with 74.5 percent for men.[119] Women also earn less, 74.3 percent of men's salaries, even though women tend to be more educated (IMF 2016).

The Kyrgyz Republic was home to an estimated 6.5 million people as of 2019 (UN DESA 2019b). The population is fairly young, as shown in Figure 3.24 (see also IMF 2016). As of 2019, the median age was about 26, and almost a third of the population was 14 or younger, while less than 5 percent was over 65. Projections of population structure to 2050 show slower growth and progressive aging. The country's birth rate in 2015–2020 was 25 births per 1,000 people, but it is projected to decline to 19 per 1,000 by 2030–2035. The population is expected to remain relatively stable to 2050, with an estimated 6.4 million people under SSP2 and even declining to 5.7 million under SSP4.[120] Almost two-thirds of the Kyrgyz people still live in rural areas (UN DESA 2018b). The largest city is the capital, Bishkek, with just over 1 million residents in 2019, followed by Osh and Jalad-Abad.

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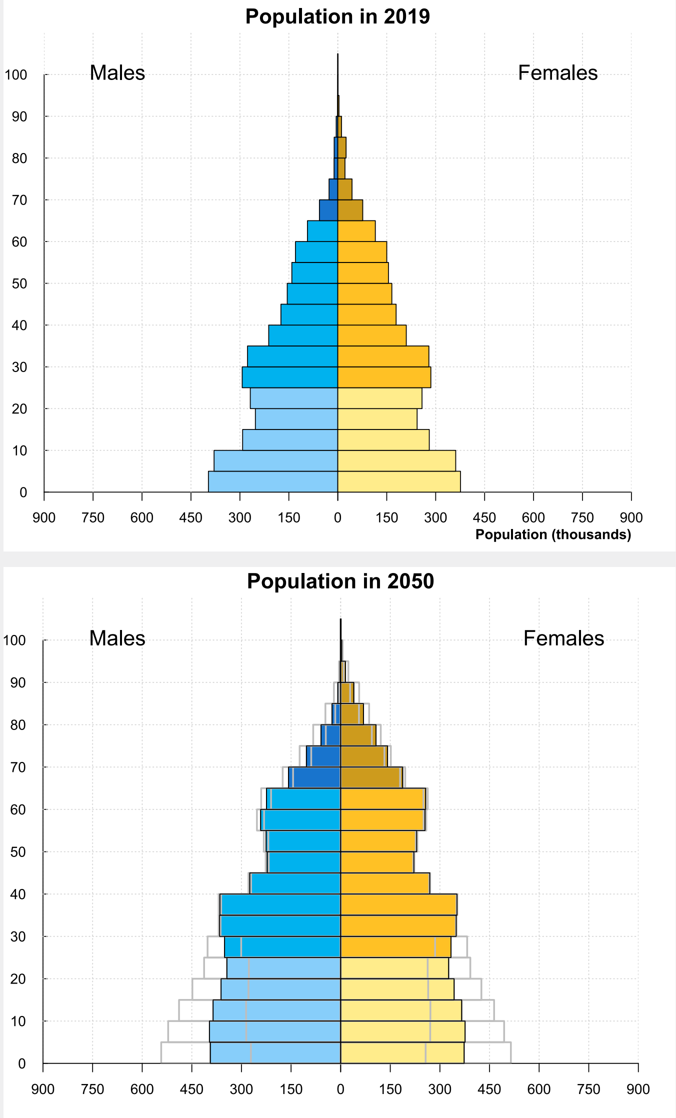
[118] See World Bank data on unemployment rates (modeled ILO estimates) for the youth (% of total labor force ages 15-24) and overall unemployment (% of labor force) rates: https://data.worldbank.org/indicator/SL.UEM.1524.ZS?locations=KG and https://data.worldbank.org/indicator/SL.UEM.TOTL.ZS?locations=KG respectively

[119] See World Bank data on labor force participation rates (modeled ILO estimates) for females (% of female population ages 15+): https://data.worldbank.org/indicator/SL.TLF.CACT.FE.ZS?locations=KG and for males: https://data.worldbank.org/indicator/SL.TLF.CACT.MA.ZS?locations=KG.

[120] These SSP population scenarios use data from World Population Prospects 2010 for the baseline. https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=10#v2 See: Riahi et al. (2017). Under SSP4, middle-income countries see attenuated population growth, and, as in the case of the Kyrgyz Republic, even declines, in contrast to rapid population growth in low-income countries.

Figure 3.24: Kyrgyz Republic population pyramids, 2019 and 2050



Source: UN DESA (2019b).
Note: Medium-variant data is shown as colored bars, and uncertainty is shown in gray for 2050 for 95 percent prediction intervals.

Historically, the Kyrgyz were nomads, with pastures and livestock grazing playing an important role in history, culture and economic life (Sabyrbekov 2019). Herders moved seasonally to high-altitude pastures in the summer and lower-lying valleys in the cooler seasons. The dissolution of the Soviet Union resulted in very large emigration flows during the 1990s, but it also triggered a high degree of internal migration, which in some cases may have been a stepping stone to international migration (Agadjanian and Gorina 2019). Recently, mobility trends have been characterized by rural-urban migration, economic out-migration into neighboring Russia and Kazakhstan, and internal displacement due to political instability and conflicts in the Ferghana Valley in 2010 (see also IOM 2019a).

Internal migrants now make up about 18 percent of the population, with ongoing migration from rural and mountainous regions and small towns toward larger urban centers with developed infrastructure and more diverse and higher-paying employment (IOM 2019a; Sagynbekova 2017).[121] The prevalent direction of internal migration has been from the poorer and more rural South to the more affluent North, especially the capital Bishkek and Chuy province, although there were also flows from other Northern regions (e.g. rural areas of Naryn and Issyk-Kul) (Agadjanian and Gorina 2019; IOM 2019a). The cities of Osh and Jalal-Abad are also urban destinations for rural migrants from the south of the country. For women, marriage was (and still is) another driver for migrating internally (related to patrilocal rules, particularly among ethnic Kyrgyz). The low diversity of income-generating activities in rural areas, including deterioration of livelihoods related to animal husbandry, increases vulnerability to environmental and economic shocks, and labor migration or engagement in trade or other business ventures have all become essential coping strategies for rural households (Rocheva and Varshaver 2018; Chandonnet et al. 2016).

The *propiska* system that was adopted throughout the Soviet Union is still in use, but in a less restrictive form (Hatcher and Thieme 2016). In Bishkek, this system allows for the existence of unregistered migrants that have settled in the outskirts of the city in informal settlements where land is cheaper and accessible. Internal migrants account for an estimated 40 percent of Bishkek's total population, with most living in peri-urban settlements lacking access to public services and utilities (Isabaeva 2013). Recent government efforts are directed towards formally recognizing these settlements through the introduction of land use legislation.

Household wealth can be an important determinant of destination for migrants. Households with sufficient means often finance relocation abroad for a household member, while poorer households might opt instead to pay for a household member to migrate internally to a city (Sagynbekova 2017). Some Kyrgyz migrants migrate to Kazakhstan seasonally, working in agriculture. There is some indication that international migration has pushed left-behind youth—especially young women—to become unpaid family workers, primarily in agriculture (Dávalos et al. 2017). Box 3.5 delves deeper into intra-regional migration dynamics.

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[121] For a summary, see the IOM web page on "Current migration situation and trends in Kyrgyzstan": https://kyrgyzstan.iom.int/news/current-migration-situation-and-trends-kyrgyzstan (accessed June 26, 2021).

Box 3.5: Intra-regional migration dynamics in the Kyrgyz Republic

International labor migration and remittances are important for Central Asian countries in general. In large parts of the Kyrgyz Republic, migration is a livelihood strategy through which families meet their immediate needs and accumulate capital for future projects (Isabaeva 2011). Up to 45 percent of Kyrgyz working-age males migrate to find work, mainly due to unemployment and low wages back home (Laruelle and Peyrouse 2012).

Estimates from 2013 found about 25–35 percent of the economically active population living abroad, with 98.1 percent of those migrants either in Russia or in Kazakhstan. Women made up 31 percent of labor migrants from the Kyrgyz Republic in 2015, more than the 15.7 percent average for the Commonwealth of Independent States (Rocheva and Varshaver 2018). External migrants tend to relocate permanently and seek citizenship or long-term residency in destination countries (Schmidt and Sagynbekova 2008).

External migration flows heavily favor Russia and Kazakhstan, facilitated by well-established social networks and Kyrgyz diasporic communities within those countries. Compared with other countries in the region, the Kyrgyz Republic has more gender-balanced migration to Russia, with women making up almost half of the migrants (Rocheva and Varshaver 2018). Over the past decade, migrant destinations have diversified, due to increased access to communications technology and new bilateral agreements that facilitate Kyrgyz migration to meet other countries' labor demand. These developments have promoted the expansion of social networks, increased government assistance for migrants, and allowed migration to more distant countries, such as Turkey, South Korea, and the Gulf states (IOM 2019b).

Personal remittances play a significant and growing role in the Kyrgyz Republic, with flows equivalent to 29.4 percent of GDP in 2020 (Ratha, Kim, and Plaza 2021).[a] One analysis found that the average remittance received by Kyrgyz households reduced the likelihood of poverty by about 8.6 percent (Murodova 2018). Remittances can represent a relatively significant share of families' income—reaching up to 20 percent in southern oblasts—and are important for alleviating poverty (IMF 2016). Remittances can temporarily delay migration, enable investments, and sustain rural livelihoods (Isabaeva 2011).

For mountain communities, remittances are primarily used to cover basic needs and are insufficient to support long-term investments (Schmidt and Sagynbekova 2008). Receiving households often funnel remittances into existing enterprises, such as animal husbandry, crop cultivation, and small-scale construction. Others argue that remittances can also spur an acceleration of land degradation through increased livestock purchases, which can lead to overgrazing (Sagynbekova 2017; Chandonnet et al. 2016; Schoch, Steimann, and Thieme 2010). At the same time, remittances can also be allocated to improving land use practices (Xenarios et al. 2019) and to the repayment of loans (Sagynbekova 2017).

The COVID-19 pandemic and the collapse of oil prices had a particularly large impact on remittances to Europe and Central Asia, which dropped by almost 10 percent overall, in part due to the depreciation of the Russian ruble (Ratha, Kim, and Plaza 2021). The value of remittances from Russia to the Kyrgyz Republic fell by 17 percent.

[a] For historical data, see World Bank data for personal remittances, received (% of GDP): https://data.worldbank.org/indicator/BX.TRF.PWKR.DT.GD.ZS?locations=KG.

3.3.2 Climate Trends

The Kyrgyz Republic's climate is defined by its geography: landlocked and situated between two major mountain systems, the Tien Shan and the Pamirs (World Bank and ADB 2021a). It has four major climatic zones: a submountain valley region with hot summers, temperate winters, and very little precipitation; a mountain zone with a temperate climate, warm summers, and cold, snowy winters; a high mountain zone with cool summers and relatively cold and snowless winters; and a high-elevation area—almost a quarter of the country's surface area—that is above 3,500 meters of elevation, with glaciers and, historically, perennial snow cover.

The majority of the country is arid, and mean annual precipitation is only about 378 millimeters, but it varies by region, from a low of 100 millimeters in the driest areas, to 1,000 millimeters in the region surrounding Jalal-Abad (World Bank and ADB 2021a). Mean annual temperatures vary from less than −10°C in highest elevations of the Tien Shan mountains, to over 12°C in the northern and western lowlands. Summer temperatures in the lowland regions around Bishkek and Osh regularly exceed 30°C.

The Kyrgyz Republic's topography and climate make large areas vulnerable to a variety of natural hazards: from earthquakes, to avalanches, to floods and mudslides, to severe droughts, to glacial lake outbursts (USAID 2018). The country's 2012–2020 disaster management strategy found that in the preceding two decades, about 200 emergencies had occurred each year, causing direct damages of US$30–35 million per year—though in recent years, there has been "steadfast growth" in the number of both natural and manmade disasters (Government of the Kyrgyz Republic 2011). Landslides are a major risk, with almost 10,000 households in over 500 settlements identified as being at risk. Glacial lake outbursts and related debris flows are also major threats in mountainous areas, causing loss of life and damage to infrastructure even in Bishkek (Zaginaev et al. 2016). During the last 50 years, more than 70 glacial lake outbursts have occurred in the country—the largest one in 1998 at Ikedavan Lake. The densely populated and agriculturally productive Ferghana Valley region is also highly exposed to floods and mudflows as a result of glacial lake outbursts (World Bank 2014b). The effects of climate change are expected to increase disaster risks.

Climate data for the Kyrgyz Republic show that average annual temperatures increased by about 1.1°C between 1960 and 2010, and the rate of warming has accelerated over the period 1990–2010 (World Bank and ADB 2021a). These trends are expected to continue in the future, with the mean annual temperature projected to rise by 1.5°C by mid-century (from 1985–2005 levels) under RCP2.6, and 2.6°C under RCP8.5. By 2100, the difference between the high-emissions and low-emissions trajectories is much greater: 1.4°C versus 5.6°C of projected warming. Warming is expected to be most pronounced in the summer.

Historical precipitation data show variability, but no distinct trend (World Bank and ADB 2021a). Projections of future precipitation are highly uncertain, but most models suggest that the amount of rainfall deposited during extreme precipitation events will increase, by 5–15 percent by the 2050s, but this phenomenon is highly dependent on local geography, so further research is needed. Overall, the IPCC *Fifth Assessment Report* found that Central Asia is expected to become warmer and increasingly arid in the coming decades (Hijioka et al. 2014).

The ISIMIP water availability and crop productivity model results used in this report broadly conform to these projections (see Appendix A.6 for further details including maps):

- Projections of water availability are particularly important in explaining future changes in climate migration for the Kyrgyz Republic (see Figure A.21 in Appendix A.6). Water availability projections to 2050 across two GCM-ISIMIP model combinations and the two emissions pathways generally show a gradient from wetter conditions in the southwest to drier conditions in the northeast. The Ferghana Valley presents wetter conditions in almost all models. Beyond this general trend, models diverge in the intensity of the changes, with RCP8.5 scenarios displaying significantly drier conditions than RCP2.6 scenarios in some areas.

- Drying is projected to intensify in the second half of the century (Figure A.22), particularly in the IPSL climate model. These models do not take into account potential changes in glacial runoff, which will affect the timing of water availability initially (with earlier melt periods), and eventually may result in a total reduction in river flow.

- The ISIMIP crop models mostly indicate increases in productivity, especially in the eastern part of the country, both in the near term, to 2050, and in the second half of the century (Figures A.23 and A.24). This is likely the result of rising temperatures in the higher elevations. Crop productivity in the breadbasket of the Ferghana Valley may remain constant or decline slightly under future climate impacts, which could offset the increases in water availability slightly in terms of climate migration. Irrigated agriculture is important in this region, which may provide a buffer to changes in water availability but may not mitigate the impacts of increased temperatures on crop growth.

Glacial runoff provides about half of the discharge of major rivers, such as the Tarim, and is an important source of freshwater for consumption and irrigation (Hagg et al. 2018). About 30 percent of all water resources in Central Asia are in the Kyrgyz Republic, but the country exploits less than 20 percent of these, mainly for irrigation in agriculture, industrial and residential consumption, and power generation (USAID 2018). The shrinkage of glaciers is expected to accelerate, and adequate water supply is projected to become one of the major challenges, with Central Asian glaciers seeing a potential reduction of 55–75 percent by 2100 (Radchenko et al. 2017). In the short to medium term, glacial melt is expected to increase runoff from the Tien Shan mountain range (World Bank and ADB 2021a), potentially peaking around 2040, but as the glaciers deplete, runoff is likely to decrease significantly, and severe water shortages could occur before the end of the century. Coupled with impacts related to increasing variability in precipitation, the timing of the "tipping point" (peak water) in glacial runoff is critical and remains highly uncertain. The intensification of runoff variability through rapid glacier and shifting precipitation patterns could increase the risk of floods, mudslides, and droughts (World Bank 2014b).

3.3.3 Projected Climate Migration Trends

Analysis for this report shows climate migration increasing to 2050 across all three scenarios (Figure 3.25 and Table 3.8). Projected magnitudes and confidence intervals are larger (reflecting a broader range of uncertainty) in the pessimistic reference scenario and smaller in the more-climate friendly scenario, with the more inclusive development scenario falling in-between, as follows:

- Pessimistic reference scenario: 0.22 million climate migrants (with a range of 0.06 to 0.39 million)
- More inclusive development scenario: 0.18 million climate migrants (with a range of 0.06 to 0.30 million)
- More climate-friendly scenario: 0.14 million climate migrants (with a range of 0.09 to 0.19 million)

The highest estimate of climate migrants, 0.39 million in the pessimistic reference scenario (95th percentile of the distribution of model runs), would represent 6.8 percent of the total projected population in 2050. The lowest estimate, 90,000 in the more climate-friendly scenario, would be about 1.6 percent of the total projected population in 2050.[122]

The pace of increase in climate migration also varies among scenarios. The pessimistic reference scenario shows a roughly linear increase, while the more inclusive development scenario shows a small acceleration after 2040, and the more climate-friendly scenario, slower growth also after 2040. Thus, while the scale of climate migration may be similar across scenarios initially, much greater climate change impacts in the scenarios with high emissions would result in accelerated climate migration beyond 2050, compared with the low-emissions scenario. These results align with the ISIMIP model results for the second half of the century, which project drier conditions overall, but more severe declines in water availability in the high-emissions scenarios.

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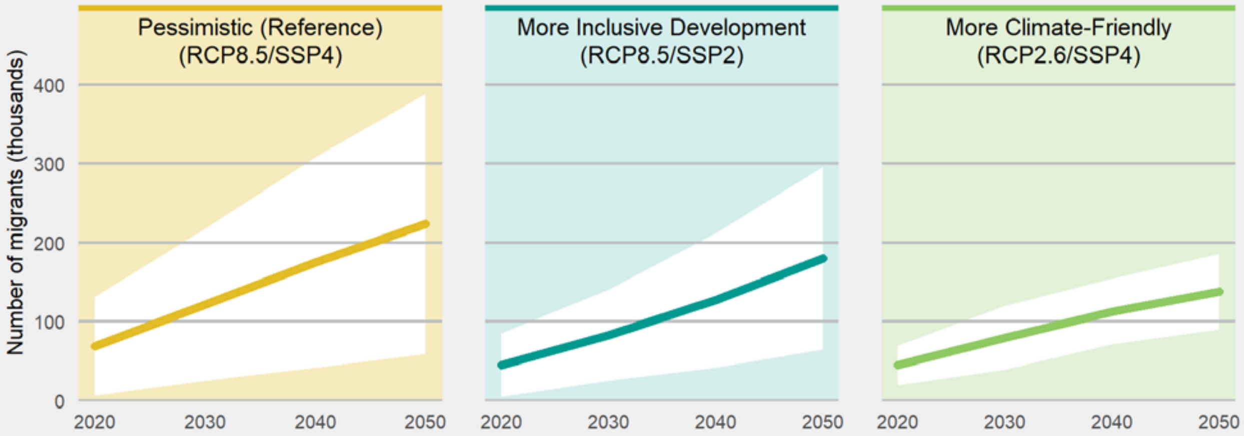
[122] The spread across model runs is also significantly narrower in the more climate-friendly scenario, a function of the greater certainty in the projections due to more consistent climate impacts across the RCP2.6 model runs.

Figure 3.25: Projected number of internal climate migrants in the Kyrgyz Republic in three scenarios, 2020–2050



Climate migrants as a percentage of the total population

Year	2020	2030	2040	2050	2020	2030	2040	2050	2020	2030	2040	2050
%	1.2	2.1	3.0	3.9	0.8	1.4	2.0	2.8	0.8	1.4	1.9	2.4

Note: Dark lines represent the average runs for each scenario. The white areas around the central trend line represent the confidence intervals, which reflect the degree of agreement among the four model runs used to provide each estimate for each scenario. Narrower confidence intervals indicate greater agreement among the model runs for each scenario. The confidence intervals get larger with each successive time interval owing to momentum that builds over time for each model run and to increasing divergence among models as the climate change signal increases.

Table 3.8: Projected number and share of internal climate migrants in the Kyrgyz Republic in three scenarios, 2050

	Scenario					
Result	Pessimistic/ Reference		More inclusive development		More climate-friendly	
Number of internal climate migrants by 2050 (thousand)	**223.5**		**180.2**		**137.8**	
5th (left) and 95th (right) percentile (thousand)	58.8	388.1	64.3	296.1	90.0	185.6
Internal climate migrants as percent of population	**3.9%**		**2.8%**		**2.4%**	
5th (left) and 95th (right) percentile	1.0%	6.8%	1.0%	4.6%	1.6%	3.2%

The projected share of internal migrants who could be climate migrants by 2050 varies across scenarios (Figure 3.26). The share is greatest in the more inclusive development scenario (rising to 42 percent), which shows lower internal migration levels overall.[123] In the pessimistic reference and more climate-friendly scenarios, which show overall internal migration rising more sharply under the SSP4 pathway, climate migrants make up 26 percent and 19 percent of the total by 2050, respectively.

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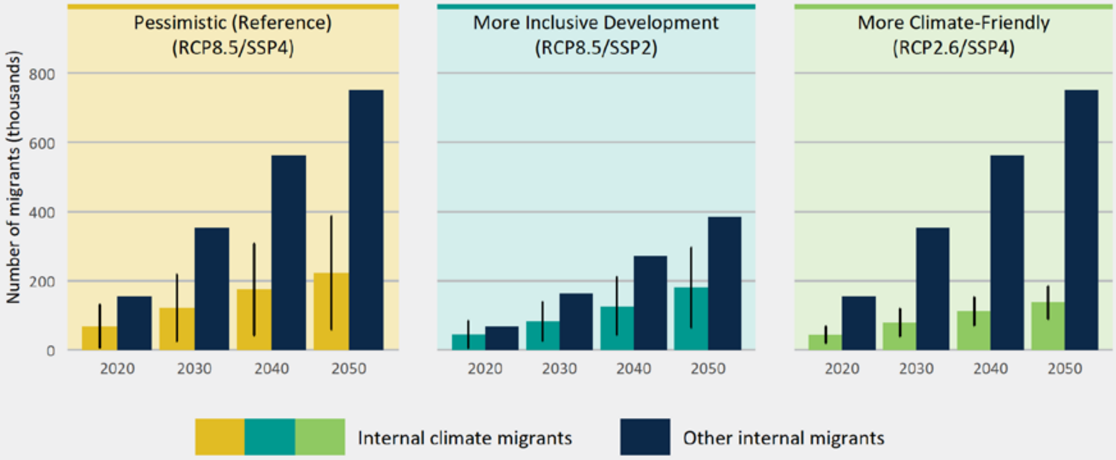
[123] An important reason for this is that under SSP2, which represents a more equitable development pathway, urbanization slows and education disparities between rural and urban areas narrow, resulting in less other internal migration overall.

Figure 3.26: Projected number of climate and other internal migrants in the Kyrgyz Republic in three scenarios, 2020–2050



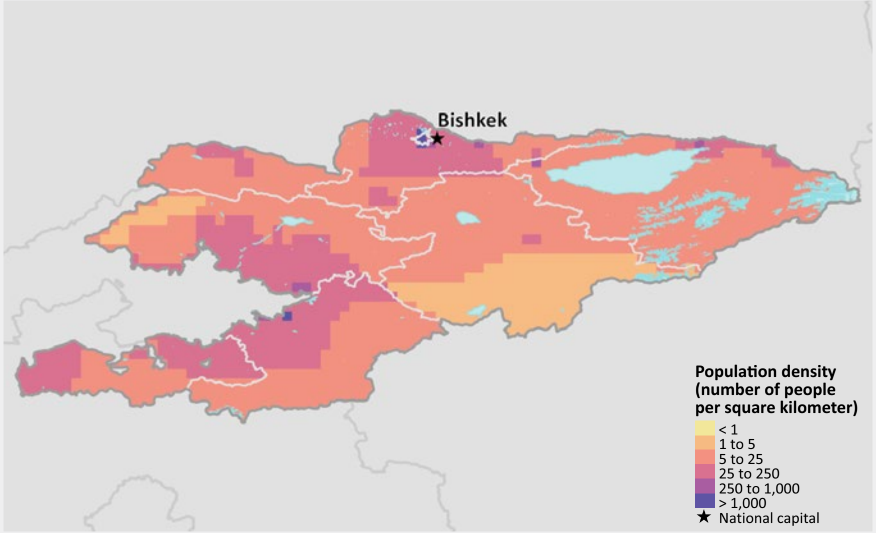
Note: The whiskers on the climate migrant bars represent the 95th percentile confidence interval for the four model runs for each scenario. There are no confidence intervals for other migrants because only a single development trajectory is use.

Projected spatial patterns of climate migration

The population distribution in the Kyrgyz Republic follows topography, with most people concentrated in lower-elevation areas (Figure 3.27a). The area surrounding Bishkek in the north and the Ferghana Valley (including the cities of Osh and Jalal-Abad) in the west, which have the largest urban centers, display the highest densities in 2010. A third area of relatively higher density is found in the northeast, by Lake Issyk-Kul, including the fourth-largest city, Karakol. In the pessimistic reference scenario, in 2050, the areas of highest density remain mostly the same, but areas in the south and center begin to see reduced population densities—although these localities have low baseline densities to start with (Figure 3.27b).

Figure 3.27: Baseline population density, 2010, and projected population density in the pessimistic reference scenario, 2050, Kyrgyz Republic

a. 2010



b. 2050

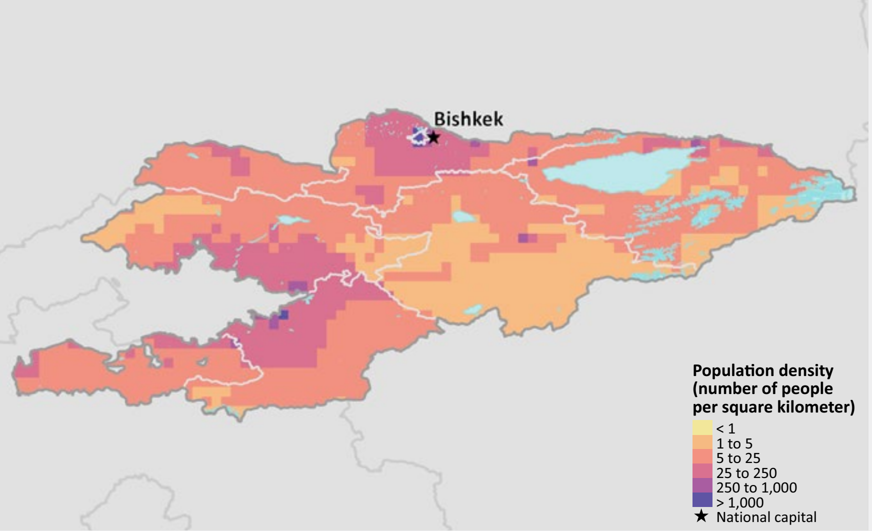
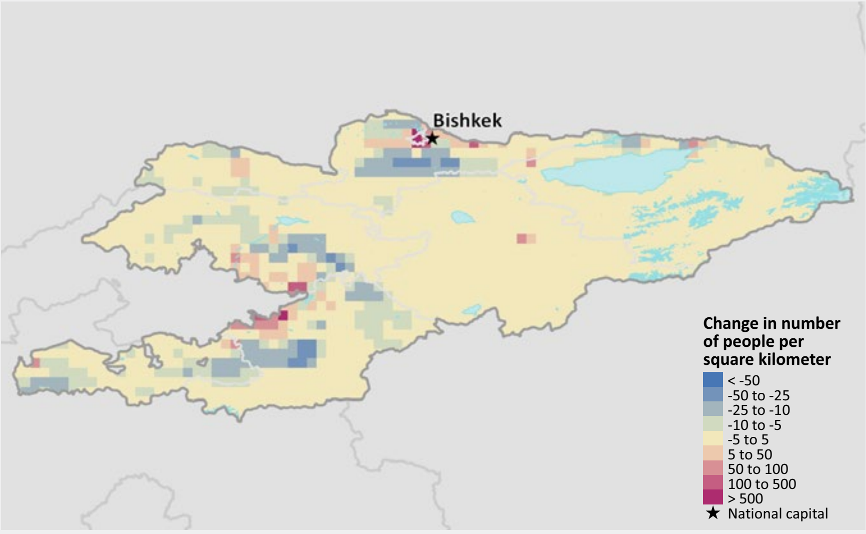


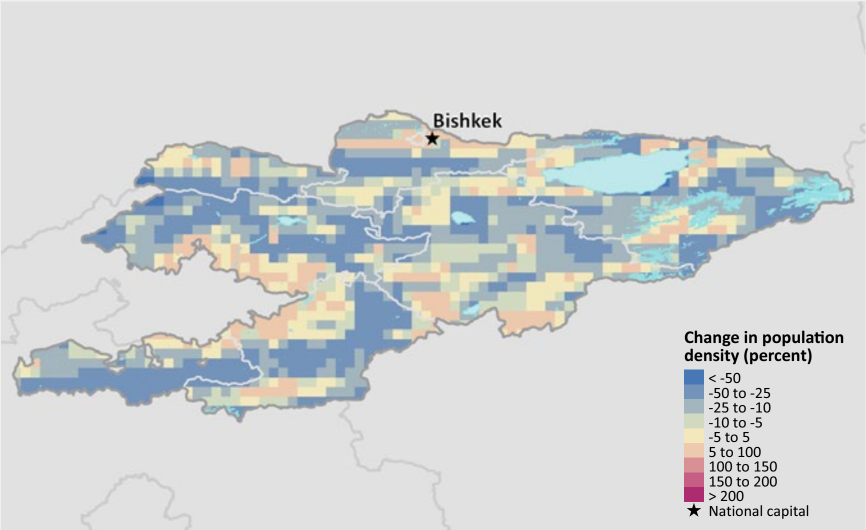
Figure 3.28 shows the projected changes in population density to 2050, in absolute and percentage change terms, in the pessimistic reference scenario. The largest projected increases are near Bishkek and in Jalal-Abad and Osh in the Ferghana Valley. In the rest of the country, the projections show small declines in population density, or else no change at all. As these are mostly mountainous zones with low baseline population levels, even small absolute numbers can translate into larger percentage changes (from 10 to 50 percent).

Figure 3.28: Absolute and percentage change in population density in the Kyrgyz Republic in the pessimistic reference scenario, 2010–2050

a. Change in population density



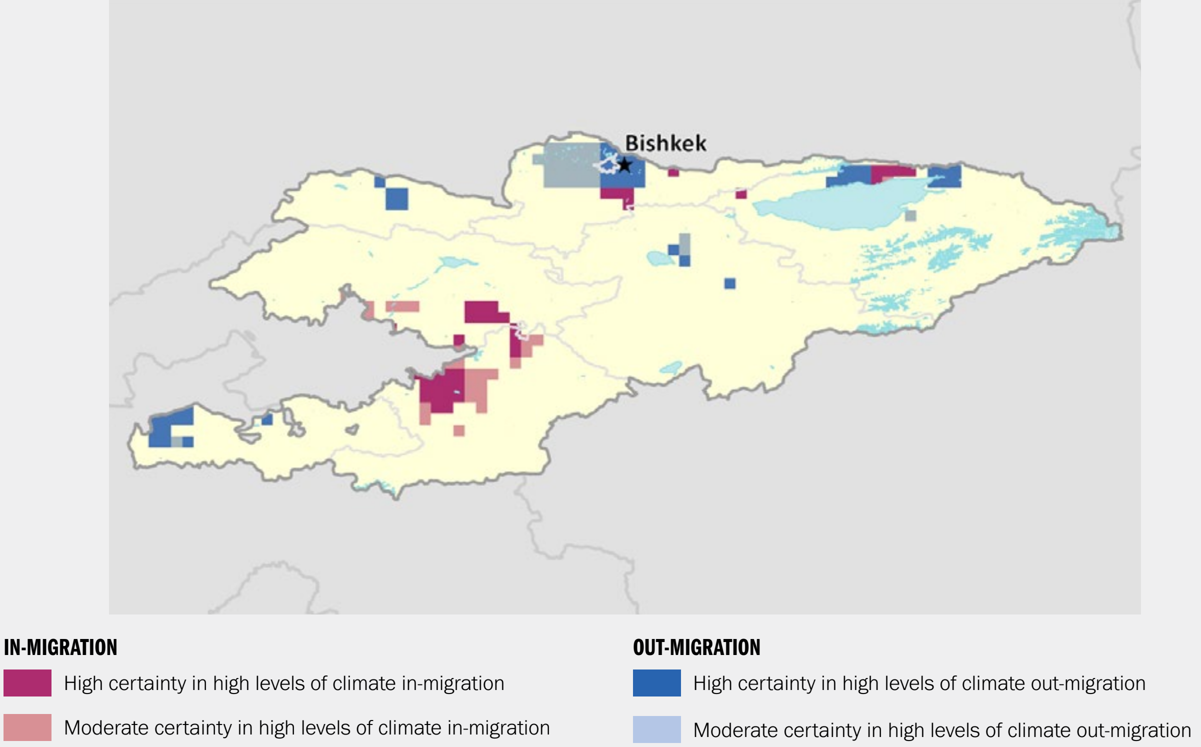
b. Percentage change in density



The largest projected climate in-migration hotspot by 2050 is close to the Ferghana Valley in the west of the country, amplifying already expected population growth there (Figure 3.29). Beside the cities of Osh and Jalal-Abad, this area is mostly irrigated croplands and pastoral and rangelands. Smaller in-migration hotspots are also expected in the northeast of the country, north of Lake Issyk-Kul—corresponding to a mix of irrigated and rainfed croplands—and in the area south of Bishkek, which is mostly pastoral and rangelands. Movement to these areas is driven mainly by projected increases in water availability and crop productivity. Crop productivity is likely to increase in high mountain regions as temperatures rise. However, these positive effects could be offset by adverse impacts on ecosystem services and an increased incidence of extreme weather events in the fragile mountain terrains.

Climate out-migration hotspots are projected around Bishkek, slightly dampening projected population growth trends in this area, along the northern border on Lake Issyk-Kul and including Karakol (due to dramatic declines in water availability projected by the LPJmL-water model), and in areas of the southwest and central region near Lake Son-Kul. The climate out-migration hotspots around Bishkek and Lake Issyk-Kul correspond mainly to irrigated croplands, while those in the central and southwest regions correspond to pastoral and rangelands. All climate out-migration hotspots display negative trends in water availability, which is the strongest predictor (Appendix A.6, Table A.6), but mixed results for crop productivity. The area north of Lake Issyk-Kul is one of the few regions projected to see declines in crop productivity.

Figure 3.29: Hotspots projected to have high levels of climate in-migration and climate out-migration in the Kyrgyz Republic, 2050



Note: High certainty reflects agreement across all three scenarios modeled, and moderate certainty reflects agreement across two scenarios. In- and out-migration hotspots are thus areas in which at least two scenarios concur on density changes in the top 10th percentile of the density distribution, which in the Kyrgyz Republic represents an increased population density in 2050 of about 2.0 to 4.41 people per km^2, depending on the scenario. For decreased population density, it is about minus –1.77 to minus –2.93 people per km^2.

Trends in livelihood zones

Figure 3.30 presents the distribution of livelihood zones in the baseline year of 2015, following the anthropogenic biome classes defined by Ellis et al. (2010).[124] By far, the dominant livelihood zone in the Kyrgyz Republic is pastoral and rangelands, while most of the dense settlements, including the cities of Bishkek, Osh, and Jalal-Abad, are surrounded by or close to irrigated croplands. Figure 3.31 shows the projected net change in the number of climate migrants by 2050 for each livelihood zone, as defined above. It is important to recognize that this represents migration into or out of the zones and does imply changes in the livelihoods of those who

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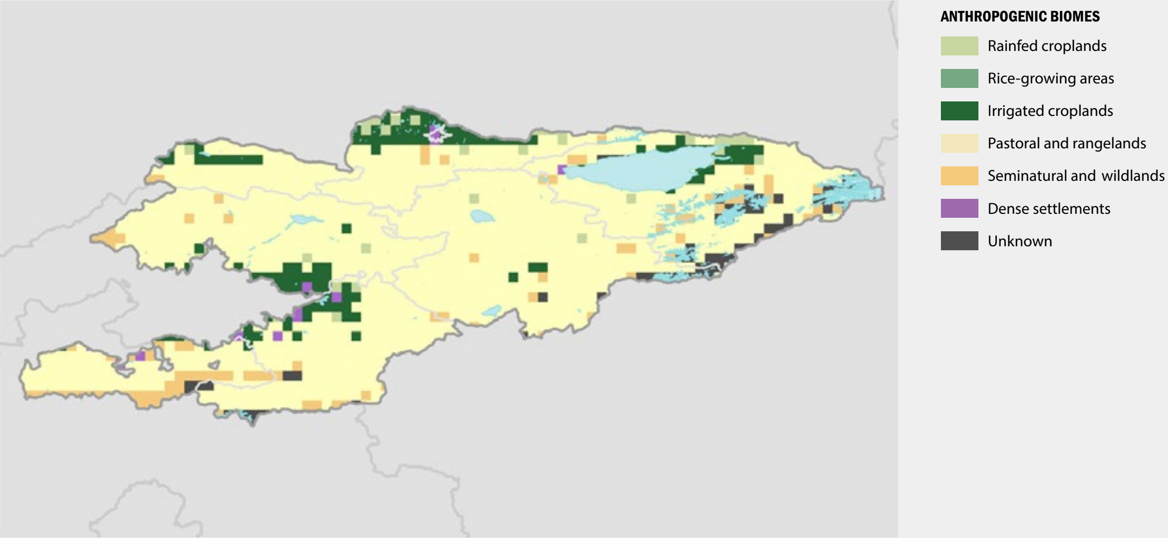
[124] The livelihoods zones used in the Groundswell reports represent an aggregation of anthropogenic biome classes in Ellis et al. (2010) into areas with relatively coherent livelihood characteristics. Note that although it is known that zones will shift with climate change, no projections of those shifts are available, so for the modeling presented in this report, the distribution of zones is assumed to remain static through 2050.

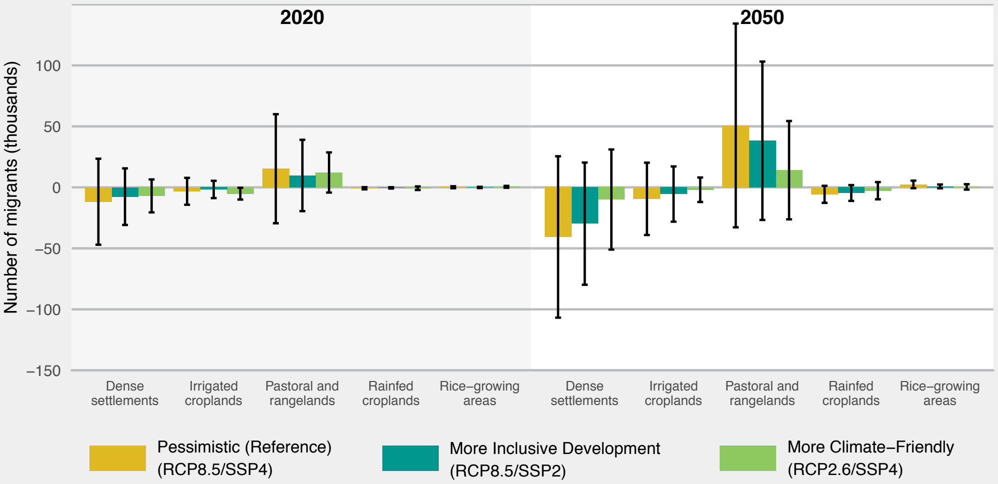
migrate. Projections for 2050 show small negative net climate migration out of dense settlements and irrigated croplands, especially in the pessimistic reference and more inclusive development scenarios. The results also indicate small positive net migration into pastoral and rangelands, because climate in-migration tends to spill over from dense settlements into that livelihood zone. That said, there are large confidence intervals in the projections for all categories, ranging from positive to negative, meaning that there is uncertainty in the projections by livelihood zone because of differing climate impact signals underlying each of the scenarios.

Figure 3.30: Livelihood zones in the Kyrgyz Republic, by anthropogenic biome, 2015



Source: Ellis et al. (2010).

Figure 3.31: Projected net migration in and out of livelihood zones in the Kyrgyz Republic in three scenarios, 2020–2050



Note: Whiskers show 95th percentile confidence intervals for climate migrants.

3.3.4 Consultations on Modeling Results

Two virtual workshops were conducted with stakeholders in the Kyrgyz Republic in March 2021 to discuss the modeling results and gather input on the case study. Participants included representatives from academia, civil society organizations, and government ministries, departments, and agencies. They were asked to reflect on historical and current migration patterns in the country, including in the context of climate change, on the plausible future climate migration scenarios and hotspots presented in the report, on potential responses. They agreed that the issues raised by the modeling were relevant and provided valuable information and nuance.

Participants noted that in the Kyrgyz Republic, migration patterns are dominated by the rural-urban transition, movement of people from the southern to northern regions, and out-migration to Russia and Kazakhstan. Young people in particular tend to migrate, motivated by a desire to shift out of agricultural livelihoods, which also drives the rural-urban transition. Socio-cultural elements such as communal and institutional ties also affect the decision to migrate.

Participants also described interconnected drivers of mobility across regions. For instance, factors for internal migration along the principal corridor from southern regions to Chuy/Bishkek include social and economic circumstances (e.g. unemployment), declining access to water resources, and dependency on vulnerable agricultural livelihoods. As another example, migration both into and out of the northeastern part of Issyk-Kul is being facilitated by developing road transport connections to Kazakhstan. With regard to projected climate in-migration hotspots around the densely populated areas of Osh and Jalal-Abad, participants said there is a need for further analysis on the implications of additional migration into these areas.

Participants also expressed the need to further unpack climate and/or environmental drivers as they relate to mobility dynamics. For example, studies of internal migration conducted by the International Organization on Migration (IOM) with the National Statistics Office in the Kyrgyz Republic have found climate and environmental issues are push factors. Yet, in national surveys on internal migration, the number of people listing climate and environment as reasons for migration is relatively low, compared with factors such as jobs, family and education. According to participants, with the country moving toward the Tunduk system—which has digitized and interconnected information across government agencies—more comprehensive data collection on mobility dynamics is expected in the future.

3.3.5 What Do These Results Mean for the Kyrgyz Republic’s Development Future?

1. **Climate change could increase rural-urban migration. Projected declines in water availability could dampen population growth in some cities, while better water availability and crop productivity in surrounding areas could amplify growth in others. It is important that urban planning be climate-informed and ensure inclusive access to adequate housing, job opportunities, infrastructure, connectivity, and services.**

Bishkek is the Kyrgyz Republic’s economic and cultural hub and a major destination for migrants from the south (Thieme 2014). In the early 2000s, migration accounted for a third of the city’s population growth. Settlements have emerged in the urban periphery (Fryer, Nasritdinov, and Satybaldieva 2014), mainly inhabited by internal migrants, who often lack adequate housing (Isabaeva 2013). Urban planning will need to accommodate a growing population, while taking into account projected declines in water availability and implications for urban services.

In addition, a majority of migrants—especially those in informal settlements, but also many renters—are not formally registered in the capital, which also limits their access to basic services (UNICEF 2020). Digitalization and the cross-agency linkages enabled by the Tunduk system may help address this challenge (Government of the Kyrgyz Republic 2020). Migrants also make up the majority of informal workers: they are the major traders in Bishkek’s bazaars and the majority of workers in the construction, service, and textile industries (Fryer, Nasritdinov, and Satybaldieva 2014). Legalizing migrants’ economic activities could help integrate them into city life (Thieme 2014; Jeenbaeva 2008).

In the Ferghana Valley, meanwhile, including the cities of Osh and Jalal-Abad, favorable climate conditions and attractive livelihood opportunities are expected to create a climate in-migration hotspot. This area is already densely populated, expecting to see continued population growth, and livelihood conflicts have already occurred there. Clashes between Kyrgyz and Uzbek ethnic groups in June 2010 in Osh and Jalal-Abad and nearby areas resulted in around 400,000 internally displaced people. They still face significant challenges today, particularly with respect to documentation, livelihoods, and access to housing and education (Agadjanian and Gorina 2019; BMP 2011). Planning for increasing connectivity and the promotion of regional integration in this area and other geographic areas, including the Issyk-Kul oblast, will need to consider potential climate-induced shifts in population patterns (World Bank 2018c).

While mobility dynamics in the Kyrgyz Republic respond mainly to economic factors, environmental factors, including climate change, can shape and compound migration decisions from rural areas (Sagynbekova 2017). Both slow and rapid-onset natural events can be detrimental to people's safety and to the sustainability of rural livelihoods and affect migration decisions, directly or indirectly (Chandonnet et al. 2016). For instance, environmental hazards can motivate rural households to use remittances to relocate to more environmentally stable areas. This redistribution is more common in remote, higher-altitude areas, such as the Naryn region, upriver from the Ferghana Valley (Sagynbekova 2017; Chandonnet et al. 2016).

Policy makers looking at climate in-migration trends will need to consider existing risks related to settlement in areas that are highly exposed to natural hazards. In the Jalal-Abad region, with some districts in Ferghana Valley, between 1994 to 2015, households were resettled due to natural hazards, including landslide risks, mudflows, river bank erosion, and increases in the level of groundwater (Chandonnet et al. 2016). State-assisted relocation from landslide-prone areas has been met with resistance by local populations due to the perception that the resettlement areas are less favorable in terms of livelihood opportunities (see, for example, Nasritdinov et al. 2010, for a case study of the Sary-Tash village in the southern Kyrgyz Republic), and the fear of losing social ties (Chandonnet et al. 2016). Continued efforts will also need to be made to reduce disaster risks, increase preparedness, and promote risk-informed policy making (World Bank 2018c).

2. **Climate change-induced changes in water availability could alter the relative attractiveness of livelihoods in key regions. Trade-offs in water resource management between major end uses—namely hydropower, agriculture, and urban centers—will need to be considered in conjunction with projected shifts in population distribution and economic activity in sending and receiving areas.**

The ISIMIP water models used in this report show a gradient from wetter conditions in the southwest to drier conditions in the northeast to 2050, though higher-emissions scenarios suggest significantly drier conditions than those in lower-emissions scenarios. As noted, these models do not take into account potential changes in glacial runoff, which could affect the timing and amount of water availability during critical periods, as well as reduce river flow volumes in the long run. According to the country's Third National Communication to the UNFCCC (Government of the Kyrgyz Republic 2016), in the worst-case scenario (RCP8.5 and an annual precipitation reduction of 5 percent), glacial runoff could be reduced by about 40 percent. Unreliable water availability poses growing risks, especially given competing demands for hydropower and agriculture.

Hydropower is the backbone of the Kyrgyz Republic's power supply, and it is likely to be negatively affected by climate change-induced variations in runoff (OECD 2016). Overall energy demand is projected to rise as the economy grows. Warming temperatures, reduced snow accumulation, and accelerated melting of snow and glaciers will increase uncertainty in the timing and amount of water available for power generation (World Bank 2014b). As the efficiency of hydropower plants depends on inter- and intra-annually stable river runoff, about 2°C of warming by the 2050s would reduce the potential of installed hydropower plants for small catchments by 19 percent. Growth opportunities in this sector will need to consider climate risks and a develop strategic and holistic approach to natural resource management in order to effectively maintain competitive advantage and service delivery (World Bank 2018b).

Compounding impacts from higher summer temperatures and declining access to water for irrigation also present major long-term risks for agriculture (Broka et al. 2016). Critically, as ice and snow melt earlier during the year due to rising temperatures, the timing of river flow is projected to shift within the next few decades, with adverse consequences for agricultural water demand during critical crop growing periods in the spring and summer months. The agricultural sector has historically relied on glacier melt as a buffer against periods of low precipitation in the drier summer months (Xenarios et al. 2019). This decrease in water availability is likely to coincide with an increased demand for agricultural water due to higher temperatures and changing rainfall patterns, leading to shortages such as those already experienced in the Syr Darya and Amu Darya basins (USAID 2018). Prolonged periods of above average temperatures also exacerbate heat stress on agricultural crops, despite the availability of irrigation, with potential implications for crop yields (World Bank 2014b). Agriculture sector development toward modernization, export-led commercialization and the enhancement of rural livelihoods will need to be guided by the consideration of climate risks to ensure sustainability (World Bank 2018c).

3. **Projected climate in-migration and out-migration hotspot patterns suggest that key agricultural regions will experience differentiated climate change impacts on water availability and crop productivity. Tailored adaptation solutions for the agricultural sector will be needed to ensure the viability of rural livelihoods and should be considered in integrated spatial planning.**

Agriculture is embedded within the traditional way of life for many people in the Kyrgyz Republic (CIAT and World Bank 2018). The vast majority of farms (94 percent) can be categorized as small-scale, averaging 3 hectares. Small-scale farms have intercropped and mixed-crop livestock systems, with produce used for domestic consumption. Commercial investments in large parcels of land are used to cultivate wheat, barley, sugar beets, maize, and potatoes. Wheat (irrigated and rainfed) is the main agricultural product of the Kyrgyz Republic, representing on average 21 percent of total harvested area for the period 2012–2016, followed by irrigated and rainfed barley (11 percent), maize (7 percent), and fodder crops, which are also economically important. Crop and livestock production amount to almost equal shares of gross agricultural output. Most rural households keep livestock, both as a safety net and as a source of income.

Climate change could adversely impact growing conditions and agricultural productivity in the Kyrgyz Republic (Broka et al. 2016). While some crops, such as cotton, could initially benefit from increasing temperatures, overall, climate change is expected to reduce production of food and fiber crops as well as overall food availability per capita (USAID 2018). A study found that between 1991 and 2014, the growing season became drier and hotter, raising concerns for future agricultural production (Chi et al. 2020). A study covering the Talas, Chui, Naryn, and Issyk-Kul regions suggests that women in agriculture may be particularly affected by climate change impacts (Camp Alatoo and UNDP 2013). Climate change will affect livestock, but the use of improved pastures and adapted breeds can increase livestock productivity and enhance resistance to climatic shock and stress (World Bank 2019). In the Talas and Naryn regions, climate-smart agriculture practices include the promotion of rotational grazing systems, the development of infrastructure in pasturelands, selection of adapted breeds, and manure management techniques (CIAT and World Bank 2018).

As noted earlier, the agriculturally important Ferghana Valley is expected to be a climate in-migration hotspot, mainly due to projected increases in water availability. The Ferghana Valley presents wetter conditions in almost all ISIMIP water models used in this report, and stable or only slightly declining crop productivity conditions by 2050. The Ferghana Valley in the Tien Shan mountain range is a hub of agriculture, industry, and ethnic and cultural diversity that is shared between Uzbekistan, Tajikistan, and the Kyrgyz Republic. Nearly a quarter of the population of Central Asia resides in this zone, which accounts for 5 percent of the region’s total land area. The Naryn and Kara-Darya rivers run through the valley, supporting local agriculture, which is the main source of income in the region. Typical crops include cotton, tobacco, melon, and fruits. Agricultural productivity in the valley makes it an appealing site for settlement and immigration (Stratfor 2013). Because of a high population density, farm sizes are often smaller in this region than in other parts of the country. Given projected climate in-migration trends, the continued viability of agricultural livelihoods in this already densely populated area will need to be sustained through appropriate planning. In addition, irrigated agriculture is important in this region, which may provide a buffer to future changes in water availability but may not mitigate the impacts of increased temperatures on crop growth, requiring adaptive measures.

Projected out-migration hotspots also warrant attention. These are scattered along the northern regions and in areas of the southwest and central region. They display negative trends in water availability, which is the strongest predictor for climate migration, and mixed results for crop productivity. The northern region includes the Chui and Talas rivers and the Lake Issyk-Kul basin. The Talas region accounted for over 90 percent of the total production of beans in 2015, the main agricultural commodity in terms of exports. In the Chui Valley, sugar beet is also an important crop, and apples from the Issyk-Kul region are marketed almost year-round (CIAT and World Bank 2018). The central zone of the Kyrgyz Republic comprises mountains, high-altitude rivers and valleys, and pastures particularly well-suited for livestock production. Potatoes, wheat, and barley are also produced, although climatic conditions are relatively unfavorable for these crops. Given projected climate out-migration trends, it will be critical to ensure that populations can adapt in place through viable agricultural livelihoods—complemented with opportunities to diversify out of climate-sensitive activities.

More generally, the climate risks faced by farmers vary by location, with implications for planning. The main concern for agricultural production at lower elevations (below 1,500 meters) is heat stress, along with increased droughts in the summer season (World Bank 2018a). Middle and high elevations (above 1,500 meters), meanwhile, could potentially see improved climate conditions— but those areas could also face more extreme events such as river floods, flash floods, and mudslides due to projected increases in the intensity of spring precipitation. Longer-term agricultural productivity conditions could also be altered in certain areas due to the redistribution of various landscape-climatic zones. For instance, the coverage of arid desert areas could increase from 1.3 percent in 2000 to 3.1 percent by 2100 (under RCP 8.5), although individual provinces may experience significantly higher levels of desertification (World Bank 2018a).

The projected impacts of rising temperatures and changes in rainfall and water availability on crop productivity also vary by crop and by region. The productivity of wheat, maize, and sugar beets could decline, while the productivity of cotton, tobacco, rice, potatoes, and melons could rise (Broka et al. 2016). The Batken and Chui regions could face falling crop productivity, coinciding with identified climate out-migration hotspots, while Jalal-Abad and Osh could benefit from rising productivity, coinciding with climate in-migration hotspots, leading to potential changes in the crop composition.

Climate conditions may become more favorable overall for livestock production, as indicated by the small net positive climate migration into pastoral/rangeland areas to 2050. Forage production may rise, feed requirements may become lower, and extreme cold may become less of a problem under projected future changes in climate (World Bank 2011b). However, changing rainfall patterns and rising temperatures occurring in the southern, warmer, and drier areas of the Kyrgyz Republic could present problems for livestock, as heat waves, insufficient drinking water, and reduced forage become more commonplace.

Increased desertification could also become an issue for high mountain pasture areas in the Tien-Shan, Ak-Say, and Alay valleys due to the combined effects of higher temperature and lower rainfall. Some studies have also suggested that collective farming and sedentarization have endangered methods of preserving Kyrgyz pastures and ecosystems, such as traditional indigenous practices of animal husbandry and agriculture, where Kyrgyz nomads migrated towards favorable climates as part of an interconnected and complex ecosystem (Nasritdinov et al. 2010). The causes of the loss of pasture productivity in the Kyrgyz Republic include both environmental factors, such as changes in weather patterns, and anthropogenic factors, such as grazing practices (Sabyrbekov 2019).

4. **The Kyrgyz Republic is already taking steps to address the resilience of climate-sensitive sectors and economic diversification through the integration of climate priorities in national development strategies and processes. Action on these fronts will continue to be crucial as the country's development trajectory continues to shift towards an industrial base and higher-value agricultural production.**

Climate change impacts could induce heavy losses in key economic sectors without adaptation measures. The Kyrgyz Republic's Nationally Determined Contribution (NDC) estimates annual losses of US$1.24 billion due to climate change, including US$70 million in the agriculture sector and US$ 718 million from the water sector, without climate adaptation measures (Kyrgyz Republic 2020). The average annual cost of damage caused by various types of climatic hazards, including drought for major crops (for example, wheat, barley, vegetables, and sugar beet) is also significant (World Bank 2018b). Studies have also suggested that adaptation measures to mitigate severe environmental impacts need to engage both the resilience and adaptation of local actors and infrastructural issues at the national level (Blondin 2019).

The Kyrgyz Republic has outlined a number of climate priorities in key national strategies and frameworks with a view to building resilience of affected sectors and populations. The National Development Strategy of the Kyrgyz Republic for 2018–2040 identifies climate change adaptation, ecosystems restoration, better environmental data collection and data-informed policy making, and improved sustainability as priorities (National Council for Sustainable Development of the Kyrgyz Republic 2018). In addition, it calls for urban areas to be made more resilient, safe, sustainable, and comfortable for their residents, enabling reduced internal migration. The Development Program of the Kyrgyz Republic for the Period 2018–2022 also emphasizes good environmental data management, including on climate change, and calls for environmental impact assessments to be fully integrated across government policies, plans, programs and investments (Government of the Kyrgyz Republic 2018).

The country's NDC has a strong focus on minimizing risks related to climate change through the implementation of adaptation measures in vulnerable sectors (Kyrgyz Republic 2020). In agriculture, this relates broadly to the efficiency of land use, and specifically to agricultural infrastructure, pasture management, breeding programs to enable farmers to access and use drought-resistant crops, and creating a system for climate and crop yield forecasting. The government has also developed adaptation approaches for specific sectors, such as the Climate Change Adaptation Programme and Action Plan for the Forests and Biodiversity Sectors (2017) and the Programme for Agriculture and Water Management Adaptation to Climate Change (2016–2020). In addition, there are several guidelines in support of GHG emission reduction, commitments to renewable energy, and energy and fuel efficiency (CIAT and World Bank 2018). Tourism and the development of the digital economy have been identified as areas of opportunity (World Bank 2018c). There is scope for bridging policy gaps at the nexus of climate change and migration through further integration in key national strategies and programs (Chandonnet et al. 2016).

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Chapter 4

Environmental and Climate-Related Mobility in Mashreq Countries

This chapter discusses environmental and climate-related mobility drivers, trends, and patterns in six countries in the Mashreq subregion: Iraq, the Islamic Republic of Iran, Jordan, Lebanon, the Syrian Arab Republic, and the Republic of Yemen.[125] Instability and associated displacement have reconfigured the population distribution of the subregion in recent decades. Such movements are not captured by the census data that underpin the 2010 baseline for the modeling used in this report.[126] Instead of presenting future projections, the analysis in this chapter thus draws on a review of the literature on environmental migration in the subregion, as well as multiple data sources.

An overview of the development, economic, demographic, and geographical context for the subregion is provided to set the stage for understanding how climate change could affect key sectors and livelihoods. Water availability and crop productivity projections to 2050 and 2100, using Inter-Sectoral Impact Model Inter-comparison Project (ISIMIP) results, are also presented and discussed. Next, the chapter examines mobility in the context of climate change in the subregion, drawing on peer-reviewed literature. The final section looks at climate change as a potential threat multiplier in the context of fragility and conflict, how it could deepen vulnerabilities in the near and long term, and the implications for migration.

Key Messages

- **The Mashreq countries are already vulnerable to climate change. Water scarcity is expected to worsen amid rising temperatures and declining precipitation, putting further pressure on surface and groundwater resources. Less water would be available for urban areas, agriculture, and livestock production. This, in turn, would affect key economic sectors, rural livelihoods, and food security. At the same time, low-lying coastal areas face sea-level rise augmented by storm surge, which could lead to flooding, damage to infrastructure, and saltwater intrusion in freshwater aquifers.**

- **Projected increases in temperature and humidity could exacerbate heat stress, with more days on which temperatures exceed thresholds of human tolerance. This trend could seriously affect the habitability of densely populated and growing urban and coastal areas across the subregion, particularly for vulnerable populations that may lack access to services and cooling.**

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[125] The countries of focus in this chapter are part of the World Bank's Middle East and North Africa region, but were not modeled for the regional projections of internal climate migration presented in Chapter 2. The Gulf Cooperation Council countries were also not modeled. Though they are not examined in depth here, they are discussed in the context of intraregional mobility dynamics, as they are important destination countries.

[126] While population data might have been sufficient for the first half of the calibration period (1990–2000), the internal and external displacement of large portions of the population in Iraq, and then in Syria, would make future projections based on these data unreliable. A full description of the methods is provided in Appendices B and C.

- **Climate change could add to the factors that already drive mobility in the subregion. Environmental thresholds for water scarcity, land degradation, and heat stress could act as additional push factors for migration. Climate change and natural resource degradation may also act as threat multipliers, particularly in situations of fragility and conflict. Efforts to deepen understanding of those interactions and compounding risks need to be paired with an urgent shift towards long-term pathways for building resilience to future shocks.**

4.1 SUBREGIONAL CONTEXT

4.1.1 Development and Economic Context

The six Mashreq countries covered in this chapter are diverse in terms of development patterns, economies, natural resources, livelihoods, and demographics. Syria and Yemen are classified as low-income countries, while Iran is classified as lower-middle income, and Iraq, Jordan, and Lebanon are classified as upper-middle income.[127] Iraq and Iran are oil exporters, with oil rents accounting for one-third to half of Iraq's GDP over the past decade, and a quarter to one-fifth of Iran's GDP.[128] Figure 4.1 provides a geographical overview.

Annual GDP growth has fluctuated in recent years. In 2019, Jordan, Yemen, and Iraq saw gains—of 2.0, 2.1, and 4.4 percent, respectively—while Lebanon's and Iran's economies contracted, by 6.7 and 6.8 percent, respectively.[129] The COVID-19 pandemic, combined with other shocks in the subregion, has had significant economic impacts. The IMF estimates that in 2020, Iran's and Jordan's GDPs shrank by 5.0 percent; and Iraq's by 12.1 percent (IMF 2021); modest growth, of 2.4–3.4 percent, is projected for 2021 across the subregion.[130]

Each country has followed its own development trajectory, but all have experienced significant shocks. Yemen, historically the poorest country in the subregion, has been devastated by conflict since 2015 and is suffering a dire humanitarian crisis.[131] Lebanon, the wealthiest country in the subregion for many years in terms of GDP per capita, is now in one of the worst economic crises seen globally since the mid-19th century (World Bank 2021). The economy began to contract in 2011, with the onset of the war in Syria, and has since experienced trade disruptions, stagnating capital inflows, the COVID-19 pandemic, and the explosion in the Port of Beirut in August 2020 (Harake, Jamali, and Abou Hamde 2020; World Bank 2020c; Arezki et al. 2020). GDP shrank from almost US$55 billion in 2018 to an estimated US$33 billion in 2020, by about 40 percent (World Bank 2021), and GDP per capita dropped from a peak of US$19,499 in 2010, to US$11,649 in 2020.[132]

Iran has historically had the highest GDP among the six countries, due to a relatively diversified economy driven by energy, agriculture, and services, as well as state presence in manufacturing and financial services.[133] Over the past decade, however, the economy has stagnated as a result of sanctions and budgetary dependence on the volatile oil sector. Jordan's economy grew rapidly from 1999 to 2009, but growth slowed after the global financial crisis of 2008, compounded by other shocks, including the Arab Spring, the Syrian conflict, and the emergence of the Islamic State in Iraq (Hausmann et al. 2019; World Bank 2020c). The economic slowdown has deepened fiscal imbalances, increased unemployment, and weakened public sector provision systems (World Bank 2020c).

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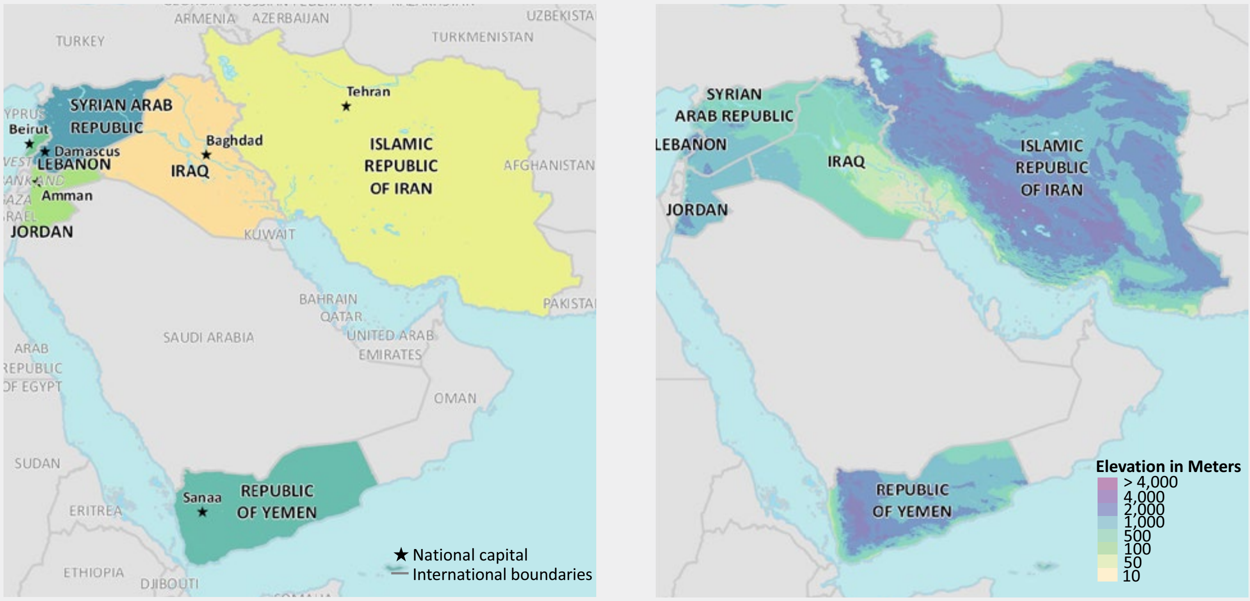
127. See World Bank income classifications (this report reflects updates as of fiscal 2021): https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups.
128. See World Bank data on oil rents as a share of GDP: https://data.worldbank.org/indicator/NY.GDP.PETR.RT.ZS?locations=ZQ-IQ-IR.
129. See World Bank data for annual GDP growth in the subregion: https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?locations=IR-IQ-JO-LB-SY-YE. The most recent data available for Syria are from 2007.
130. The IMF estimates for 2020 GDP contraction do not include Syria or Yemen, nor is there a projection for Lebanon's growth in 2021 (IMF 2021).
131. See the World Bank's country overview for Yemen: https://www.worldbank.org/en/country/yemen/overview.
132. See World Bank data on GDP per capita, in purchasing power parity (PPP) terms, constant 2017 international dollars for Lebanon, Iran, Iraq and Syria (no data are available for Yemen): https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.KD?locations=IR-IQ-JO-LB-SY-YE. For an overview of Lebanon's current situation, see also the World Bank's country overview for Lebanon: https://www.worldbank.org/en/country/lebanon/overview.
133. See World Bank data on GDP (current US$): https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=IR-IQ-JO-LB-SY-YE. For an overview on Iran, see: https://www.worldbank.org/en/country/iran/overview.

Figure 4.1: Mashreq countries included in this chapter (left) and elevation (right)



Overall, despite a significant poverty decline across the Middle East and North Africa region between 1981 and 2013, the extreme poverty rate has risen again in recent years, from 2.3 percent in 2013 to 7.2 percent in 2018, driven by the conflicts in Iraq, Syria, and Yemen[134] (World Bank 2020b; 2020c; Arezki et al. 2020). In Lebanon, the overall poverty rate reached 45 percent in 2019, and it has likely surpassed half the population in 2021 (World Bank 2021; Harake, Jamali, and Abou Hamde 2020).

Income levels vary significantly within countries, and income inequality remains high. The most recent Gini coefficient estimates range from 29.5 for Iraq (2012) to 42.0 for Iran (2018), with values in the 30s for the other four countries.[135] Of the 189 countries ranked on the 2020 Human Development Index, Iran was No. 70, Lebanon was No. 92, Jordan was No. 102, Syria was No. 151, and Yemen was No. 179 (UNDP 2020). On the Human Capital Index, values for the subregion range from 0.37 in Yemen to 0.59 in Iran.[136]

Conflicts in Iraq, Syria, and Yemen have led to the reversal of some development gains (World Bank 2017c; Abdellatif, Pagliani, and Hsu 2019; Arezki et al. 2020); exacerbated instability, with spillover effects across the region (Ianchovichina 2018; World Bank 2020c); and led to large-scale internal displacement and external migration.[137] The conflict in Syria alone is estimated to have reduced average annual GDP growth rates by 1.2 percentage points in Iraq, 1.6 percentage points in Jordan, and 1.7 percentage points in Lebanon in real terms (World Bank 2020c). Cumulatively, these reductions correspond to 11.3 percent of the three countries' combined 2010 GDP. Box 4.1 delves deeper into the economic impacts of recent conflicts in three Mashreq countries.

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134. The lack of data for economies in fragile and conflict-affected situations (FCS) appears to be leading to some underestimates in the measurement of poverty by existing methods, particularly in Sub-Saharan Africa and the Middle East and North Africa—regions where one in five persons lives in proximity to conflict (World Bank 2020b).
135. The Gini index measures the extent to which the distribution of income (or, in some cases, consumption expenditure) among individuals or households within an economy deviates from a perfectly equal distribution. A Gini index of 0 represents perfect equality, while an index of 100 implies perfect inequality. See World Bank Gini index data: https://data.worldbank.org/indicator/SI.POV.GINI?locations=IR-IQ-JO-LB-SY-YE.
136. The Human Capital Index calculates the contributions of health and education to worker productivity. The final index score ranges from 0 to 1 and measures the productivity as a future worker of child born today relative to the benchmark of full health and complete education. See World Bank data: https://data.worldbank.org/indicator/HD.HCI.OVRL?locations=IR-IQ-JO-LB-SY-YE.
137. By the end of 2015, 2.5 million Yemenites, 4.4 million Iraqis, and 6.6 million Syrians accounted for more than half of the annual conflict-related displacements in the world (Lutz et al., 2018).

Box 4.1: Economic impacts of major conflicts since 2010 in Iraq, Syria, and Yemen

Iraq's economic growth, social development, and institutions have been devastated by decades of conflict. Between 2011 and 2014, surging oil prices and a production increase jump-started an economic recovery, boosted fiscal revenues and expenditures, and energized growth in non-oil sectors. In the following four years, however, though oil production grew by another 40 percent even amid a growing Islamic State insurgency, oil revenues fell due to declining oil prices, only returning to 2014 levels by 2018 (World Bank 2020c). Iraq's current situation is fragile, as oil price instability and the COVID-19 pandemic are placing unprecedented strains on its economy, health care and social safety systems, and constraining service delivery (Arezki et al. 2020).[a]

Syria averaged annual GDP growth of 4.3 percent from 2000 to 2010 in real terms, almost entirely driven by growth in non-oil sectors (World Bank 2017c), before the escalation of conflict. By 2017, economic activity had shrunk by more than 60 percent relative to 2010 levels. A decade later, social and economic impacts continue to grow, as millions have been pushed into unemployment and poverty, institutions and infrastructure are further degraded, and external shocks such as the COVID-19 pandemic are taking a toll (Arezki et al. 2020; World Bank 2020c).[b] A large share of Syria's population has also been displaced; the country, which had 21.4 million residents in 2010, now has an estimated 17.5 million (UN DESA 2019), 6.7 million of whom are internally displaced, while another 6.6 million Syrians are refugees, mainly in neighboring countries.[c]

Yemen was already the poorest country in the subregion before conflict escalated in early 2015, stifling the economy, destroying critical infrastructure, and leaving 80 percent of the population vulnerable to hunger and disease in an unprecedented humanitarian crisis (Arezki et al. 2020).[d] Socio-economic conditions have deteriorated further in 2020, affected by low global oil prices, the COVID-19 pandemic outbreak, and extreme climate events and natural disasters. There are currently over 4 million internally displaced people in Yemen and around 137,000 refugees and asylum-seekers have fled the Horn of Africa.[e]

a For more context, see the World Bank's overview for Iraq: https://www.worldbank.org/en/country/iraq/overview.
b For more context, see the World Bank's overview for Syria: https://www.worldbank.org/en/country/syria/overview.
c See the UNHCR "Syria emergency" website (accessed July 3, 2021): https://www.unhcr.org/en-us/syria-emergency.html.
d For more context, see the World Bank's overview for Yemen: https://www.worldbank.org/en/country/yemen/overview.
e See the UNHCR "Yemen emergency" website (accessed July 8, 2021): https://www.unhcr.org/en-us/yemen-emergency.html.

Agriculture contributes a relatively low share of GDP in these six Mashreq countries due to the limited amount of arable land, coupled with water scarcity (Table 4.1). About a quarter of Syria's land area is arable, but only 11–13 percent in Lebanon and Iraq, 9 percent in Iran, and less than 3 percent in Jordan and Yemen. In Iraq, due to limitations related to soil salinity, drought, a shortage of irrigation water in summer, fallowing, and the unstable political situation, only an estimated 3 to 4 million hectares are cultivated per year, out of a total of 8 million hectares of cropland.[138] Syria, which had become a net producer of wheat and livestock, has suffered major setbacks due to the ongoing conflict Syria, which had become a net producer of wheat and livestock, has suffered major setbacks due to the ongoing conflict (World Bank 2017c). Pumping stations (both for surface and groundwater irrigation) have been heavily damaged, along with irrigation structures and equipment, and the availability of electricity, fuel, and farm labor has been affected. By 2017, Syria's wheat and livestock production had been halved, and overall agriculture GDP contracted by 41 percent between 2011 and 2015 alone. Despite the low contribution of agriculture to GDP in the Mashreq subregion, in some of the countries, significant shares of the population depend on it for their livelihoods, particularly in Yemen, where 29 percent of total employment is in agriculture.

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[138] See the Food and Agriculture Organization's overview of Iraq: http://www.fao.org/iraq/fao-in-iraq/iraq-at-a-glance/en/ (accessed May 3, 2021).

Table 4.1: Agriculture sector indicators for Mashreq countries

	Iraq	Iran	Jordan	Lebanon	Syria	Yemen
Arable land (% of land area) (2018)	11.5	9.0	2.3	12.9	25.4	2.1
Agriculture, forestry and fishing, value added (% GDP)	1.5	12.2	4.9	3.1	19.5 (2007)	5.7
Agriculture (% employment)	18.3	17.4	2.5	11.3	10.1	27.6
Rural population (% of total population)	29.3	24.6	8.8	11.2	45.2	62.7

Source: All 2019 data, except where indicated, from World Bank Open Data (http://databank.worldbank.org).

The Middle East and North Africa region is one of the most water-scarce in the world. By SDG Indicator 6.4.2, which measures water stress as the ratio of freshwater withdrawals to available resources, Yemen and Syria have critical water stress, with ratios of 170 and 126 percent, respectively. Jordan and Iran have high water stress, with ratios of 100 and 81 percent, respectively. Lebanon and Iraq have medium water stress, with ratios of 59 and 54 percent, respectively.[139] Figure 4.2 shows surface and groundwater stress levels as of 2010, and Figure 4.3 shows trends in renewable water resources per capita. Across the subregion, population growth and irrigation expansion have strained scarce resources, and water resources per capita have declined steadily (World Bank 2018). Jordan's renewable freshwater supply, for example, less than 100 cubic meters per capita, is well below the 500 cubic meters considered the threshold for absolute water scarcity (ESCWA 2019). Five of Syria's seven water basins face water shortage issues as well (Khaldoon A. Mourad and Berndtsson 2012). Several countries rely on unsustainable levels of groundwater withdrawals (Al-Azawi and Ward 2017). In addition, several factors are exacerbating water scarcity across the subregion, including the expansion of cities; underpricing of water; limited governance arrangements and enforcement; unmanaged trade-offs in the water-energy-food nexus—and as discussed further below, climate change (World Bank 2018).

Across the Mashreq countries, there are large gaps in income and disparities in access to public services, as well as transportation, internet connectivity, and other infrastructure (Abdellatif, Pagliani, and Hsu 2019). Poverty rates are higher in rural areas than in cities—for example, 31 versus 15 percent in Iraq, 40 versus 21 percent in Yemen, and 17 versus 14 percent in Jordan. Informal employment is also common, leaving many workers without the benefits and protections of formal employment.

Unemployment rates in much of the subregion remain pervasively high, particularly among youth and women (see Table 4.2 as well as Abdellatif, Pagliani, and Hsu 2019; Kabbani 2019). High unemployment and inactivity have led to losses in human capital, with highly skilled workers increasingly taking up potential opportunities abroad (see, e.g., Harake, Jamali, and Abou Hamde 2020). In Lebanon, for instance, limited employment opportunities are leading to out-migration and brain drain, a potential human capital loss for the country.

Progress in women's status, in terms of human, social and citizen rights, has also been slower in the subregion than in other parts of the world (Abdellatif, Pagliani, and Hsu 2019). Youth unemployment is about 80 percent higher among young women, who already have low labor force participation rates, despite increases in educational attainment (Kabbani 2019). This is the so-called "MENA paradox" described by Assaad et al. (2020). The COVID-19 pandemic is widening the employment gaps between men and women, as the latter are particularly likely to work in the service sector or the informal economy, which have shed the most jobs (Arezki et al. 2020).

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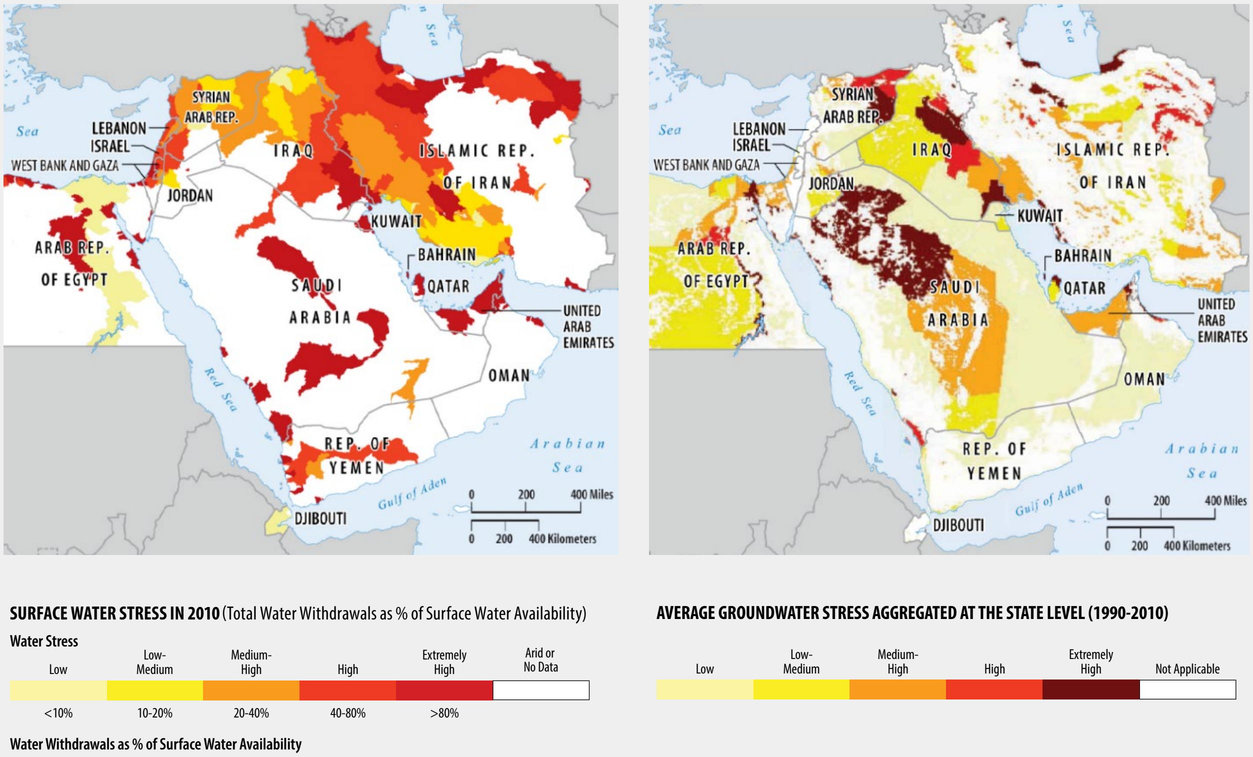
139. See UN Water data for Indicator 6.4.2: https://sdg6data.org/indicator/6.4.2 (accessed May 15, 2021).
140. See World Bank data on renewable internal freshwater resources per capita (cubic meters): https://data.worldbank.org/indicator/ER.H2O.INTR.PC?locations=IR-IQ-JO-LB-SY-YE.

Table 4.2: Employment indicators for Mashreq countries

	Iraq	Iran	Jordan	Lebanon	Syria	Yemen
Total unemployment (% of total labor force) (2020)	13.7	11.0	18.5	6.6	9.0	13.4
Unemployment, youth total (% of labor force ages 15–24) (2020)	25.2	25.5	37.3	17.1	20.8	24.2
Unemployment, female (% of female labor force)	30.6	18.1	23.8	9.8	20.4	25.3
Labor force participation rate, female (% of female population ages 15-64)	12.1	18.9	15.6	25.6	15.8	6.3

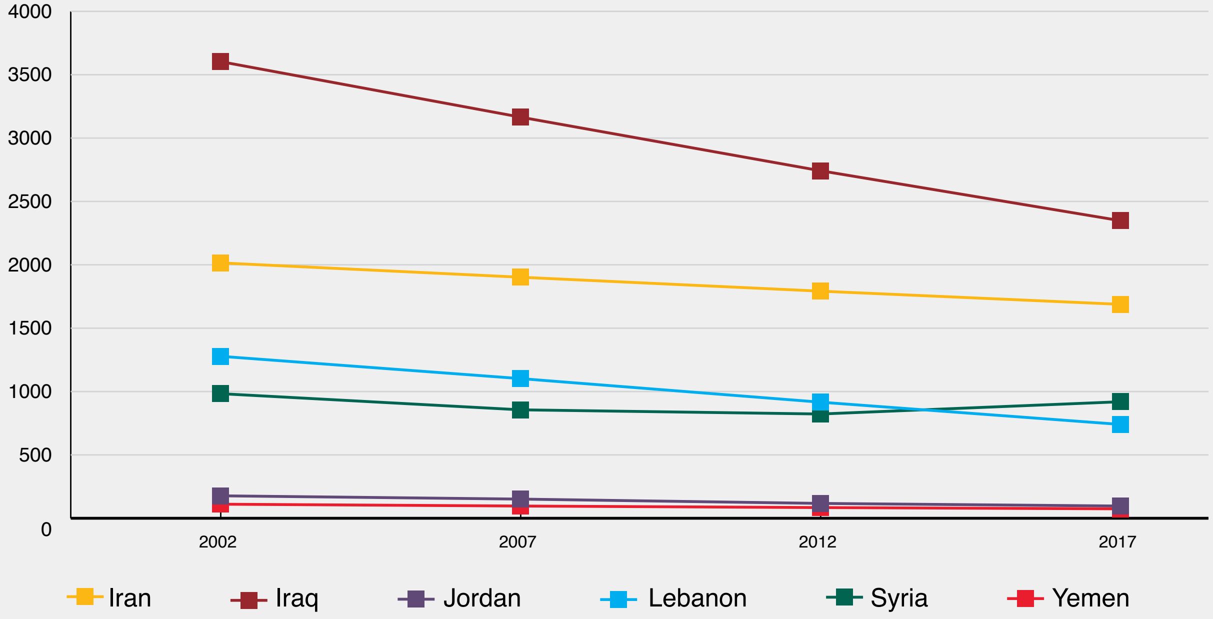
Source: All 2019 data, except where indicated, from World Bank Open Data (http://databank.worldbank.org); indicators are modeled ILO estimates.

Figure 4.2: Baseline surface water stress, 2010 (left) and average groundwater stress in 1990–2010 (right) in the Mashreq countries



Source: Reproduced from World Bank (2018).

Figure 4.3: Total renewable water resources per capita (m3/person/year) in Mashreq countries, 2002–2017



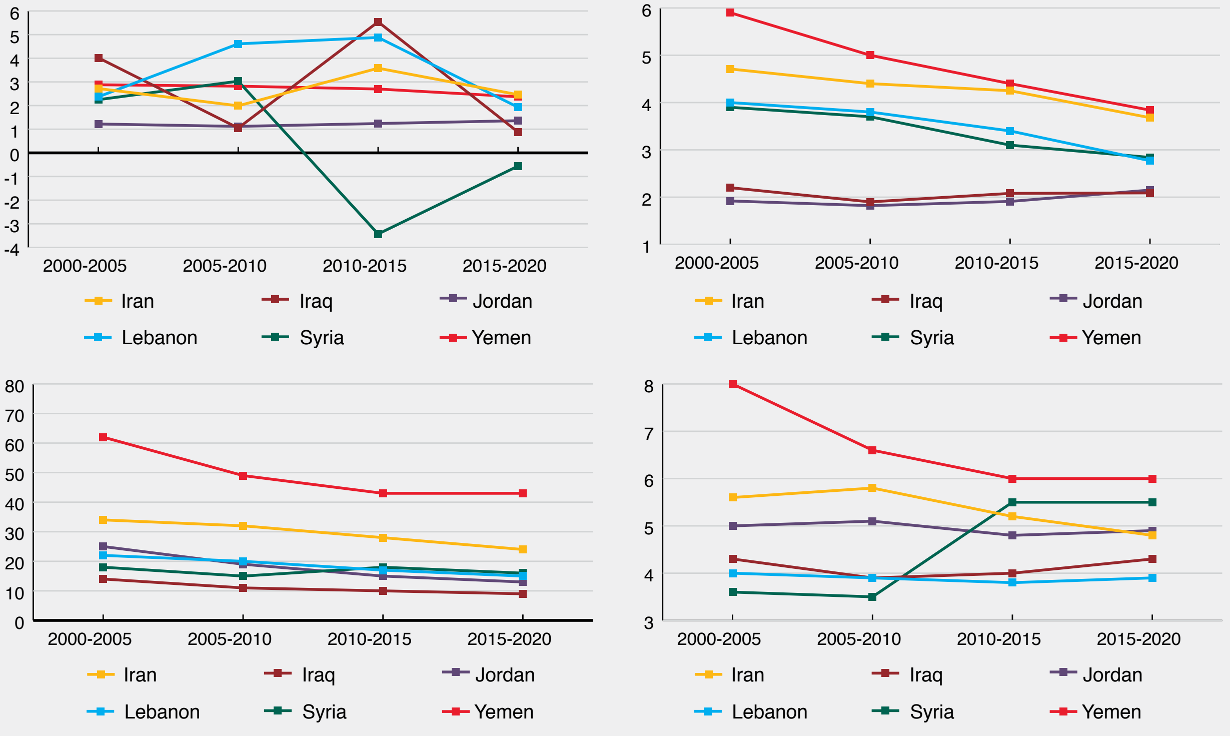
Source: Authors' analysis based on values from FAO AQUASTAT database.[16]

4.1.2 Population Dynamics

As of 2019, the combined population of the six Mashreq countries was 185 million, up from 155 million in 2010. Iran is the most populous country, with 82.9 million people, while Jordan has the smallest population, 10.1 million (UN DESA 2019). Population growth rates vary, reflecting different levels of fertility, infant mortality, and general mortality. Overall, those three variables are trending downward, but with noticeable fluctuations as a consequence of cross-border displacement, particularly in Syria between 2010 and 2015 (Figure 4.4). By 2050, the combined population of the six countries is projected to be 256.4 million under the moderate development pathway (SSP2) and 284.5 million under the unequal development pathway (SSP4), as shown in Figure 4.5.

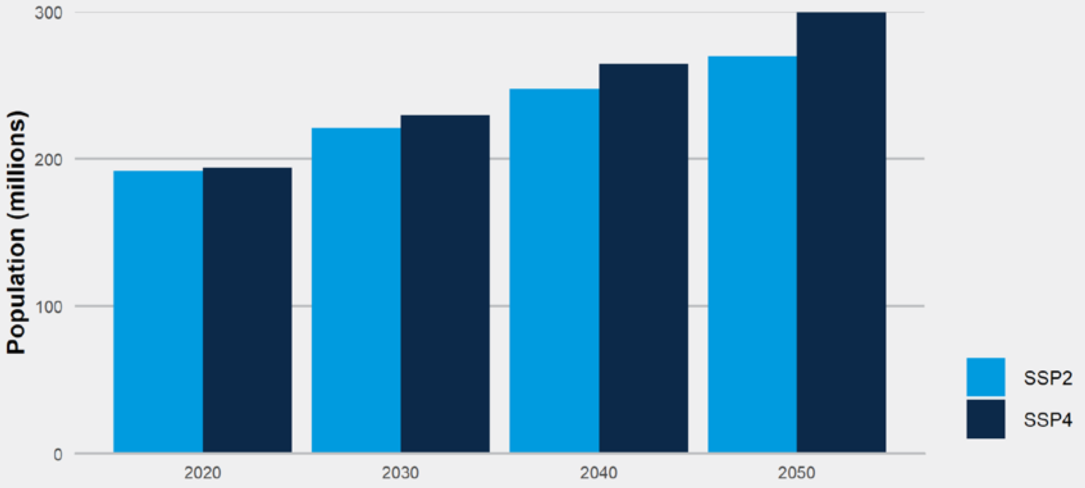
Figure 4.6 shows population pyramids with the demographic composition of the six countries in 2020, revealing differences among them. Iraq and Yemen have very young populations, while Jordan displays an incipient reduction of fertility, and Lebanon, Syria, and Iran's structures correspond to a more mature stage of the demographic transition, with some signs of aging (UN DESA 2019). The share of residents ages 15–29 ranged from 21 percent in Iran to 30 percent in Yemen in 2020. By 2050, this average proportion is projected to decline, ranging from 18 percent in Iran to 25 percent in Yemen. Expanding the opportunities available to young people—in terms of education as well as jobs—is critical for the subregion to leverage the demographic dividend (Lin 2012); as noted above, current levels of youth unemployment are high. Notably, the propensity to migrate in general is higher among younger people (IOM 2019; UN DESA 2011).

Figure 4.4: Population dynamics for Mashreq countries, 2000–2020: average annual rate of population change (top left), total fertility rate (children per woman of reproductive age) (top right), infant mortality rate (infant deaths per 1,000 live births) (bottom left), and crude death rate (deaths per 1,000 residents) (bottom right)



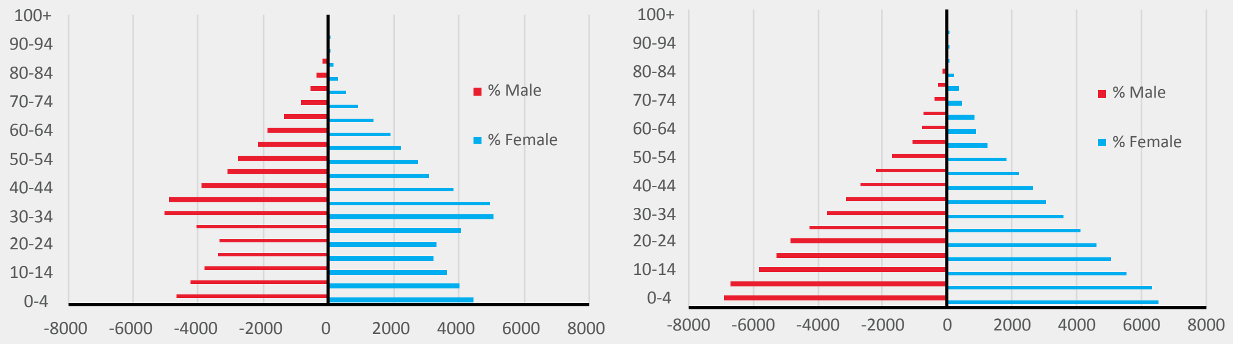
Source: UN DESA (2019).

Figure 4.5: Projected population in the six Mashreq countries under two Shared Socioeconomic Pathways, 2020–2050

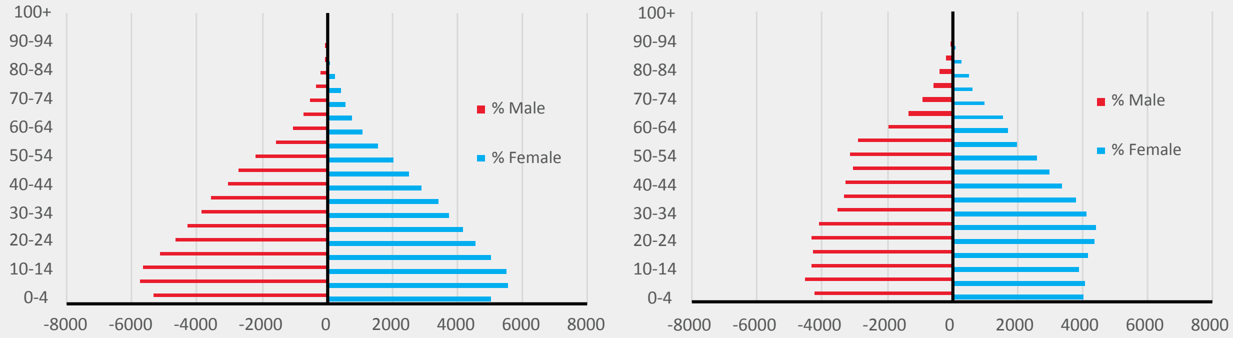


Source: Jones and O'Neill (2016).
Note: SSP2 = moderate development and SSP2 = unequal development. The SSP population projections are based on recent trends of urban growth and the historical experiences of reference countries. They do not account for the impacts of ongoing conflicts. The projections are presented here to provide a general view of population growth trends for the six Mashreq countries to mid-century.

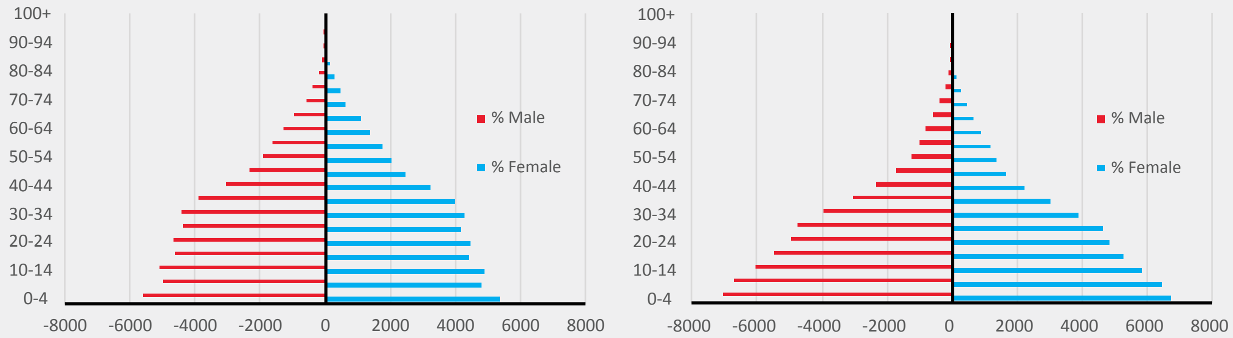
Figure 4.6: Population pyramids for Mashreq countries, 2020


Iran, 2020

Iraq, 2020


Jordan, 2020

Lebanon, 2020


Syria, 2020

Yemen, 2020

Note: Population in thousands.
Source: Authors' analysis based on data from UNDESA (2019).

4.1.3 Geography, Population Distribution and Key Livelihood Zones

The six Mashreq countries have a diverse topography and ecosystems, including highlands, river basins, coastal areas, and large swaths of arid and desert landscapes. Highlands include the Sarawat Mountains of Yemen, the Elburz Mountains in the east of Iran, and the Zagros Mountains in the west. The central and southern areas comprise a series of lowlands, plains, and plateaus. The primary lowland area is the Tigris-Euphrates Basin, and elevations gradually increase from the plains in a southwesterly direction (Figure 4.1). Coastal areas border the Mediterranean Sea, the Red Sea, and a series of gulfs connected to the Indian Ocean through narrow straits.

Precipitation is low, but also highly variable over time and across space. The subregion is arid to semiarid, located in the transition zone between equatorial and mid-latitude climates (Beaumont, Blake, and Wagstaff 2016; Selvaraju 2013). The highlands have more temperate climates and higher population densities.

Natural hazards in the subregion are linked to geomorphology, water action, and the arid climate. They include landslides and mudflows in the highlands during the rainy season, floods affecting river valleys and lowlands, and earthquakes along the tectonic plate boundaries (Beaumont, Blake, and Wagstaff 2016). Droughts recurrently affect livestock and agriculture, increasing the risk of food insecurity. The 2010 drought in Syria and Iraq, for instance, further decreased agricultural production (Hameed, Ahmadalipour, and Moradkhani 2020; Kelley et al. 2015; Eklund and Seaquist 2015). Dust storms are also part of the natural environmental dynamics in the subregion, and anthropogenic factors, such as land use and climate change, are making them more frequent and more intense (World Bank 2019a). Overall, between 1990 and 2020, there were at least 171 weather- and/or water-related extreme events, including floods, droughts, heat waves, landslides and wildfires, directly affecting more than 5.4 million people in the subregion; 15 were logged in 2020 alone.[141]

The population distribution is very heterogeneous, reflecting geography (particularly water availability) and history (Figure 4.7). Large areas of very low population density are visible in southern Syria, southwestern Iraq, southern and eastern Jordan, and eastern Yemen, corresponding to hyper-arid desert zones. Areas of high density, including cities, appear at relatively higher altitudes and along rivers and other water bodies, as well as near irrigated croplands. These include the Tigris and Euphrates valleys of Syria and Iraq, the Jordan River valley, the mountains of Lebanon, the An-Nusayriyah in the west, the southern arc of mountain chains of Iran, and the highlands of western Yemen.

The distribution of livelihood zones is presented in Figure 4.8 for the baseline year of 2015, following the anthropogenic biome classes defined by Ellis et al. (2010).[142] In a context of acute scarcity of arable land and water (World Bank 2014), the dominant biome in Mashreq countries is seminatural and wildlands (largely desert), followed by pastoral and rangelands. Croplands (rainfed and irrigated) are concentrated in the highlands (for example, the Iranian Plateau) and along the few rivers (e.g. in Iraq and Jordan), where there are also dense settlements. Because of the overall aridity of the subregion, agriculture is very dependent on irrigation. The ratio of irrigated to rainfed croplands is generally high, though with significant variations: As of 2017, 23.3 percent of Syria's cultivated land was irrigated, compared with 38.0 percent of Iraq's and Yemen's, 40.2 percent of Jordan's, 51.2 percent of Lebanon's, and 52.2 percent of Iran's.[143]

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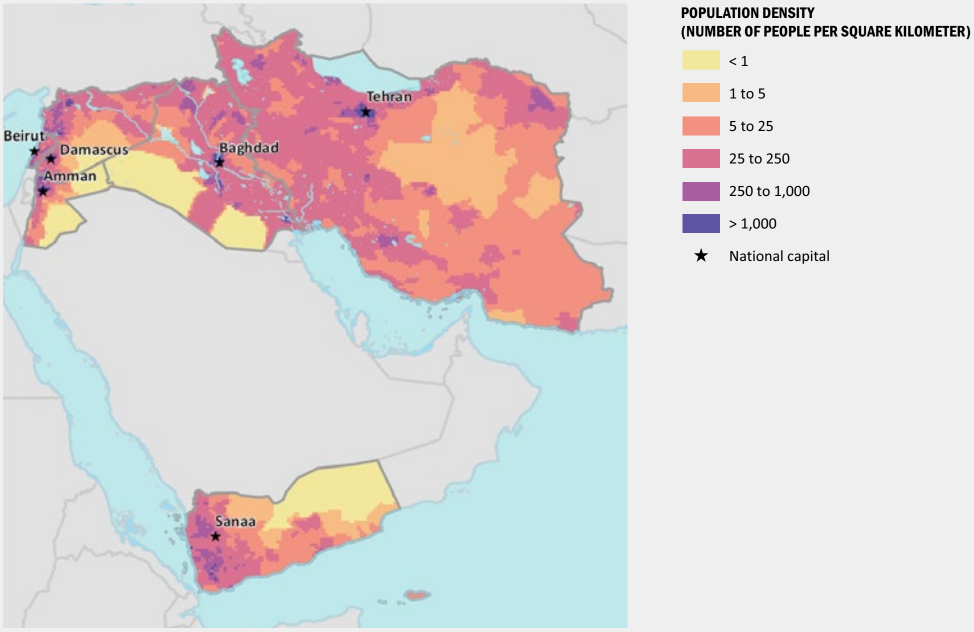
[141] See EM-DAT, the Emergency Events Database: https://public.emdat.be (accessed July 3, 2021).

[142] The livelihoods zones used in the Groundswell reports represent an aggregation of anthropogenic biome classes in Ellis et al. (2010) into areas with relatively coherent livelihood characteristics. Due to high prevalence of conflict in the Mashreq subregion, livelihood zones might have been altered since 2015.

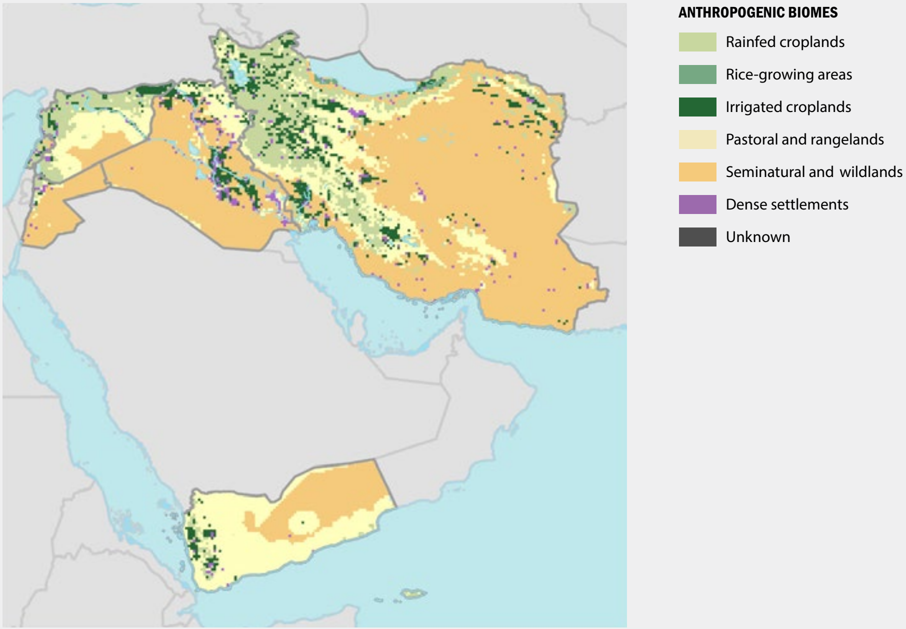
[143] See FAOSTAT data for % of cultivated land irrigated (harvested crop): http://www.fao.org/aquastat/statistics/query (accessed May 15, 2021).

Figure 4.7: Population density in Mashreq countries, 2015



Note: This map is provided to give a general sense of the population distribution within the six Mashreq countries. There are uncertainties in baseline population distribution for 2010 due to recent and ongoing conflicts in Iraq, Syria, and Yemen, as well as refugee flows.

Figure 4.8: Livelihood zones in the six Mashreq countries, by anthropogenic biome, 2015



Source: Ellis et al. (2010)

Urbanization in Mashreq countries has been rapid, driven by economic development and environmental and political crises (World Bank 2020a). The subregion's urban population more than quadrupled from 1970 to 2010, driven by internal migration and influxes of refugees. Urbanization levels in the region vary widely, from 37 percent in Yemen, to 91 percent in Jordan (UN DESA 2018). The largest cities are Tehran (8.9 million), Baghdad (6.8 million metro area as of 2018), Mashhad (3.1 million), Sana'a (2.8 million urban agglomeration), Damascus (2.3 million, though the current population is highly uncertain), Beirut (2.4 million urban agglomeration), and Amman (2.1 million).[144] Overall, the six countries have similar urban hierarchies, with one dominant, primary city and several smaller ones, except for Lebanon, which has only one large urban area, Beirut.

Looking ahead, the urban share of the population by 2050 is projected to reach between 80 and 95 percent in Iran, Iraq, Jordan, and Lebanon, depending on the SSP, and lower levels in Syria (72 in SSP2 and 82 percent in SSP4) and Yemen (56 percent in SSP2 and 70 in SSP4) (Table 4.3). Population growth rates, continuing patterns of rural-urban migration, a continuing influx of refugees, and increases in domestic water demand could place further burdens on critical urban services (World Bank Group 2020; IOM 2019). Specifically, the increasing concentration of population in a few cities amid worsening water scarcity could magnify water stress and compromise access to drinking water and sanitation (World Bank 2020a; 2018). As economic dependence on agriculture declines, however, this could reduce demand for irrigation, freeing up water resources for urban areas.

Table 4.3: Urban projections for Mashreq countries to 2030 and 2050, under two Shared Socioeconomic Pathways

Country	Urban share (% of population)					
	SSP2			SSP4		
	2010	2030	2050	2010	2030	2050
Iran	70.8	78.0	82.9	70.8	84.2	89.5
Iraq	66.2	75.1	81.0	66.2	78.3	85.3
Jordan	78.5	85.1	89.1	78.5	89.9	94.9
Lebanon	87.2	90.4	92.1	87.2	90.4	92.1
Syria	55.7	66.2	72.3	55.7	71.1	82.5
Yemen	31.8	45.0	55.8	31.8	52.6	69.8

Source: Jiang and O'Neill (2017).

4.2 CLIMATE CHANGE IMPACTS

4.2.1 Climate Trends and Projections

Historical climate data shows a robust upward trend in average temperatures in the six countries (see top row of Figure 4.9). Between 1961 and 1990, the subregion warmed by about 0.2°C (World Bank 2014), and there is robust evidence of an increase in extreme heat (Seneviratne et al. 2012). Heat waves have also become more intense since the 1960s, particularly in the eastern Mediterranean and the Arabian Gulf (Waha et al. 2017).

Average precipitation, meanwhile, has declined very slightly (see bottom row of Figure 4.9), while extreme precipitation events have increased. Some studies have found significant declines in precipitation over the eastern Mediterranean (the Levant) and the Arabian Peninsula over the past century, with a recent upward trend in drought frequency (Zittis 2018). The patterns of temperature and precipitation changes across the subregion are complex. In Lebanon and Jordan, for instance, warming has tended to be greater at higher elevations and farther from the Mediterranean (Verner et al. 2013). Along with historical data, Figure 4.9 also shows projections for both average temperature and precipitation under different emissions pathways.

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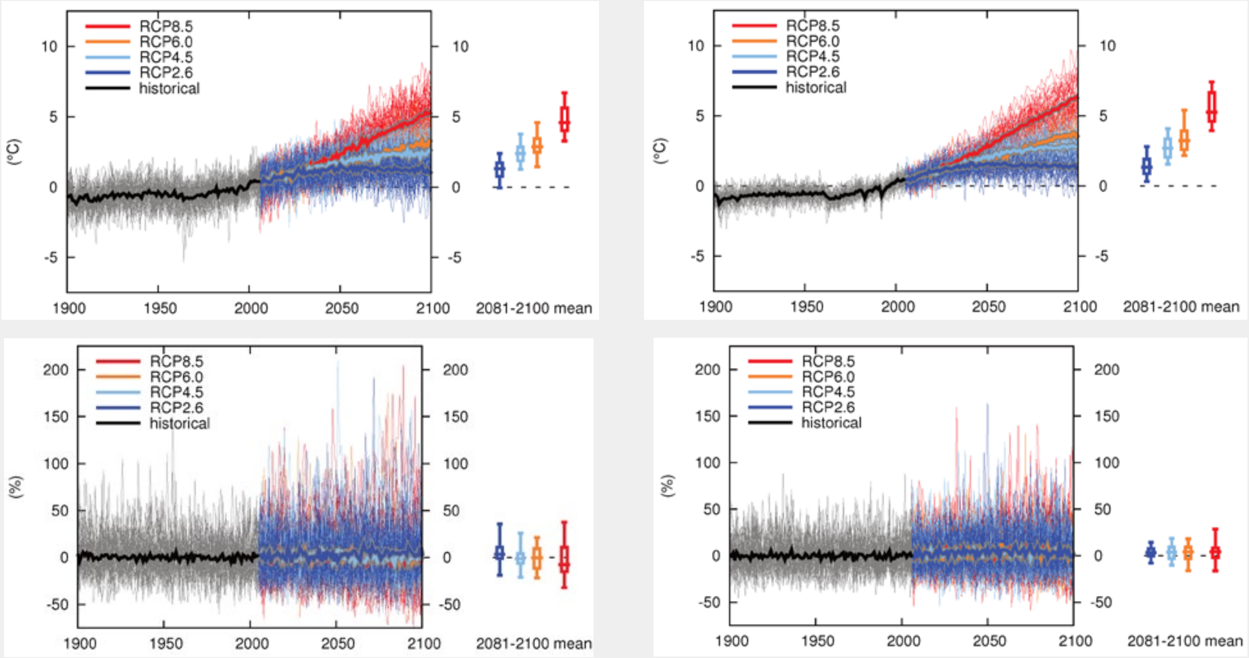
[144] Except as explicitly noted, all population figures are for the city proper.

Figure 4.9: Climate trends and projections for West Asia: temperature change December–February (top left) and June–August (top right); precipitation change October–March (bottom left) and April–September (bottom right)



Source: IPCC (2013), figures AI.52–55.
Note: In addition to the Mashreq countries of this chapter, West Asia includes all the countries of the Arabian Peninsula as well as Turkey, Georgia, Armenia, and Azerbaijan.

Projecting future trends, climate models agree that it is very likely temperatures will continue to rise (Christensen et al. 2013). The strongest warming is projected to occur in countries close to the Mediterranean—where warming of 3°C could be expected by the end of the century even under RCP2.6, the lowest emissions pathway (World Bank 2014). Under RCP8.5, the highest emissions pathway, average summer temperatures are projected to be up to 8°C warmer by 2100 in parts of Iraq. A regional summer warming is also projected for most of the Mashreq subregion. In addition, even under RCP2.6, by the end of the century, extreme heat is likely to occur on about 30 percent of summer months, with each year having, on average, a full month of unusually hot temperatures.

Average precipitation is projected to steadily decline, but these changes are also more difficult to assess (Christensen et al. 2013). The lower panels in Figure 4.9 above indicate a very slight declining trend in precipitation under the high emissions pathway for the October–March period, no trend for the April–September period, and an increase in precipitation extremes overall (IPCC 2013). Various studies project an overall continued decline in precipitation in the Mediterranean region (Syria, Lebanon, and Jordan) and extending across to Iraq and Iran, but increases in the southernmost area, including Yemen (IPCC 2013; World Bank 2014). This is as a result of northward shifts of air moisture that could affect rainfall. Under a high emissions pathway, projections show rainfall declining by as much as 50 percent along the Mediterranean, with more variability and extreme events such as droughts and floods (World Bank 2014).

Changes in precipitation are expected to affect surface and groundwater resources, including snow cover and water storage, and could lead to longer dry seasons, with impacts on irrigated agriculture, among others (World Bank 2014). Mountain areas in Lebanon, Syria, Iraq, and Iran store a fraction of precipitation as snow, so they play an important role in the water supply of the subregion. Decreases in snow water storage could result in decreased river runoff—for example, in the Jordan, Euphrates and Tigris rivers—already by mid-century. The snowpack in the upper Nahr el Kalb Basin (Lebanon) is projected to shrink by 40 percent with 2°C warming and 70 percent with 4°C warming by the end of the century. Combined with rising temperatures and more frequent extreme events, the Mashreq countries could also face increased droughts and accelerated desertification.

4.2.2 Water Availability, Crop Productivity, and Sea-Level Rise Projections

The Inter-Sectoral Impact Model Intercomparison Project (ISIMIP) water availability and crop productivity model results to 2050 used in this report broadly confirm the projected trends described above (Figures 4.10 to 4.13):[145]

- Index values for water availability to 2050 show a drying trend in the north, west and central areas of the subregion (Lebanon, Syria, Jordan, Iraq, and part of Iran), as shown in Figure 4.10. On the other hand, they indicate a wetting trend in Yemen[146] and in the hyper-arid regions of southern Iraq and Iran. Such increases, however, are against a very low baseline.

- The trends in water availability, both positive and negative, are intensified for the 2050–2100 period (Figure 4.11). It is noteworthy that under the IPSL high emissions RCP8.5 climate model, the Tigris and Euphrates show a significant drying—perhaps reflecting broader drying in upstream areas in Turkey.

- Index values for crop productivity to 2050 show slight increases in most of the subregion (Figure 4.12). However, Iran is projected to have larger pockets of crop productivity decreases in the northeast and south, on the order of 30–50 percent declines. Patterns intensify in the second half of the century (4.13). Increases in crop productivity contrast with the results for declining water availability. These increases could reflect the wide use of irrigation in several countries; the extent to which they could eventually be limited by rising temperatures and water stress needs to be further examined.[147] Hyper-arid areas unsuitable for agriculture make up a significant proportion of the land area in five of the six countries (except Lebanon), which have no current or projected crop productivity.

In coastal areas, sea levels are expected to keep rising over the coming decades, with implications for many low-lying areas in Mashreq countries. As shown in Figure 4.14, these include coastal Iraq (e.g. the Mesopotamian Marshes of southern Iraq and extending into southeastern Iran), coastal Iran, and some port cities on the Mediterranean, such as Latakia and Jablah in Syria and Beirut in Lebanon (World Bank 2014; Vaghefi et al. 2019). In Yemen, sea-level rise could increase coastal damage due to storm surges, linked to intensifying storms in the Gulf of Aden.[148] Sea-level rise could also aggravate saltwater intrusion in aquifers that are already overdrawn (Waha et al. 2017). Sea-level rise in the Mediterranean Basin was below global levels in the 20th century, averaging 1.1–1.3 millimeters per year (World Bank 2014). However, there has been significant interdecadal variability, with a slow gradual increase from 1960 to 1990, and rapid above-average sea-level rise after 1990.

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[145] In Chapters 2 and 3, ISIMIP water availability and crop productivity projections were used as inputs to the three internal climate migration scenarios modeled in this report to understand spatial population shifts induced by climate change. While this modelling was not done for the six Mashreq countries, the ISIMIP projections can provide insights on how slow-onset climate change impacts could affect key sectors and livelihoods, acting as push and pull factors for migration.

[146] There is significant uncertainty in future climate projections in the Horn of Africa.

[147] Increasing atmospheric CO_2 concentrations can also potentially increase crop productivity (Verner et al. 2013), though some studies considering this effect show statistically insignificant relationships (Waha et al. 2017).

[148] See ThinkHazard data on coastal flood risks in Yemen: https://www.thinkhazard.org/en/report/269-republic-of-yemen/CF (accessed May 15, 2021; data last updated on July 2, 2020). Also see Yemen country page in the World Bank Climate Change Knowledge Portal: https://climateknowledgeportal.worldbank.org/country/yemen.

Figure 4.10: ISIMIP average index values during 2010-2050 against 1970–2010 baseline for water availability, from LPJmL/water and WaterGap, forced with the HadGEM2-ES climate model (left) and IPSL-CM5A (right) under RCP2.6 and RCP8.5, Mashreq countries

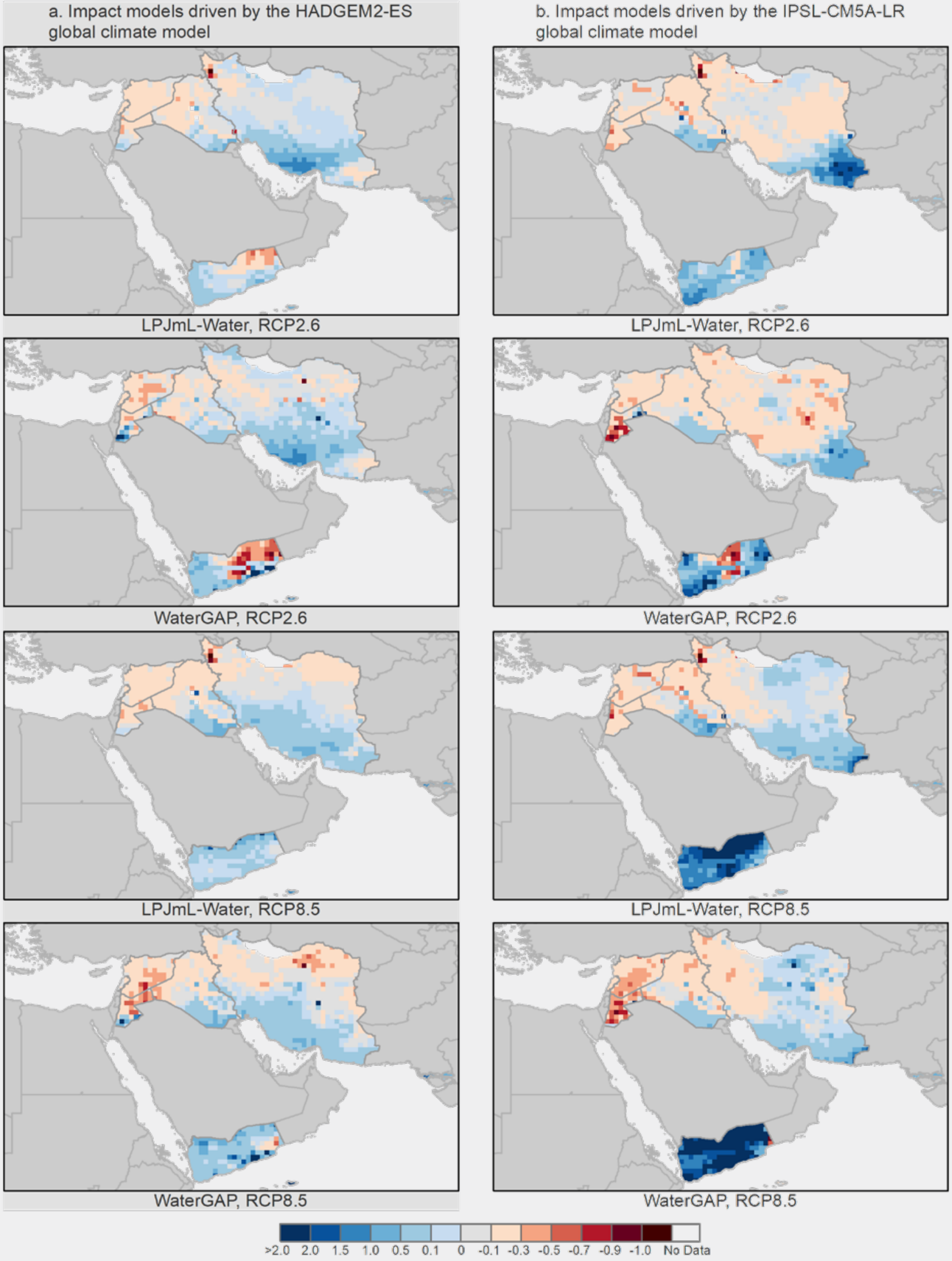


Figure 4.11: ISIMIP average index values during 2050–2100 against 1970–2010 baseline for water availability, from LPJmL/water and WaterGap, forced with the HadGEM2-ES climate model (left) and IPSL-CM5A (right) under RCP2.6 and RCP8.5, Mashreq countries

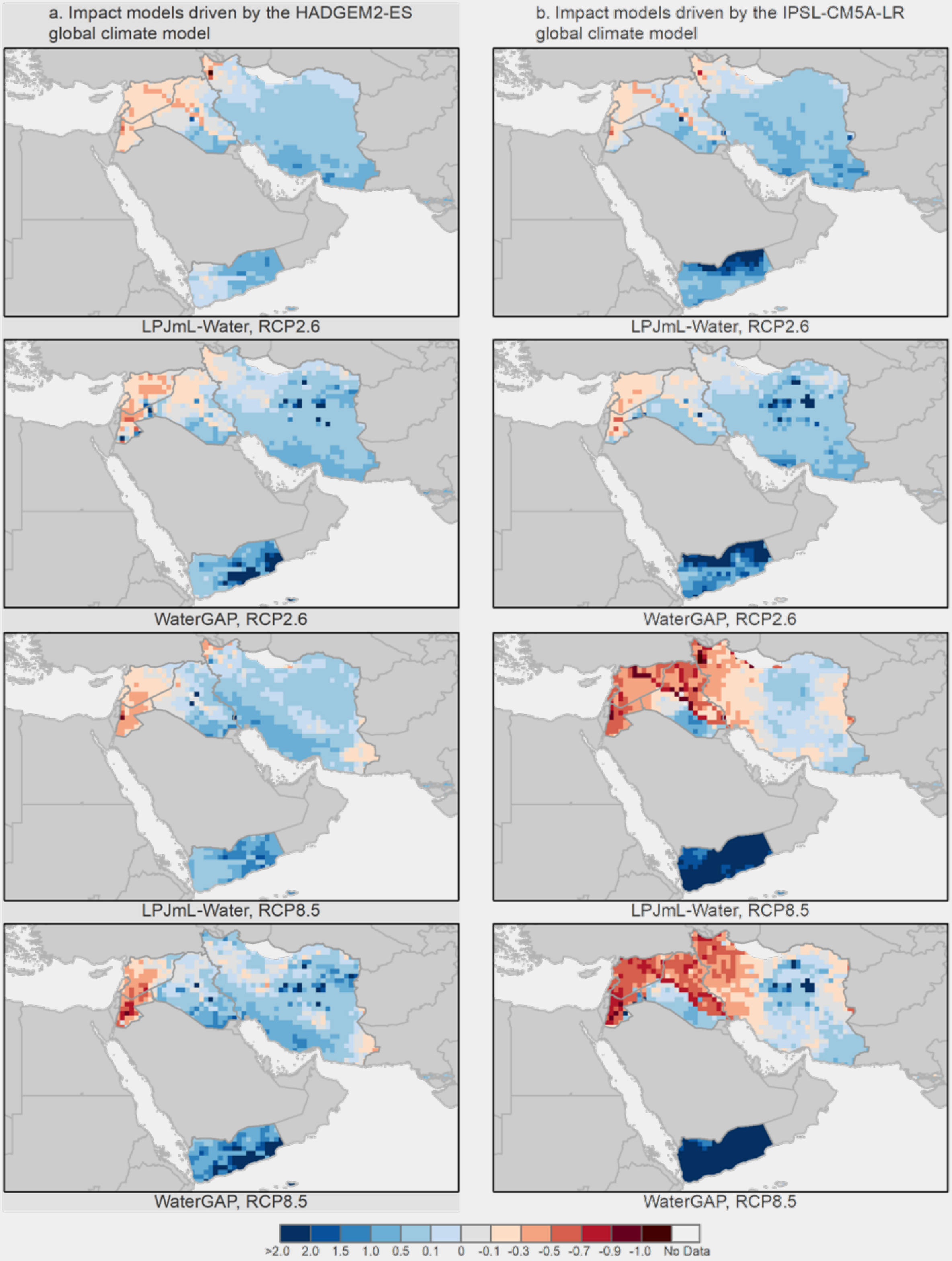


Figure 4.12: ISIMIP average index values during 2010–2050 against 1970–2010 baseline for crop productivity, from LPJmL/crop and WaterGap, forced with the HadGEM2-ES climate model (left) and IPSL-CM5A (right) under RCP2.6 and RCP8.5, Mashreq countries

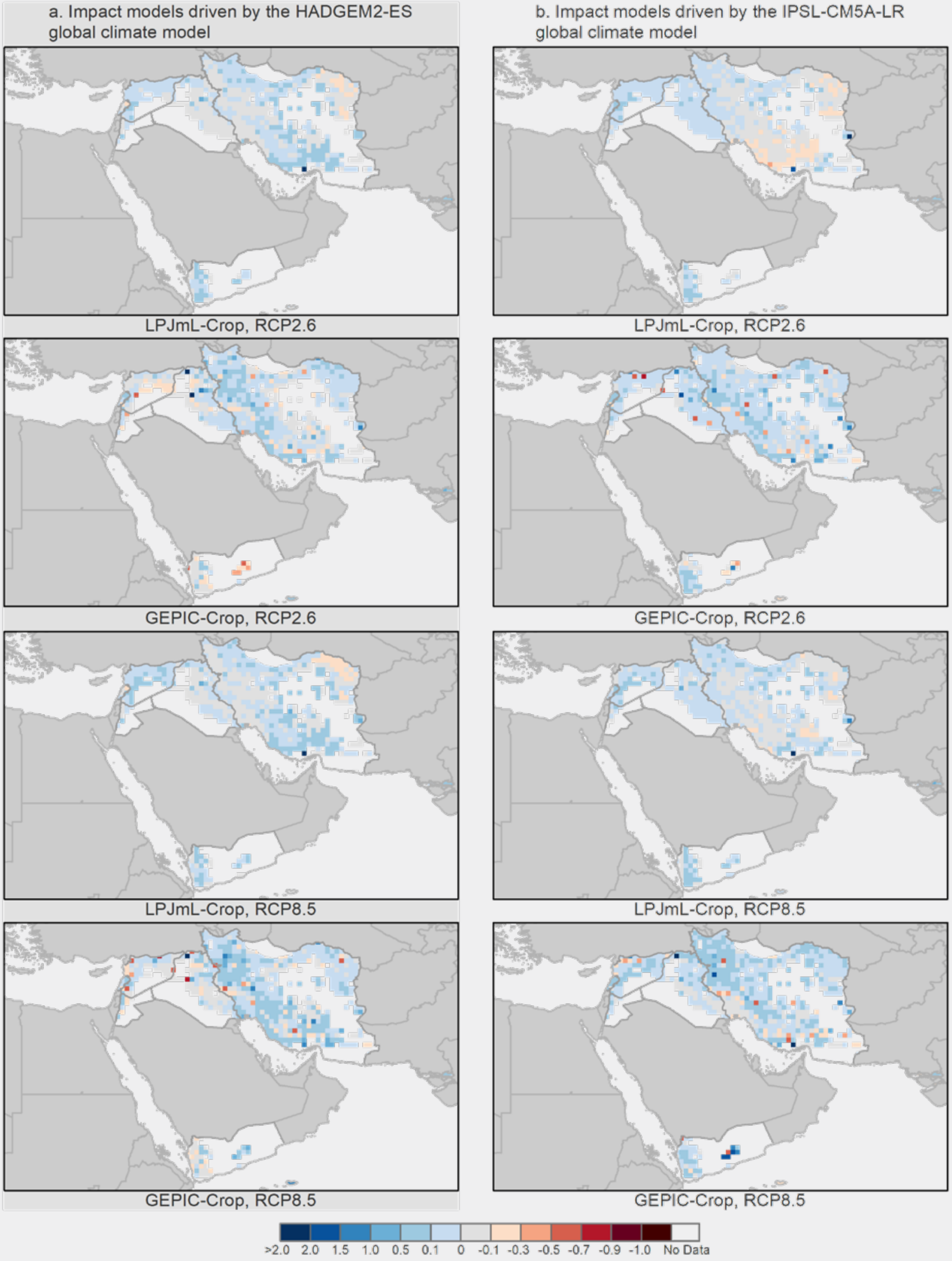


Figure 4.13: ISIMIP average index values during 2050–2100 against 1970–2010 baseline for crop productivity, from LPJmL/crop and WaterGap, forced with the HadGEM2-ES climate model (left) and IPSL-CM5A (right) under RCP2.6 and RCP8.5, Mashreq countries

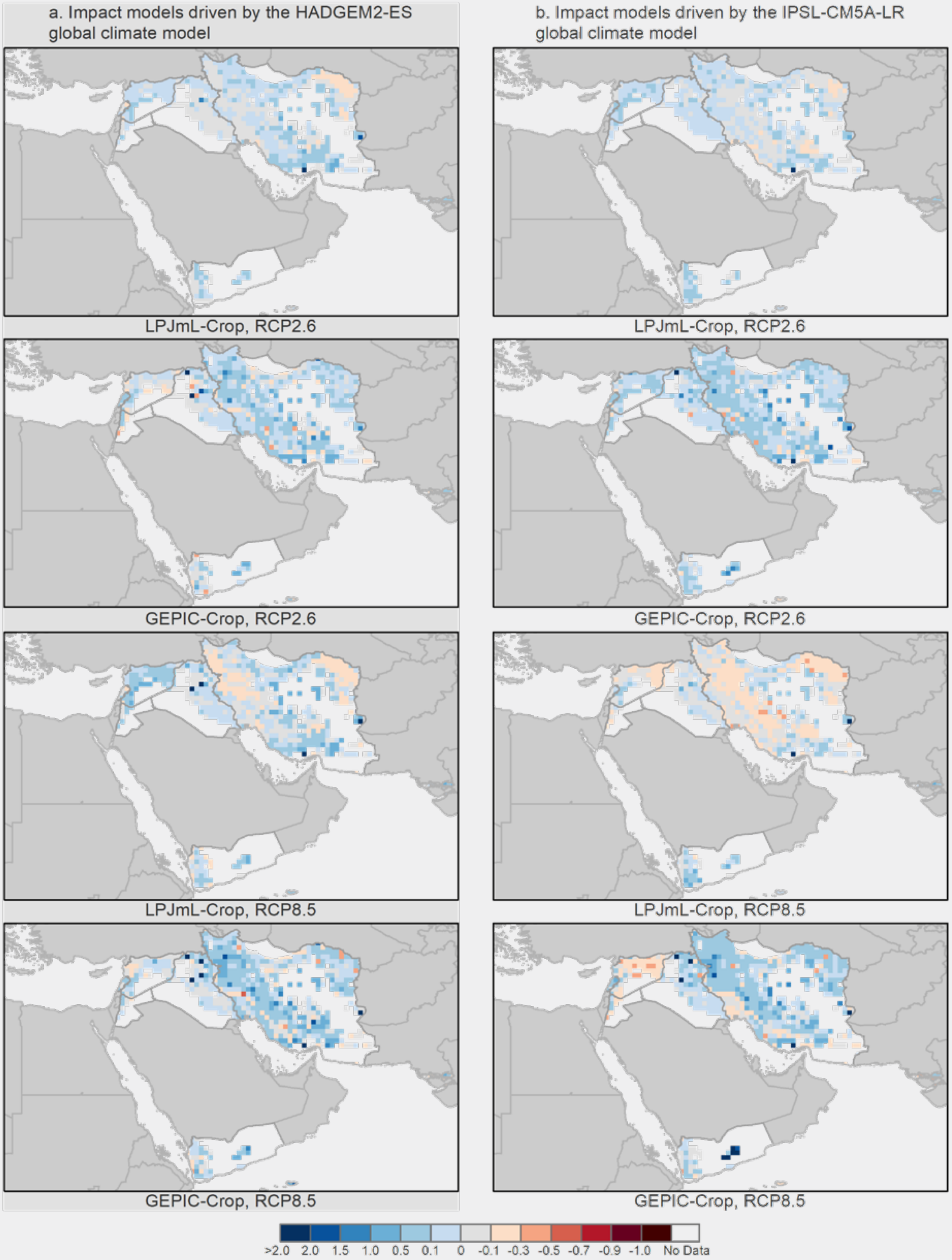
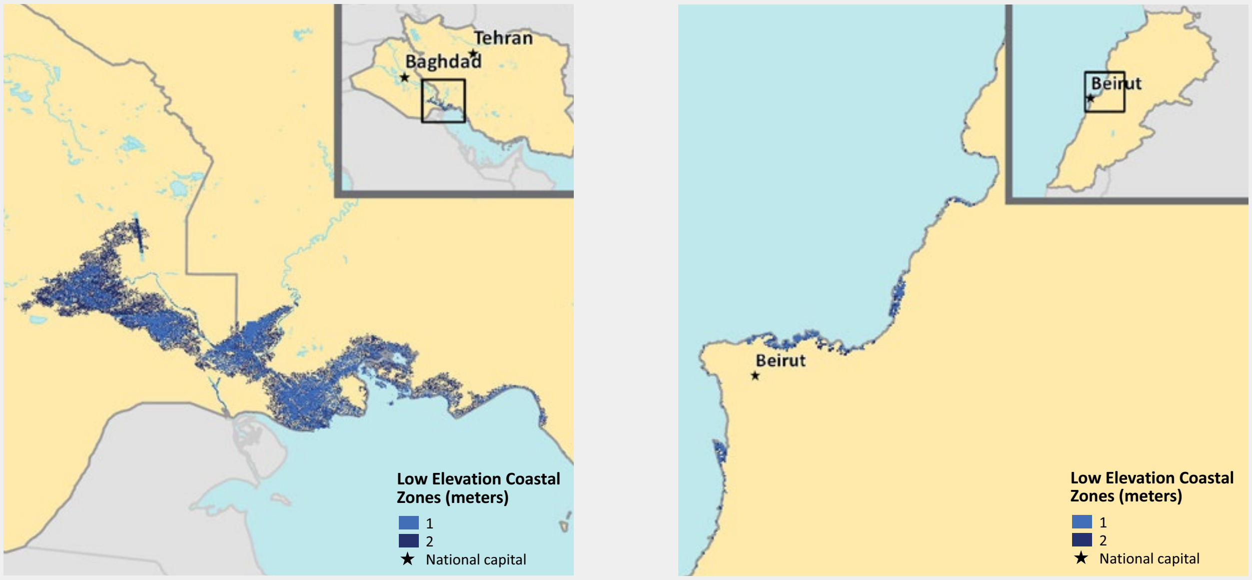


Figure 4.14: Land area inundated by 1-meter and 2-meter combined sea-level rise and storm surge for coastal areas of Iraq and Iran (left) and Lebanon (right), by 2050



4.2.3 Climate Change Impacts on Agriculture and Livestock

As noted, the Mashreq countries already face extreme heat and water stress, and both are expected to worsen in the coming decades as a result of climate change. Such impacts would put further pressure on agriculture and livestock production, and consequently on rural livelihoods, food security, and the role of agriculture in national economies (World Bank 2014) .

A warmer and drier climate could impact croplands by shifting vegetation and agricultural zones and growing periods. With 4 °C of warming by 2100, agriculture zones could shift up to 75 kilometers northward from where they were at the start of the century (World Bank 2014). Crop growing periods are projected to shorten due to lower rainfall and higher temperatures. The growing period for wheat in large parts in the subregion could be reduced by about two weeks by mid-century, for instance. The incidence of pests and diseases could also change. Higher temperature may increase the number of insect life cycles per season, while extreme events such as droughts and floods can trigger insect outbreaks (Mbow et al. 2019). Crop pests, including fall armyworm and desert locusts, are having disastrous impacts in Yemen. In the 2020 growing season alone, the locust outbreak caused an estimated US$222 million in damages and losses.[149]

Livestock production systems are vulnerable to climate change both directly, through the physiological impacts of hot and dry conditions, and indirectly, through fluctuations in food and water supplies (Easterling and Apps 2005). Climate change may affect the quantity and quality of available feeds, change the length of the grazing season, reduce drinking water, induce additional heat stress, and increase the prevalence of livestock diseases (World Bank 2014). Likewise, climate-related pressures may also negatively impact rangelands and other ecosystems that underpin rural livelihoods (Herrero et al. 2016). Between 2005

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[149] See the FAO's "Yemen Crisis" web page: http://www.fao.org/emergencies/crisis/yemen/intro/en/ (accessed May 15, 2021).

and 2010, recurring droughts cost herders in Syria almost 85 percent of their livestock (Selvaraju 2013). Livestock issues in one country can spill over into others: for instance, the collapse of the animal health system in Syria has been associated with a higher incidence of outbreaks of animal diseases in Lebanon due to seasonal transboundary movements of livestock.[150]

Climate change can also modify the natural conditions of biomes, with implications for key ecosystems. As the Mashreq subregion is mostly covered by drylands, and a large portion is covered by deserts, increases in temperature and evapotranspiration, and changes in precipitation and extreme events, could result in increased wildfires, biodiversity loss, and greater vulnerability to invasive species. Climate change could speed up land degradation and trigger or accelerate desertification processes, further disrupting livelihoods (World Bank 2014). A study examining projected climate change impacts in the Mediterranean region for the period 2071–2100 concluded that the western Mashreq could be especially at risk of increased water stress on natural ecosystems and desertification (Gao and Giorgi 2008).

All of this has implications for food security in the subregion, which has also been undermined by land degradation, wind and water erosion, crop pests, farming practices, unplanned urban encroachment, as well as institutional fragility and political instability (Al-Kofahi et al. 2018; OECD and FAO 2018). Ongoing conflicts, the COVID-19 pandemic, and other shocks have significantly worsened the situation, particularly in Yemen, Syria, and Lebanon, all three of which were recently identified as “hunger hotspots” (WFP and FAO 2021).

The Mashreq countries—already some of the world’s largest importers of food—are expected to become increasingly dependent on food imports.[151] This increases their vulnerability to shocks from disruptions in trade and in supply chains, international price fluctuations, and currency depreciations (OECD and FAO 2020). Jordan, for example, is almost self-sufficient in high-value crops—mainly vegetables—but imports around US$4 billion worth of food and agriculture products and has a cereal import dependency ratio of around 90 percent (World Bank et al. 2020). A decline in fisheries’ productivity has also been mentioned as a concern for Iran (OECD and FAO 2020), Yemen, and Syria (Wodon et al. 2014).

Climate change affects certain agriculture-dependent populations disproportionately, and they are also the ones with the least capacity to cope or adapt. Water scarcity, for example, is likely to create a greater burden on women than on men, as women are often responsible for water-related tasks on farms and around the home, and they often also have less access to assets that can buffer against the impacts of rainfall variability (World Bank 2018; Parker et al. 2016). Similarly, smallholder farmers dependent on rainfed agriculture are highly vulnerable to food insecurity and malnutrition through direct impacts on crop yields, while urban populations are more vulnerable to rising food prices (Waha et al. 2017). A 2011 survey of households in Syria and Yemen found almost all had been affected by a climate-related disaster between 2005 and 2010, particularly drought (Wodon et al. 2014). In Syria, 87 percent of respondents reported crop losses; 20 percent, lost income; and 17 percent, lost livestock. In Yemen, 61 percent of respondents reported crop losses; 52 percent, lost income; and 26 percent, livestock and fishing losses.

4.2.4 Climate Change Impacts on Water Resources

Climate change projections suggest that Iraq, Lebanon, Jordan, and Syria could all experience significantly increased water stress due to warming and precipitation changes, while socioeconomic changes could drive smaller increases in surface water stress in Iran and Yemen (World Bank 2018). Climate-related water scarcity in the broader Middle East and North Africa region could induce GDP reductions of 6–14 percent by 2050 (World Bank Group 2016). In Syria, more than 70 percent of total renewable water resources

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[150] See the FAO’s web page on Lebanon: http://www.fao.org/lebanon/fao-in-lebanon/lebanon-at-a-glance/en/ (accessed May 15, 2021).

[151] The Middle East and North Africa region as a whole produced 41 percent of its cereals, 72 percent of its meat, 34 percent of its sugar, and 25 percent of its vegetable oil in 2017–2019 (OECD and FAO 2020). Though the region’s self-sufficiency ratios for key foods are projected to hold relatively steady, several are projected to decline, and overall, by 2029, food trade relative to the region’s domestic output is projected to rise to 94 percent. Imports are projected to increase for almost all commodities, except for fish and meat products. The region’s imports will maintain high shares of certain global markets, such as maize, other coarse grains and wheat.

originated outside the country in 2017 (World Bank 2018). This dependency ratio reached 60 percent in Iraq and 27 percent in Jordan. Further water scarcity is expected to directly reduce agricultural output and affect other key economic sectors as well, including power generation, industry, manufacturing, and services (Taheripour et al. 2020). Given the interlinkages between sectors, there could also be feedback loops.

Hydrological models that include climate change show substantial decreases in surface and groundwater for most countries in the broader region (ESCWA 2019). Groundwater recharge is projected to see the largest decline, with reductions of up to 25 percent by 2040–2050 relative to a 2000–2009 baseline. Use of non-renewable groundwater is a concern, discussed in various case studies of the subregion's aquifers. In southern Iraq, for example, groundwater withdrawals already exceed sustainable levels and could lead to reduced capacity to support economic use (Al-Azawi and Ward 2017). Surface water over-abstraction is also a concern in the subregion; about one-tenth of surface water consumption is unsustainable or is sustained at the expense of environmental flows (World Bank 2018).

With projected reductions in snowfall and snow water storage in upstream mountain systems, peak flows of meltwater could shift towards earlier months in the year by the end of century (World Bank 2014). This would affect downstream river systems that supply agriculture and livestock production, while also increasing water stress and erosion. For example, an annual surface runoff decrease of 25–55 percent by end of century is projected in the eastern Anatolian mountains—the headwaters of the Euphrates and Tigris (Bozkurt and Sen 2013). Another study of the tributaries of the Jordan River projects a 17 percent reduction in daily mean surface flow to 2060 (Samuels et al. 2010).

In Syria, models of future water supply and demand under climate change, including projections for population and industrial growth, show that water shortages in the country may exceed 3.5 billion cubic meters by 2050 (K.A. Mourad and Alshihabi 2016). However, in a scenario with improvements to drinking water systems and implementation of modern irrigation systems, the model showed the shortage could be reduced by about half.

Clear incentives are needed to change the way water is managed, conserved, and allocated in a participatory manner (World Bank 2018). Access to safe drinking water varies across countries: from 63 percent of households in Yemen as of 2017, to 95 percent in Iran.[152] Urban areas generally enjoy better access than rural areas: 97 versus 89 percent in Iran and 79 versus 55 percent in Yemen. Lebanon, which is considered to have adequate water resources, nevertheless faces complex water challenges due to increased pollution and consumption (ESCWA 2019). In addition to integrated water resource management, potential also exists to tackle water scarcity in the subregion by expanding wastewater reuse, while also ensuring quality to avoid contamination of surface and groundwater supplies. Jordan and Yemen are among the few countries reusing wastewater in irrigation.

The Mashreq countries face two other significant groundwater-related challenges: salinization in both riverine and coastal areas, which is expected to worsen with sea-level rise, and land subsidence, particularly in Iraq and Iran (Herrera-García et al. 2021; World Bank 2014). Salinization is a complex process involving several factors, including irrigation and land subsidence, but sea-level rise is expected to compound other drivers of salinization and affect densely populated coastal areas the most. River salinization has been documented in the Euphrates, Tigris, and Jordan rivers. The combination of sea-level rise and diminished volumes of river outflows has allowed brackish water to be pushed far upstream in deltas and river systems such as the Shatt-al-Arab in Iraq and the Litani river basin in Lebanon, turning river waters and connected groundwater resources brackish and causing harmful effects on riverine ecology (World Bank 2018; Ramadan, Beighley, and Ramamurthy 2013). In Yemen, sea-level rise could interact with expected increases in storm surges, leading to both increased coastal flooding and salinization challenges.[153]

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152. See country data on the WHO/UNICEF Joint Monitoring Programme (JMP)'s global repository of data on water supply, sanitation, and hygiene: https://washdata.org/data/household (accessed May 16, 2021). Totals include both "safely managed" and "basic" water access; 92 percent of Iranian households had access to "safely managed" drinking water supplies as of 2017, while Yemen's entire coverage was classified as "basic" access.

153. See ThinkHazard data on coastal flood risks in Yemen: https://www.thinkhazard.org/en/report/269-republic-of-yemen/CF (accessed May 15, 2021; data last updated on July 2, 2020).

The Mashreq's coastal, wetland and riverine ecosystems (also referred to as "Wadi") provide numerous ecosystem services, including water purification and supply. These ecosystems are at risk from climate change impacts due to sea-level rise, floods, damages from extreme events (including storms and storm surges), and resulting increases in erosion and saltwater intrusion (World Bank 2014). It is projected that wetlands in the broader region could be severely affected by climate change, with large losses in coastal wetlands, saline wetlands, and freshwater marshes (Blankespoor, Dasgupta, and Laplante 2014). The Mashreq's extensive marine ecosystems, important for coastal and fisheries livelihoods, could also be impacted by climate change. The gulfs of the subregion are highly exposed to rising sea surface temperatures, which can heighten species range shift and lead to coral bleaching, particularly in the Gulf of Aden (Hereher 2020; Ben-Hasan and Christensen 2019; El-Mashjary and Ali 2010; PERSGA 2010).

4.2.5 Climate Change Impacts on Urban Areas and Human Health

Projected increases in temperature and humidity are expected to result in even higher exposure to heat stress in Mashreq countries (World Bank 2014; Coffel, Horton, and de Sherbinin 2018). Extreme temperatures and heat waves are linked to several health impacts, among them heat exhaustion and heat stroke, particularly among children, the elderly and people with preexisting conditions. Figure 4.15 shows the projected number of days exceeding historical annual maximum wet bulb temperature[154] under the RCP8.5 scenario to 2060–2080, which could surpass thresholds of human tolerance and with detrimental health effects to those without access cooling (Raymond, Matthews, and Horton 2020). The highest values correspond to coastal areas: southern Yemen, the countries on the eastern Mediterranean, the southern coast of Iran, and the southernmost area of Iraq.

Urban areas, including several capital cities such as Baghdad and Amman, are likely to be severely impacted by increases in wet bulb temperatures (Waha et al. 2017). As shown in Figure 4.15, many coastal urban centers will likely suffer a substantial increase in the number of very hot and very humid days, with related health impacts. Several of these cities are also growing very fast (World Bank 2020a). For example, the population of Aden in Yemen is projected to increase by 62 percent between 2020 and 2035, from 980,000 to 1.6 million (UN DESA 2018). By 2060–2080, the city is expected to have 112 days exceeding the historical annual maximum temperature. The risk of thermal discomfort and heat stress is even higher in dense urban areas because of the urban heat island effect. This risk usually disproportionately affects the urban poor and those without access to cooling and electricity. Increasing temperatures could also have indirect impacts on health by worsening air pollution, particularly in urban areas (Lelieveld et al. 2014).

As noted above, the Mashreq countries face serious drought and water stress risks, and this is likely to affect urban water supplies. Current urbanization trends could magnify water scarcity and further limit access to adequate drinking water and sanitation. Vulnerable populations, such as recent migrants from rural areas and refugees, are likelier to be affected, as many live in slums, lacking access to services. In Iraq, for instance, 47 percent of the urban population lives in slums, and in Yemen, 61 percent (Abdellatif, Pagliani, and Hsu 2019).

Sea-level rise is also set to affect a number of cities, including Latakia, Jablah and Tartus in Syria; Beirut in Lebanon; Aden in Yemen; Basra in Iraq; and Bandar Bushehr and Chabahar in Iran (Hasan 2020). While exposure varies depending on local topography, urban areas house a large proportion of the population as well as important economic activities that are at risk. Storms and storm surges, on the other hand, are less of a concern for most of the subregion, except for Yemen.

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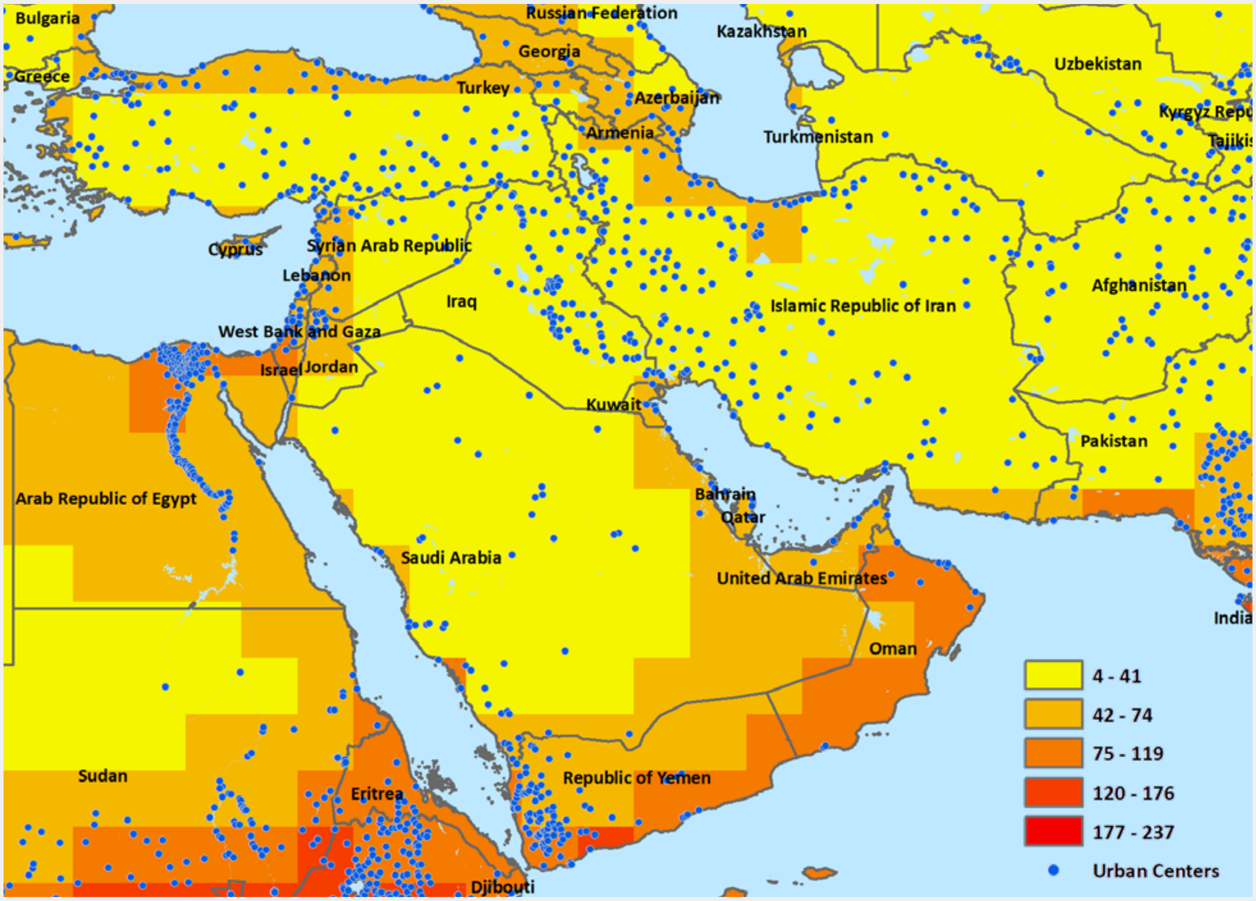
[154] Wet bulb temperature is an indicator of dangerous heat-humidity combination. It is defined as the temperature that an air parcel would reach through evaporative cooling once fully saturated. When the outside wet bulb temperature exceeds the body skin temperature, about 35°C, evaporative cooling will be significantly less effective, and the body will likely accumulate heat (Coffel, Horton, and de Sherbinin 2018).

Figure 4.15: Wet bulb temperature: average annual number of days exceeding historical annual maximum, 2060–2080, RCP8.5



Sources: Coffel et al. (2018); Florczyk et al. (2019).

Climate change may compound the risks of viral and vector-borne diseases that are already on the rise in the Mashreq countries, including malaria, leishmaniasis and lymphatic filariasis (Lelieveld et al. 2012). Malaria, for example, is prevalent in Yemen (WHO 2020). There is evidence that a change in climatic factors can affect incidence of the disease in the region, and malaria occurrence has previously been linked to temperature, elevation, humidity, and low rainfall in Iran (Salehi et al. 2008). Climate change could also increase the occurrence of food- and water-borne diseases. For example, cholera outbreaks follow seasonal patterns, correlate with high temperatures, and can follow extreme weather events that disrupt water supplies, including in urban areas (Emch et al. 2008).

Table 4.4 provides a summary of key climate change trends and impacts for the Mashreq countries, while Table 4.5 provides an overview of implications for key sectors and livelihoods.

Table 4.4: Overview of climate change trends and impacts for Mashreq countries

Temperature	Precipitation	Sea-level rise and storm surge	Natural hazards
Rising temperatures and more extreme heat, including heat waves[a] Strongest warming in countries close to the Mediterranean coast, up to 3°C by the end of the century under RCP2.6 and increases of up to 8°C in Iraq under RCP 8.5[b] Extreme heat projected in 30 percent of summer months and average of one very hot month per year under RCP2.6[b]	Decline in average annual precipitation in north, west and central areas to mid-century, increase in precipitation for Yemen, though with uncertainty as per ISIMIP projections[c] Precipitation declines by as much as 50 percent in the Mediterranean region under RCP 8.5[b] Seasonal declining trend in October–March under RCP 8.5[d] Increase in overall precipitation extremes[d]	Sea-level rise with impacts on low-lying coastal areas, including urban centers[b] Storm surges increasing coastal damage, especially in Yemen[e] Saltwater intrusion in freshwater aquifers[b]	Longer dry seasons[b] Increases in drought frequency[f] Increased variability of floods[e]

Sources: (a) Christensen et al. (2013); (b) World Bank (2014); (c) ISIMIP projections; (d) IPCC (2013); (e) World Bank Climate Change Knowledge Portal[155]; (f) Zittis et al. (2018).

Table 4.5: Summary of climate change impacts on key sectors and livelihoods for Mashreq countries

Agriculture, livestock and fisheries	Water	Urban areas and human health	Ecosystems
Slight increase in crop productivity to mid-century, but 30-50 percent declines in northeast and southern Iran as per ISIMIP projections[a] Longer dry seasons that can impact irrigated agriculture, and shift vegetation and agricultural zones[b] Shorter crop growing periods[b] Increased risks of pests and diseases[c] Physiological risks to livestock and impacts on quality and quantity of feeds[b] Declines in fisheries, especially in Yemen, Iran, and Syria[d] Negative impacts on food security through reduced agricultural output and increased dependency on imports[b]	Decreases in surface and groundwater, declines in groundwater recharge (25 percent by 2040–2050)[e] Reduced water supply and river runoff in upstream and downstream countries due to decreased snow cover in mountain areas in Lebanon, Syria, Iraq and Iran[b] Shift in peak flows of melt water, decrease of 25–55 percent of annual surface runoff in eastern Anatolian mountains, impacting Euphrates and Tigris[b] Reduction in daily mean surface flow of 17 percent to 2060 of tributaries of the Jordan River[f] Disproportionate impacts of water scarcity on vulnerable groups, including women[g]	Temperature and humidity extremes leading to higher exposure to heat stress[b] Highest increases in wet bulb temperatures in coastal areas and urban areas (often located along the coast), including due to the urban heat island effect[h] Indirect impacts of heat and drought on health through air pollution, respiratory, and infectious diseases[i] Compounding risks make it more difficult to manage viral and vector-borne diseases and food- and water-borne diseases[i] Impacts of drought on urban water systems and water stress[b]	Impacts on pastoral livelihoods and rangeland ecosystems[b] Increased wildfires, biodiversity loss, vulnerability to invasive species[b] Desertification, especially in the western Mashreq[b] Salinization, land subsidence, and erosion in coastal, wetland, and riverine ecosystems (particularly in Iraq and Iran)[b] Significant drying of Euphrates and Tigris under RCP 8.5 to end of century, per ISIMIP projections[a] Salinization of Euphrates, Tigris, and Jordan rivers and of the Litani river basin in Lebanon

Sources: (a) ISIMIP projections; (b) World Bank (2014); (c) Mbow et al. (2019); (d) Wodon et al. (2014); (e) ESCWA (2019); (f) Samuels et al. (2010); (g) World Bank (2018); (h) Coffel et al. (2018); (i) Lelieveld et al. (2014); (j) Ramadan et al. (2013).

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155. See World Bank Climate Change Knowledge Portal projections for the MENA region: https://climateknowledgeportal.worldbank.org/region/middle-east-north-africa/climate-data-projections.

4.3 MOBILITY DRIVERS AND PATTERNS IN MASHREQ COUNTRIES

Mobility is already significant in the Mashreq countries. Drawing on data for the subregion and the literature on development and population dynamics, coupled with climate change impacts, this section examines the drivers of that mobility. It reviews historical and current patterns, including internal and international migration, displacement due to natural hazards and conflict, and instances of mobility in the context of climate change. As noted earlier, future migration was not modeled for this subregion, but the discussion here provides some indications of the potency of climate change as a driver of mobility.

4.3.1 Migration Dynamics

The Mashreq countries already have important internal, intraregional, and international mobility dynamics, including displacement due to conflict and disasters. There are also differences in the levels of internal mobility in each of the countries. Table 4.6 displays the results for five of the Mashreq countries of 2012–2013 Gallup surveys of internal migration (as analyzed in Mueller et al. 2015). It shows far higher rates of internal migration in Syria and Iraq, the countries that were afflicted by conflict at the time. Another analysis, counting both migrants and displaced people (internally and externally), found that from 2005 to 2015 alone, the migrant population in the Middle East more than doubled, and from 2011 onward, the rise was driven mainly by conflicts (Connor 2016).

Internal migration

Internal migration is closely related to economic, family, and conflict drivers, in some cases interwoven with environmental impacts. A recent study based on surveys in 2013–2015 found that unemployment, rural residence, and difficult economic conditions in the household are strong push factors for more educated young adults (Ramos 2019). Their choice of destination varies by country: abroad in the case of Jordan, internally in the case of Lebanon. There has been a pattern of rural-urban migration across the subregion since the 1960s; today only Yemen has more people living in rural areas than in urban areas (Wenger and Abulfotuh 2019).

Seasonal migration, including for agriculture, is also common, both within and across borders (Wenger and Abulfotuh 2019). For instance, Jordan and Lebanon have been receiving seasonal agricultural workers from Syria since before the conflict. Migrant agricultural workers are often low-skilled and employed informally, so they tend to not be covered by social protection systems. In most countries, there are relatively small gender differences in migration. As shown in Table 4.6, in Yemen and, to a lesser extent, in Iraq, surveys in 2012–2013 found women were likelier to be migrants than men, while in the other countries, men were slightly likelier to have moved (Mueller et al. 2015).

Table 4.6: Share of population in 2013 that reported migrating internally in the preceding five years

Country	% male	% female	% total	Sample size
Iraq	18.7	19.5	19.1	2,003
Jordan	4.4	3.8	4.1	2,000
Lebanon	5.4	5.1	5.2	2,001
Syria	24.3	23.1	23.7	2,047
Yemen	3.4	8.3	5.9	2,000

Source: Gallup (2013),[156] cited in Mueller et al. (2015).
Note: The survey question asked, "Did you move from another city or area within this country in the past five years?" The numbers reflect those who responded "yes." These results are based on country-level samples, which have a margin of error from ±2.1 to ±5.3. Subgroups (such as gender) from country-level samples have a greater margin of error than the country-level sample. All country-level analyses use country weights. Data were collected in 2012–2013, before the onset of the conflict in Yemen.

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[156] See Gallup (2013), "381 Million Adults Worldwide Migrate Within Countries," May 15, 2013. https://news.gallup.com/poll/162488/381-million-adults-worldwide-migrate-within-countries.aspx (does not include data at the level of detail presented here).

International migration

International mobility includes regular and irregular labor migration, forced migration, and mixed flows. The vast majority of international migrants in the Arab region stay within the region, and most labor migrants travel to neighboring Gulf countries (Bahrain, Kuwait, Oman, Saudi Arabia, and the United Arab Emirates), but there are also flows to Europe and North America (ESCWA and IOM 2015). Women and children, who make up an important share of migrants, often move to join family members who are already abroad. As shown in Figure 4.16, international migrant flows increased in most of the subregion from the 1990s to 2015, though with different balances of in- and out-migration across countries (Abel and Cohen 2019). The patterns of migration have also changed, from mostly permanent migration to the Persian Gulf, for example, to circular mobility across Lebanon, Jordan, and the Gulf States (Burger et al. 2014). Recent conflict in the subregion has also contributed significantly to these flows, especially since 2011 (Connor 2016). For Yemen, Lebanon, and Jordan, remittances from international migrants amount to relatively large shares of GDP: 16.7, 14.3, and 9.9 percent, respectively, in 2019.[157] In Iran and Iraq, however, remittances only equal 0.3 and 0.4 percent of GDP, respectively.

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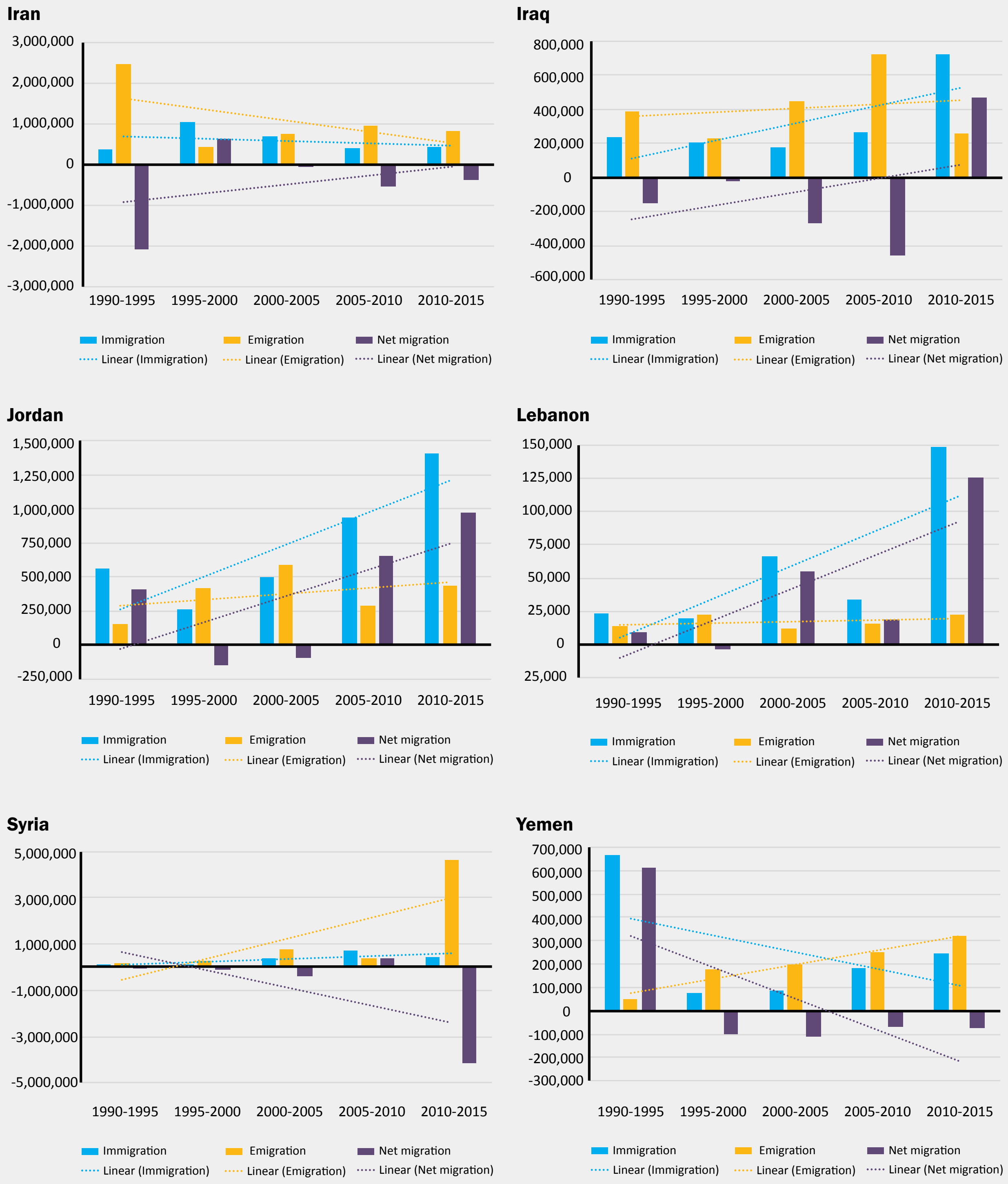
[157] See World Bank data for personal remittances as % of GDP: https://data.worldbank.org/indicator/BX.TRF.PWKR.DT.GD.ZS?locations=IR-IQ-JO-LB-SY-YE. The latest available data for Iran are from 2018, and for Syria, from 2007 (when remittances amounted to 2.6 percent of GDP).

Figure 4.16: Trends in international migration in Mashreq countries, 1990–2015



Source: Abel and Cohen (2019).

Conflict and displacement

Conflict has been a recent common denominator for countries in the Mashreq. Between 2015 and 2020 alone, conflicts resulted in 336,000 fatalities in the subregion (Figure 4.17).[158] Iraq, Syria, and Yemen have seen the largest losses, but with different trends and timelines. These last two decades of intense conflict have also resulted in a substantial number of refugees and internally displaced persons in the subregion (Table 4.7). Between 2015 and 2019, there were 16.8 million new internal displacements due to conflict, about 60 percent of them in Syria, and the rest almost entirely in Iraq and Yemen.[159] These far exceed the 1.2 million new internal displacements brought on by disasters, including weather-related, for the same period, though the latter are already substantial.

Table 4.7: New conflict and disaster internal displacement, by country and year, 2015–2019

			New Disaster Displacements			
Country	**2015**	**2016**	**2017**	**2018**	**2019**	**Total**
Iran	5,400	78	225,000	74,000	520,000	**824,478**
Iraq	23,000	0	3,900	69,000	37,000	**132,900**
Jordan	0	0	160	2,000	46	**2,206**
Lebanon	110	0	0	0	4,300	**4,410**
Syrian	0	0	2,300	27,000	17,000	**46,300**
Yemen	83,000	45,000	13	18,000	31,000	**177,013**
Total	**111,510**	**45,078**	**231,373**	**190,000**	**609,346**	**1,187,307**
			New Conflict Displacements			
Country	**2015**	**2016**	**2017**	**2018**	**2019**	**Total**
Iran	0	0	0	0	0	**0**
Iraq	1,114,000	659,000	1,379,000	150,000	104,000	**3,406,000**
Jordan	0	0	0	0	0	**0**
Lebanon	3,000	110	200	0	0	**3,310**
Syrian	1,300,000	2,200,000	2,911,000	1,649,000	1,847,000	**9,907,000**
Yemen	2,175,000	478,000	160,000	252,000	398,000	**3,463,000**
Total	**4,592,000**	**3,337,110**	**4,450,200**	**2,051,000**	**2,349,000**	**16,779,310**

Source: Internal Displacement Monitoring Centre, Global Internal Displacement Database: https://www.internal-displacement.org/database/displacement-data.

Conflicts have also resulted in important flows between Mashreq countries. In total, the UN High Commissioner for Refugees estimates that there were 2.8 million refugees in the subregion at the end of 2020.[160] Lebanon and Jordan are among the top five host countries for refugees relative to population in the world, with Lebanon at 1 in 8 and Jordan at 1 in 15 (UNHCR 2021b). The subregion also includes the largest source country of refugees and asylum-seekers globally—Syria, at 6.7 million. The subregion has multiple refugee camps, but a large share of displaced people live in individual housing, often in urban areas (World Bank 2017a); as of April 2021, that was the case for 95 percent of Syrian refugees.[161]

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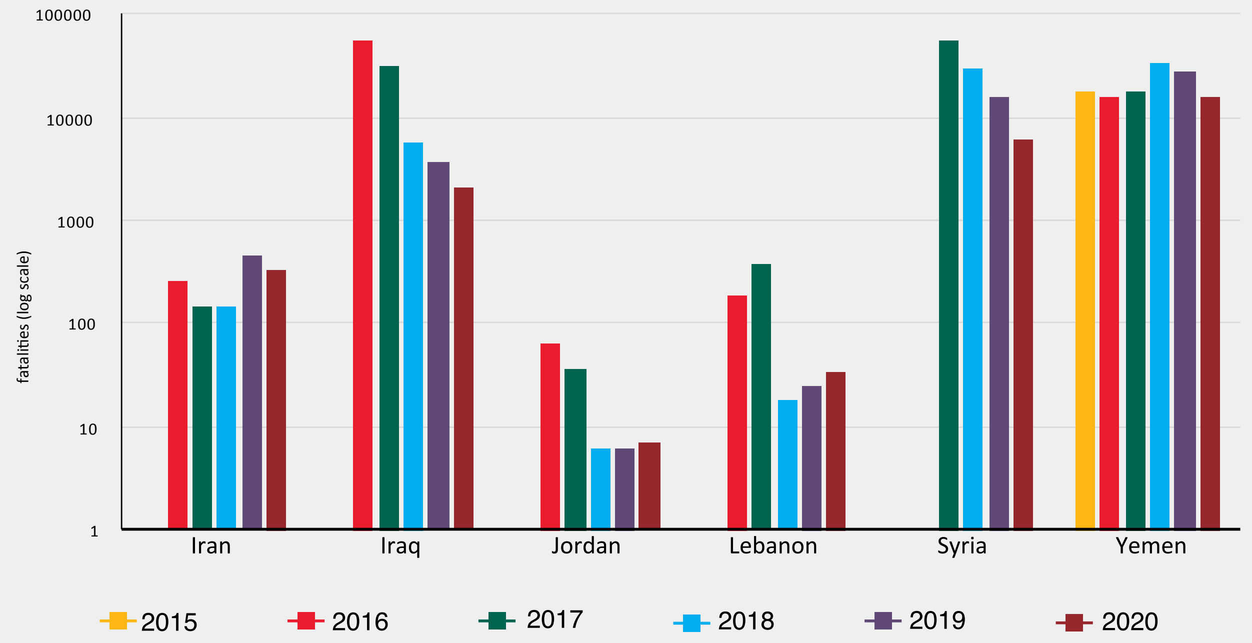
[158] See ACLED Data Dashboard: https://acleddata.com/dashboard/.

[159] See IDMC Global Internal Displacement Database: https://www.internal-displacement.org/database/displacement-data.

[160] See UNHCR Refugee Data Finder: https://www.unhcr.org/refugee-statistics/download/?url=RQ90m3 (accessed July 3, 2021).

[161] See the UNHCR Syria Regional Refugee Response data platform: https://data2.unhcr.org/en/situations/syria (accessed May 18, 2021).

Figure 4.17: Conflict-related fatalities by year and country, 2015–2020



Source: ACLED Data Dashboard, https://acleddata.com/dashboard/.
Note: Yemen is the only country for which there is information for 2015. Syria is also missing information for 2016.

Displaced populations often face dire living conditions, which are particularly harsh in refugee camps. Food insecurity and poor access to drinking water and sanitation are among the most pressing challenges (World Bank 2017a). In 2020, 58 percent of Syrian refugee families in Lebanon, for example, lived in shelters that were overcrowded, below humanitarian standards, or in danger of collapse (UNHCR, UNICEF, and WFP 2021). In addition, 89 percent of Syrian refugees were living in extreme poverty, up from 55 percent in 2019. Compounding shocks add to these vulnerabilities. A study on Jordan, the Kurdistan Region of Iraq, and Lebanon estimates that 4.4 million people in host communities and 1.1 million refugees and internally displaced people have been driven into poverty in the immediate aftermath of the COVID-19 crisis (JDCFD, World Bank Group and UNHCR, 2020).

4.3.2 Environmental and Climate Migration

Although socioeconomic factors continue to be the main drivers of migration in the Mashreq, changing environmental conditions—including, increasingly, climate change—can accentuate drivers of migration and add new layers. A global meta-analysis of climate-related migration studies found that in the Middle East and North Africa region, environmental factors appeared to increase migration, but only slightly (Hoffmann et al. 2020). Various case studies conducted in the Mashreq region, however, have highlighted how environmental change can induce mobility: for example, prolonged displacement as a result of water stress in Iraq (IDMC 2020b), rural-urban migration linked to reduced groundwater levels in Iran (Khanian et al. 2018), or acute forced displacement due to flooding in Yemen (OCHA 2020).

Extreme events such as heavy rainfall, flooding, and cyclones are known drivers of displacement and mobility. Data on disaster and displacement in the Mashreq are scarce and often provide conservative estimates (IDMC 2020a); that said, as shown in Table 4.7, there were 1.2 million new internal displacements brought on by disasters, including weather-related, between 2015 and 2019. About 70 percent of these were due to the 2017 earthquake and the 2019 floods in Iran. In Yemen, cyclones Chapala (2015) and Luban (2018) and other flood events caused the largest displacements; in Iraq, both floods and droughts were triggers. Climate change is expected to increase the scale and intensity of natural hazards such as floods and storms in the Mashreq subregion (Table 4.4). Such events could continue to act as push factors for displacement and, if left unmanaged, could affect increasing numbers of people.

Slow-onset climate change impacts, meanwhile, including reduced water availability, land degradation, sea-level rise, and groundwater and soil salinization, could affect agriculture, food security, livelihoods, health, and assets in the subregion. Climate change could thus amplify existing mobility trends, hinder seasonal movements, change migration patterns (e.g. from temporary to permanent), and deprive people of traditional coping strategies (Wenger and Abulfotuh 2019). For instance, a study in Iran found that factors such as average annual temperature and precipitation levels affected inter-provincial migration, after controlling for other usual predictors (Shiva and Molana 2018). In particular, increasing temperatures and precipitation declines were shown to increase out-migration, while better income and welfare opportunities were pull factors in the choice of migration destinations. Another study in Iran found the overall vulnerability of rural households to increasing water stress was associated with poverty, lack of income alternatives, and a lack of institutional adaptation policies (Schmidt, Gonda, and Transiskus 2020). In Yemen, a study found that climate variables were likely to affect the attractiveness of destination areas, but were not predictive of migration out of source areas (Joseph and Wodon 2013).[162]

As an already water-scarce region with limited arable land, the Mashreq could see increased droughts and a decline in overall water availability become important drivers of migration in the subregion. Syria, for instance, has experienced rural–urban migration spurred by drought and environmental degradation since the mid- to late 1990s; it is estimated that around 40,000–60,000 families migrate from rural to urban areas each year because of droughts (World Bank 2020c). Many rural people in Syria work in agriculture, but there is little irrigation. As a result, the 2007–2010 drought has been linked to the loss of rural livelihoods, farm and village abandonment, and out-migration and displacement, particularly in the eastern part of the country (Burger et al. 2014; Kelley et al. 2015; Palinkas 2020). Similarly, in southern Iraq, where water scarcity and pollution have increased significantly since around 2007, water shortages were estimated to have triggered almost 15,000 new displacements in the governorates of Thi-Qar, Missan, and Basra as of January 2019 (IDMC 2020b).

The effect of droughts on migration depends in part on the prevalence of agricultural livelihoods. For example, in a study in the Kurdistan Region of northern Iraq, where less than 20 percent of respondents worked in agriculture, the three main reasons for migration were found to be economics, family/marriage, and security (Eklund and Pilesjo 2012). Individuals and households migrated internally (to urban and rural destinations) and also internationally. While these migrants could be seen as having low vulnerability to climate impacts, environmental factors could still be interwoven with economic factors for non-agricultural households.

A changing climate can also affect traditional intraregional mobility patterns. Pastoral nomadism (grazing and browsing) is still practiced by Bedouins living in the Badia, the semiarid and arid area of the northern Arab Peninsula shared by Jordan, Lebanon, Iraq, and Syria, although sedentarization is increasing (Kingdom of Jordan 2016; Ghattas et al. 2013). Nomadic Bedouins are vulnerable to climate change impacts and have limited resources to adapt to them. These groups have been badly affected by droughts, suffering important herd losses, and many have settled in urban areas—in Syria, often in informal settlements (Verner et al. 2013).

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[162] It should be noted that indirect effects (e.g. changing water availability for irrigation) were not part of the study design.

Several studies have highlighted environmental thresholds that, when crossed, may induce environmental and climate migration (Owen and Wesselbaum 2020; Rigaud et al. 2018; McLeman 2018). This is particularly likely when such thresholds are combined with other social and economic factors that exceed people's ability to cope (H. Adams and Kay 2019; Hunter, Luna, and Norton 2015; Meze-Hausken 2008). In drylands, extreme heat, drought, and unreliable precipitation can lead to declines in pastoralism and a shrinking of the average farm size, and could lead to an increase in labor migration and rural to urban migration (Rigaud et al. 2018).

As noted, water stress exacerbated by climate change is a particular concern in the Mashreq, which is already highly dependent on irrigation. It is also expected to accelerate land degradation, and more than half of all land and a quarter of arable land in the subregion is already degraded (World Bank 2019b). In Iraq and Syria, over 60 percent of the land is severely degraded, and in Jordan, the share of severely degraded land is as high as 80 percent. Studies show that if water scarcity increases by 20 percent, then cropland under irrigation is expected to decrease across the subregion, potentially leading to a return to low-productivity rainfed agriculture (Taheripour et al. 2020). Farmers could try to cope by extending areas under cultivation at the expense of key ecosystems, including remaining forests and natural habitats and their hydrological services, leading to feedback cycles.

With the Mashreq's key ecosystems already highly vulnerable to changes in climatic conditions (World Bank 2014; Gao and Giorgi 2008), combined with projected drying trends and temperature increases, the subregion's most sensitive ecosystems risk becoming unproductive, which could act as a compounding driver for migration. At the same time, rising temperatures and extreme heat threaten to make some of the Mashreq countries' densely populated urban areas difficult to live in for parts of the year, particularly along the coast, where thresholds of human heat tolerance are projected to be increasingly exceeded (Figure 4.15).

Climate change can prolong and intensify other extreme events that cause displacement. Areas such as Yemen's coastal regions, which are vulnerable to storm surges, or flood-prone areas in Iran and Iraq, could face damaged productive assets (e.g. infrastructure, livestock, and natural resources), with threats to lives and livelihoods. Over time, temporary displacement could turn into more permanent migration along a continuum of more voluntary to more forced, as people might seek more secure livelihoods and conditions of habitability that are less affected by climate hazards.

4.4 THE NEXUS OF CLIMATE CHANGE, FRAGILITY, AND MOBILITY

Climate change, fragility, and mobility can be interconnected, with effects that manifest themselves at the local and national level while also transcending national borders (World Bank Group 2020). There is a growing body of research indicating that scarcity and lack of access to land, water, and natural resources, as well as climatic events related to deviations in temperature and precipitation patterns, can sometimes exacerbate important drivers of conflict (Abel et al. 2019; Mach et al. 2019; United Nations and World Bank 2018; Burke, Hsiang, and Miguel 2015). Recent research has also explored relationships between rising temperatures and increases in violence related to scarcity of cropland and other key environmental resources (Miles-Novelo and Anderson 2019; Levy, Sidel, and Patz 2017; Mares and Moffett 2016). Disputes over scarce water resources—within and between communities, between citizens and the state, and between neighboring states—have received particular attention (United Nations and World Bank 2018). Notably, in a changing climate, displacement and migration in fragile contexts can itself increase pressure on receiving areas and thus contribute to further unrest (Abel et al. 2019).

It is important to recognize the complexity and interconnectedness of these issues, however, and not oversimplify the linkages between climate change, conflict, and fragility (Borgomeo et al. 2021; Selby et al. 2017; Brzoska and Fröhlich 2016). Some analysts argue that evidence of these linkages has not been examined carefully enough, or that existing studies present ambiguous and non-generalizable results (C. Adams et al. 2018; Buhaug et al. 2014; Salehyan 2014). Indeed, in the broader Middle East and North Africa region, cooperation to address water risks has been found to be more common than conflict, both within countries and with regard to transboundary rivers and aquifers (Borgomeo et al. 2021). Such cooperation can range from verbal agreements over water-sharing, to joint construction of infrastructure.

Still, several escalated disputes over land and water resources have been observed in Mashreq countries, warranting further examination (Abel et al. 2019). In Yemen, for instance, water scarcity has led to conflicts over water wells (Werz and Hoffman 2013). In Iran, a study found that reduced rainfall and droughts from 2007 to 2014 contributed significantly to interpersonal disputes in Iran's provinces (Feizi, Janatabadi, and Torshizi 2019). Others have pointed to the linkages between climate-related stressors, namely drought, and other social, economic, and political factors and the Arab Spring (Werrell and Femia 2013). In Syria, the 2007–2010 drought has been identified as a contributing factor in the country's ongoing conflict, acting through impacts on vulnerable livelihoods and food insecurity and on rural-urban migration (Kelley et al. 2015; De Châtel 2014). The precise role of drought is difficult to gauge, however, given the vast number of intermediating variables contributing to the conflict. Conversely, fragility, political instability, and conflict can slow or reverse gains in resource security, particularly water (Borgomeo et al. 2021; World Bank 2018).

In-migration flows can also increase pressure on receiving areas, exacerbate fragility, and deepen poverty (Abel et al. 2019). A sudden influx of displaced populations can put pressure on host cities and areas, which may already face difficulties in providing basic services to growing populations (Borgomeo et al. 2021; United Nations and World Bank 2018). Refugees from the Syrian crisis, for example, have placed an unplanned burden on water services and resources in Jordan and Lebanon (ESCWA 2019; World Bank 2018). Migrants can often find themselves at the center of frictions over land and resources in host communities (United Nations and World Bank 2018). For instance, a large percentage of Syrian refugees in Lebanon are living in the main agricultural areas of the North and the Bekaa, putting additional pressure on farmlands, rangelands, groundwater, and forest resources.[163] Some people displaced by conflict lack access to water and other resources, including in urban areas (World Bank 2018). Their vulnerability can also be compounded by unclear property rights, scarcity of formal documentation, weak mechanisms for integration, and lack of access to health care, jobs and social services (United Nations and World Bank 2018; Sahin Mencutek and Nashwan 2020). Moreover, the poorest people might not have the means to migrate (Castelli 2018), and thus be trapped in difficult situations, facing the compounding impacts of conflict and climate change.

In the Mashreq countries, efforts to understand the roles of climate change, disasters, and natural resource degradation as stress multipliers, particularly in fragile and conflict situations, need to be paired with an urgent shift towards long-term pathways for building resilience to future shocks (Borgomeo et al. 2021). There is potential for synergies between adaptation and resilience-building and conflict risk reduction, as similar factors can determine vulnerability to both (Mach et al. 2019). For example, it is often not water scarcity itself that leads to tensions, but the way that resources are managed (Pedraza and Heinrich 2016).

People- and area-based approaches can help to address grievances and social inclusion barriers, notably gender gaps, related to access to water resources and services in protracted crisis situations (Borgomeo et al. 2021). These interventions need to be aligned with investments in national-level institutions and infrastructure, both of which are essential to ensure sustainable water management and service delivery. Climate-informed measures that address these or similar factors can support food, water and livelihood security, help diversify economies, and eventually contribute to equitable growth, sustainable development, and human security (Mach et al. 2019; World Bank Group 2020). Box 4.2 looks more closely at connections between climate, mobility, and conflict in Jordan, as well as policies and initiatives to address them.

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[163] See the FAO's "Lebanon at a Glance" website: http://www.fao.org/lebanon/fao-in-lebanon/lebanon-at-a-glance/en/ (accessed May 16, 2021).

Box 4.2: How climate change, mobility, and fragility intersect in Jordan

Since the mid-20th century, Jordan has seen rapid population growth due to large inflows of refugees from the Palestinian territories and, more recently, Syria and Iraq (Kumaraswamy and Singh 2017). The country hosts one of the largest shares of refugees per capita in the world (UNHCR 2021a). Most refugees in Jordan live in urban areas, or else in refugee camps in the north. Jordan has also seen large recent rural-urban migration, driven in part by land and water resource constraints (Wenger and Abulfotuh 2019). Rapid urbanization has put further stress on limited resources and services, increased energy demand, and pushed agriculture to more arid and degraded areas in the east and south.

At the same time, Jordan is considered highly vulnerable to climate change, which is projected to continue making the country warmer, drier, and subject to more extreme events, including droughts and floods. Water scarcity is one of the country's main development challenges. As climate change reduces water availability even more, underground aquifers—the main source of drinking water—will be under increased pressure, as will the Jordan and Yarmouk rivers, which are used for irrigation and are resources shared with neighboring countries (ESCWA 2019; Rajsekhar and Gorelick 2017).

Climate change could also reverse some of the increases in crop and livestock productivity that Jordan has seen in recent decades (World Bank Group 2018). Reduced rainfall and increased temperatures are expected to affect the production of staple crops such as wheat and barley (Verner et al. 2013). Droughts, desertification, and the degradation of rangelands, meanwhile, could harm livestock production.

The spillover effects of the COVID-19 pandemic have further increased pressure on food security. As of mid-2020, 21 percent of refugee households in host communities were considered food-insecure, and 53 percent of Jordanians were considered vulnerable to food insecurity (World Bank et al. 2020). Households in Jordan already spend over 30 percent of their income on food (Jordan Department of Statistics 2018).

To address these compounding challenges, Jordan has outlined national strategies and priorities for adaptation to climate change and resilience-building. Jordan's First Nationally Determined Contribution (NDC) highlights the country's unique position in between two major areas of instability and prolonged conflict and discusses migration as a key demographic challenge that increases demand for energy and electricity (Kingdom of Jordan 2016). Adaptation actions included in the NDC—such as crop diversification and efficient water use—are aimed at food and water security. Jordan is pioneering water augmentation solutions at the regional level by collecting wastewater, treating to safer levels, and reusing around 90 percent of it, mainly in agriculture (ESCWA 2019).

In concert with national policy frameworks, reform programs can help create more resilient jobs, recover economic stability, and sustain key livelihoods and their resources systems, while at the same time supporting vulnerable migrant populations. For example, Jordan's Second Equitable Growth and Job Creation Programmatic Development Policy Financing (World Bank 2019c) focuses on improving conditions for the poor, including supporting Syrian refugees in Jordan through more flexible and integrated labor markets and better and more efficient social assistance.

Reform programs can be combined with targeted interventions to improve key services and support sustainable livelihoods for both host populations and migrants. Examples include:

- The Mitigating Impact of Syrian Displacement Project, completed in 2015, provided urgently needed health care services and food and fuel subsidies for both Jordanians and Syrian refugees (World Bank 2015). This helped reduce increased pressure from large influxes of refugees on services for Jordanian citizens, while accommodating refugees in the Jordanian public system.

- The ongoing Jordan Emergency Health Project has supported the continued provision of critical health care services to target populations at a time when an influx of Syrian refugees to the country has severely strained the delivery of vital basic services (World Bank 2017b).

- The Jordan Education Reform Support Program-for-Results Project, also ongoing, aims to benefit both Jordanian and Syrian refugee children (World Bank 2017d). It has helped expand access and improve quality of early childhood education, improve teaching and learning conditions, monitor student learning, and strengthen the education system's capacity to manage an increasing number of schools and students, notably due to enrollment of a large number of refugee children in Jordanian schools.

- The Badia Ecosystem and Livelihoods Project, completed in 2017, has helped enhance ecosystem services through participatory approaches in the Badia (World Bank 2017e). The project aimed to develop sustainable alternative livelihoods with close involvement of communities, by establishing an ecotourism corridor and supporting adaptive rangeland management through the construction of multipurpose water harvesting structures.

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Chapter 5

Environmental and Climate-Related Mobility in Small Island Developing States

This chapter discusses environmental and climate-induced mobility drivers, trends and patterns in Small Islands Developing States (SIDS). Internal climate migration projections for SIDS have not been modeled, as the approach, which uses 14-kilometer grid cells, is not easily applicable to small islands.[164] Even for SIDS with larger land areas (such as Fiji or Jamaica), climate migration would not be well captured by the model, so the resulting projections would not be useful. The analysis in this chapter thus draws on a review of the literature on environmental migration in SIDS, as well as multiple data sources.

The chapter begins with an overview of the development and economic context of SIDS, their population dynamics, and geographic characteristics, to set the stage for understanding how climate change could affect key economic sectors and livelihoods. Next, the chapter describes climate change trends in the Pacific, Indian Ocean, and Caribbean SIDS, particularly with regard to rising sea levels, ocean warming and acidification, extreme weather events, and droughts. The chapter then examines mobility in the context of climate change in SIDS. It ends with recent policy directions, including examples of how SIDS are proactively integrating resilience-building and planning for environmental and climate-related mobility into national policies and regional and global dialogues.

Key Messages

- **Climate change impacts are increasingly threatening development gains in SIDS. The Pacific and Indian Ocean SIDS, in particular low-lying islands, are most vulnerable to the effects of sea-level rise, through increased saltwater intrusion, flooding, erosion, and damage to critical infrastructure. In the Caribbean, the frequency and intensity of tropical storms, coupled with the effects of temperature increases and changes in precipitation, are putting stress on livelihoods, ecosystems, and food systems.**

- **Island nations with economies that are highly dependent on agriculture, fisheries, and tourism are at particular risk. As climate change continues to put stress on terrestrial and marine ecosystems that are the backbone of key economic sectors, and the effects of sea-level rise and coastal erosion grow more severe, SIDS could face serious development challenges, which could also be compounded by other shocks.**

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[164] A full description of the methods is provided in Appendices B and C.

- **Historically, people have adjusted to social and environmental changes, and migration has been one of several coping strategies. Climate change now poses great risks to the habitability of some areas and could result in the loss of customary land, an integral part of individual and community identity in many SIDS. This sense of loss affects perceptions of environmental and climate-induced migration.**

- **SIDS have been leaders in proactively integrating climate resilience and mobility in the context of climate change in regional and global dialogues. A central aspect of this is the agenda on loss and damage, put forward by the Alliance of Small Island States (AOSIS), which was enshrined in Article 8 of the Paris Agreement.**

- **SIDS are making headway on a range of options for building resilience at the nexus of climate, mobility, and development. SIDS are implementing national policy frameworks that explicitly address migration and relocation, while also implementing measures to enable people to adapt in place, including the consolidation of geographic areas and shoring up of habitability of population centers, as well as investments to strengthen the adaptive capacity of key economic sectors.**

5.1 SUBREGIONAL CONTEXT

5.1.1 Development and Economic Context

The designation Small Island Developing States (SIDS) was developed at the 1992 Earth Summit in Rio de Janeiro to describe a group of countries facing unique social, economic, and environmental challenges (UN-OHRLLS 2013). In practice, SIDS are a heterogeneous group, not all of which are islands, small, or sovereign states (Kelman 2018), including 38 UN Member States and 20 non-UN members.[165] The vast majority of SIDS are in three subregions that are the main focus of this chapter: Oceania (in the Pacific), the Indian Ocean, and the Caribbean.[166] Though they have much in common, those subregions have different geographies, histories, socio-economic realities, and development trajectories.

Collectively, SIDS tend to outperform other developing countries in GDP terms (OECD 2018), though some are very small economies. Among the Oceania SIDS, GDPs range from US$47.3 million in Tuvalu to US$5.5 billion in Fiji in 2019; among Indian Ocean SIDS, from US$1.2 billion in Comoros to $14.0 billion in Mauritius; and in the Caribbean, from US$2.1 billion in Saint Lucia to US$88.9 billion in the Dominican Republic.[167]

About three-quarters of SIDS are classified by the World Bank as high- or upper-middle-income countries, though this does not always translate to a high quality of life or even adequate public services for the entire population—and some SIDS are very poor.[168] Within Oceania alone, SIDS' gross national income (GNI) per capita in 2019 ranged from US$2,370 in the Solomon Islands to US$16,630 in Nauru. In Indian Ocean SIDS, it ranged from US$1,400 in Comoros to US$15,930 in the Seychelles, and in Caribbean SIDS, from US$1,330 in Haiti to US$11,080 in Saint Lucia.[169] Human Capital Index Values range from 0.42 in the

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[165] For a list of SIDS, see https://sustainabledevelopment.un.org/topics/sids/list. For an overview, see "About Small Island Developing States" on the UN-OHRLLS website: https://www.un.org/ohrlls/content/about-small-island-developing-states.

[166] Cabo Verde is in the Atlantic Ocean, and Timor-Leste, though close to Oceania, could be considered part of Southeast Asia. The chapter discussion is not meant to extensively cover SIDS that are considered high-income. In addition, Belize, Cuba, and Guyana were modeled as part of the Latin America regional results in the first Groundswell report, while Guinea Bissau was modeled as part of the Sub-Saharan Africa regional results. Papua New Guinea and Timor-Leste were modeled as part of the East Asia and Pacific regional results presented in Chapter 2. The remaining SIDS were not modeled.

[167] See World Bank data on GDP (current US$): https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=TV-FJ-KM-MU-LC-DO.

[168] See World Bank Country and Lending Groups classifications (updated July 1, 2021): https://datahelpdesk.worldbank.org/knowledgebase/articles/906519. Haiti had been classified as a low-income country, but was upgraded to lower-middle-income after updating its economic data (Hamadeh, van Rompaey, and Metreau 2021). Note that not all SIDS are included in the World Bank classifications.

[169] Although 2020 figures are now available, 2019 data are provided here to reflect pre-pandemic conditions; as discussed in the text, several tourism-dependent SIDS saw their economies contract significantly in 2020. See World Bank data on GNI per capita, Atlas method (current US$): https://data.worldbank.org/indicator/NY.GNP.PCAP.CD?locations=SB-NR-KM-SC-HT-LC.

Solomon Islands to 0.50 in Samoa among Oceania SIDS; 0.41 in Comoros to 0.63 in Seychelles among Indian Ocean SIDS; and 0.45 in Haiti to 0.60 in Saint Lucia among Caribbean SIDS.[170] There are similarly large variations in SIDS' rankings on the Human Development Index: about one-fifth of the SIDS are rated as having only medium or low human development, with Haiti ranked at No. 170 and Guinea-Bissau, at No. 175 (UNDP 2020).

The unique characteristics of SIDS, particularly the smaller SIDS, and their generally small populations can pose challenges for development (UN DESA 2013). Dependence on trade and international markets makes them vulnerable to global forces, while geographic isolation reduces the capacity of many SIDS to compete with larger and more connected economies. The 2008 financial crisis significantly affected many SIDS, with GDP growth rates dropping to an average of 0.9 percent in 2009, compared with an average of 3 percent among all developing countries (OECD 2018).

Between 2000 and 2019, mainly after the financial crisis, the external debt of SIDS rose by 24 percentage points of GDP, to an average of 62 percent, even as it fell by 6.2 points across developing countries on aggregate (Bouhia and Wilkinson 2021). A recent UN analysis found that the combination of environmental vulnerability and heavy dependence on international flows of people and capital—through tourism, remittances, and foreign direct investment—makes SIDS some of the most vulnerable economies in the world (Assa and Meddeb 2021). Measured by a multidimensional index of economic vulnerability, 82 percent of 34 SIDS evaluated were found to have "high" or "very high" vulnerability, with Pacific SIDS making up seven of the top 10 (Kiribati was No. 1).

The COVID-19 pandemic has not been as severe in most SIDS as in other parts of the world, but the economic impacts have still been devastating, with their collective GDP projected to contract by 6.9 percent in 2020, versus 4.8 percent for all other developing countries (OECD 2021).[171] The main reason is the sharp drop in tourism, which was projected to reduce GDP by 16 percent or more in the most tourism-dependent SIDS, such as Antigua and Barbuda, Belize, Fiji, the Maldives, and Saint Lucia. Disruptions in global trade and commodity price fluctuations also took their toll. Though in the Caribbean, remittances from abroad recovered quickly from an early-pandemic drop and actually rose in 2020, flows to East Asia and the Pacific declined by an estimated 7.9 percent, affecting SIDS in the region (Ratha, Kim, and Plaza 2021). As noted, several SIDS were highly indebted even before the pandemic, and there are now concerns that without interventions, some countries could default on their debt (Bouhia and Wilkinson 2021).

Diversification in SIDS' economies varies considerably, with some mainly based on smallholder agriculture and fisheries and others with well-developed service industries. In some SIDS, agriculture and fisheries are important sources of employment and GDP. In Comoros, for example, those sectors represent 34.4 percent of employment and 33.1 percent of GDP; in Fiji, it is 17.6 and 11.8 percent, respectively, and in Haiti, 29.0 and 19.4 percent.[172] Coastal communities in SIDS are heavily reliant on marine resources for their livelihoods and food security.

Food security continues to be an issue in many SIDS, with high energy costs, limited infrastructure, and in some cases, a shortage of arable land, which puts pressure on food systems (FAO 2019). Malnutrition rates are high, due in large part to an agricultural economy concentrated on exports and local food consumption reliant on small subsistence farms and imports. Islands in the Caribbean and Oceania import 60 percent of their food, at a cost of about US$5 billion a year. Inadequate access to quality food has had serious health consequences in SIDS. Undernutrition is around 17 percent across all SIDS, and

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[170] The Human Capital Index calculates the contributions of health and education to worker productivity. The final index score ranges from 0 to 1 and measures the productivity as a future worker of child born today relative to the benchmark of full health and complete education. See World Bank data: https://data.worldbank.org/indicator/HD.HCI.OVRL?locations=SB-WS-KM-SC-HT-LC.

[171] This projection was based on economic data as of October 2020. No updated estimate is available for all SIDS combined, but it is possible that GDP contraction was smaller than projected; in April 2021, the International Monetary Fund estimated that the Caribbean countries' economies had contracted by 4.3 percent, for instance, and Other Emerging and Developing Asia, which includes several SIDS, but also non-SIDS, by 1.1 percent (IMF 2021).

[172] See World Bank data on employment in agriculture (% of total employment) (modeled ILO estimate): https://data.worldbank.org/indicator/SL.AGR.EMPL.ZS?locations=KM-FJ-HT and agriculture, forestry, and fishing, value added (% of GDP): https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?locations=KM-FJ-HT.

about 33 percent of the population of Caribbean countries is obese, with obesity rates among women double those among men.

Many SIDS are highly reliant on tourism, which provides jobs, income, and foreign exchange earnings. On average, tourism accounts for almost 30 percent of SIDS' GDP, according to data from the World Travel and Tourism Council (Coke-Hamilton 2020). For the Maldives, Seychelles, St. Kitts and Nevis, and Grenada, the share is over 50 percent. From 2000 to 2013, the number of international tourists visiting SIDS grew from 28 million to 41 million in 2013, and in the same period, exports from tourism grew from US$26 billion to US$53 billion (UNWTO 2014).

SIDS are disproportionately vulnerable to climate change impacts, including sea-level rise—and related coastal erosion, flooding, and reduced freshwater availability—as well as coral bleaching, loss of marine species, more frequent severe coastal storms, erratic weather patterns, and related socio-economic pressures (Hoegh-Guldberg et al. 2018). Even a global temperature increase of 1.5°C could lead to the loss of, or changes to, critical natural and human systems, and warming of 2°C or more would significantly heighten those risks.

More than 60 percent of the countries with the highest losses from disaster events in the world are SIDS.[173] Between 2000 and 2018, SIDS suffered US$22.7 billion in direct damages and innumerable aftershocks from 335 natural hazards (OECD 2018). Thirteen of the top 20 countries on the 2020 World Risk Index, which measures the risk of disasters arising directly from natural hazards, are SIDS, including seven of the top eight: Vanuatu, Tonga, Dominica, Antigua and Barbuda, Solomon Islands, Guyana, and Papua New Guinea (Bündnis Entwicklung Hilft and IFHV 2020).

Climate-related shocks, including those stemming from tropical cyclones, can affect economic growth rates for decades[174]—and several SIDS have experienced one or more major disasters in recent years. The devastation of Hurricane Dorian in the Bahamas, which killed 77 people and caused US$3.4 billion in damages (equivalent to almost a third of GDP), made the country the third-most affected by extreme weather events in 2019, according to Germanwatch's Climate Risk Index. For the period 2000–2019, Puerto Rico, Haiti, and the Bahamas are ranked No. 1, No. 3, and No. 6, respectively. Puerto Rico and Haiti have held top spots on that list for two decades due to several exceptionally severe hurricanes.[175] In the Pacific region, meanwhile, some SIDS are recognized as facing existential threats from climate change (Handmer and Nalau 2019).

5.1.2 Population Dynamics

Collectively, SIDS were home to an estimated 71.4 million people in 2019, but SIDS' populations vary widely: from about 11,000 in Nauru, to 11.3 million in Haiti (UN DESA 2019). A review in 2013 found the median population size of SIDS was about 195,000 (UN DESA 2013). The islands' demographics are very diverse, with thousands of ethnicities and languages, particularly in Oceania, and people living in urban, peri-urban, and rural communities alike.

Population growth tends to be low, averaging only 0.91 percent per year in 2015–2020, well below the 1.26 percent average for developing countries (UN DESA 2019), but it ranges widely—from 0.14 percent in Barbados (and less than 0.5 percent in several other SIDS), to 2.49 percent in Vanuatu and 2.60 percent in the Solomon Islands.

Population pyramids also show large differences among SIDS in terms of age composition (Figure 5.1). The average birth rate for SIDS declined from 27.6 per 1,000 in 1985–1990 to 18.5 in 2015–2020

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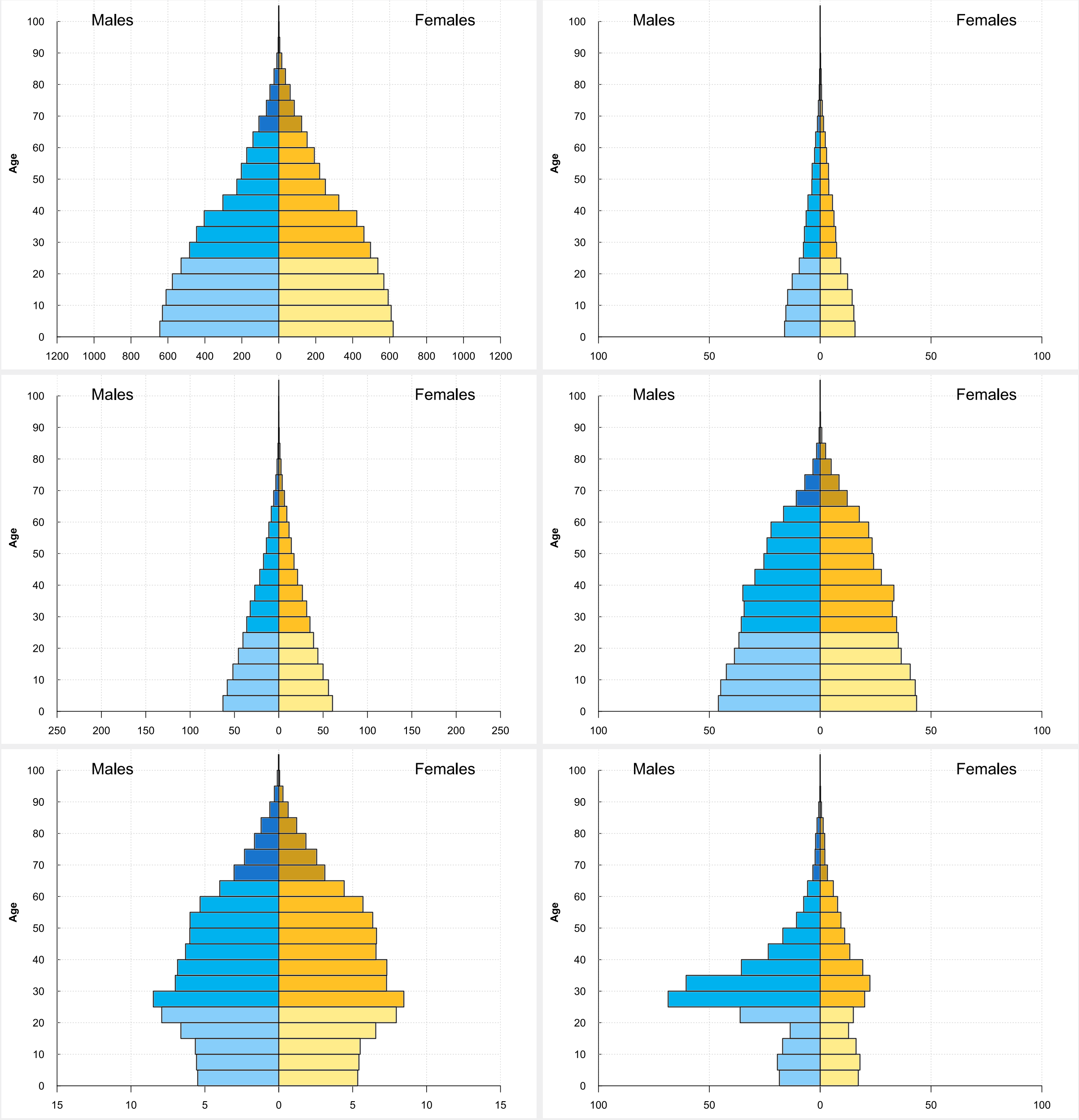
[173] See the Global Facility for Disaster Reduction and Recovery (GFDRR) web page on the Small Island States Resilience Initiative: https://www.gfdrr.org/en/sisri (accessed July 26, 2021).

[174] In a study of tropical cyclones from 1950 to 2008, Hsiang and Jina (2014) found that a 90th percentile event reduced per capita income by 7.4 percent two decades later, effectively undoing 3.7 years of average development.

[175] The Germanwatch Climate Risk Index includes metrics for death toll, deaths per 100,000 inhabitants, total losses in millions of US$ (PPP), losses per unit GDP in percent, and number of events (total 2000–2019).

(UN DESA 2019), but it, too, varies considerably, with multiple Caribbean islands averaging fewer than 12 births per 1,000, while Haiti and several Pacific SIDS exceed 24 per 1,000—topped by the Solomon Islands, at 32.7. Some islands including Haiti, São Tomé and Príncipe, and Comoros still have large young populations. SIDS such as Fiji, Saint Lucia, and the Maldives are at more mature stages of the demographic transition, with some signs of aging. Some SIDS, such as the Maldives, have substantially more men than women in the middle age range, indicating that more women are emigrating than men.

Figure 5.1: Age pyramids for selected SIDS. First row: Haiti and São Tomé and Príncipe; second row: Comoros and Fiji; bottom row: Saint Lucia and Maldives, 2020



Note: Population in thousands.
Source: UN DESA (2019).

5.1.3 Geography and Population Distribution

SIDS are generally characterized by a small overall land area, a high ratio of coastline to total area relative to larger continental countries, and low-lying coastal areas (UN-OHRLLS 2013). Many island nations are situated on active or extinct volcanoes and have relatively steep slopes ascending from the water's edge. Examples include Hispaniola (which includes the Dominican Republic and Haiti), Mauritius, and Fiji. Others were formed by the subsidence of ancient volcanoes, which disappeared below the surface of the ocean, leaving only the surrounding coral barrier reefs; over time, they solidified and became atolls. The latter, including Kiribati, Tuvalu, the Solomon Islands, and the Maldives (there are no coral atolls in the Caribbean), are low-lying and particularly at risk from flooding associated with sea-level rise, king tides,[176] and cyclones. Some Pacific islands have mixed reef and volcanic features.

SIDS share geographic features such as relative isolation from larger mainlands, but the degree of continental proximity varies across subregions. The Pacific Islands are considerably more remote than the Indian Ocean and Caribbean islands, resulting in distinct environmental, migration, and economic patterns. More than 3,000 miles away from Australia, the nearest continent, Samoa, the Marshall Islands, Tuvalu, Kiribati, and Tonga are among the world's most isolated states (Becker 2012). SIDS in Oceania are, on average, four to five times as far from the nearest continent as the average Caribbean country.

Islands are notable for endemic biodiversity due to their isolation and island biogeography. SIDS are home to unique flora and fauna, providing habitats for thousands of endemic species. Coral reefs form a critical part of biological diversity—10 percent of the world's coral reefs are in the Caribbean, 75 percent of known coral species live in ecosystems along the Pacific's East Melanesian Islands' Coral Triangle, and there are 10,000 shallow water marine species in the coastal areas of the Indian Ocean (UN-OHRLLS 2017).

Rainfall patterns, sea level, and weather in SIDS are strongly influenced by the El Niño Southern Oscillation (ENSO). During El Niño years, the central Pacific and the Caribbean are wetter than normal, while the western Pacific is drier, with more warm nights and hot days. La Niña events present the mirror image. Recent studies suggest that the frequency of El Niño events increases with rising global temperatures, and changes in El Niño and La Niña are expected to exacerbate the impacts of sea-level rise and may also increase the frequency of droughts and floods in South Pacific islands (Hoegh-Guldberg et al. 2018).

Atolls generally have lower rainfall than volcanic islands, which trap moisture from prevailing winds through a phenomenon known as orographic precipitation. High exposure to natural hazards such as cyclones, floods, earthquakes, tsunamis, and volcanic eruptions is a common trait of SIDS, though the specific configurations of hazards vary greatly across regions and countries (Shultz et al. 2016). Cyclone exposure is greatest in the Caribbean, but several islands in other subregions have significant exposure, including Fiji, Vanuatu, the Solomon Islands, Mauritius, and Comoros.

Around 26 percent of the land area across the SIDS is less than 5 meters above sea level—though there are large differences: While the Maldives and Tuvalu have their entire area at less than 5 meters above sea level, less than 4 percent of Haiti and less than 2 percent of Papua New Guinea is at such a low elevation (UN-OHRLLS 2013). Similarly, though on average, almost 30 percent of SIDS residents live at less than 5 meters above sea level, there are SIDS with most or all their people that close to sea level, and others with 6 percent or less. In many SIDS, large shares of the population are concentrated in a few coastal cities, which can put pressure on scarce resources and makes urban resilience a top priority (Mycoo and Donovan 2017). In Suriname, for example, more than 42 percent of the population as of 2018—about 239,000 people—lived in the capital, Paramaribo, which is at 3 meters above sea level (UN DESA 2018). Overall, about 68 percent of Surinamese live at less than 5 meters above sea level, the fourth-largest share among SIDS (UN-OHRLLS 2013).

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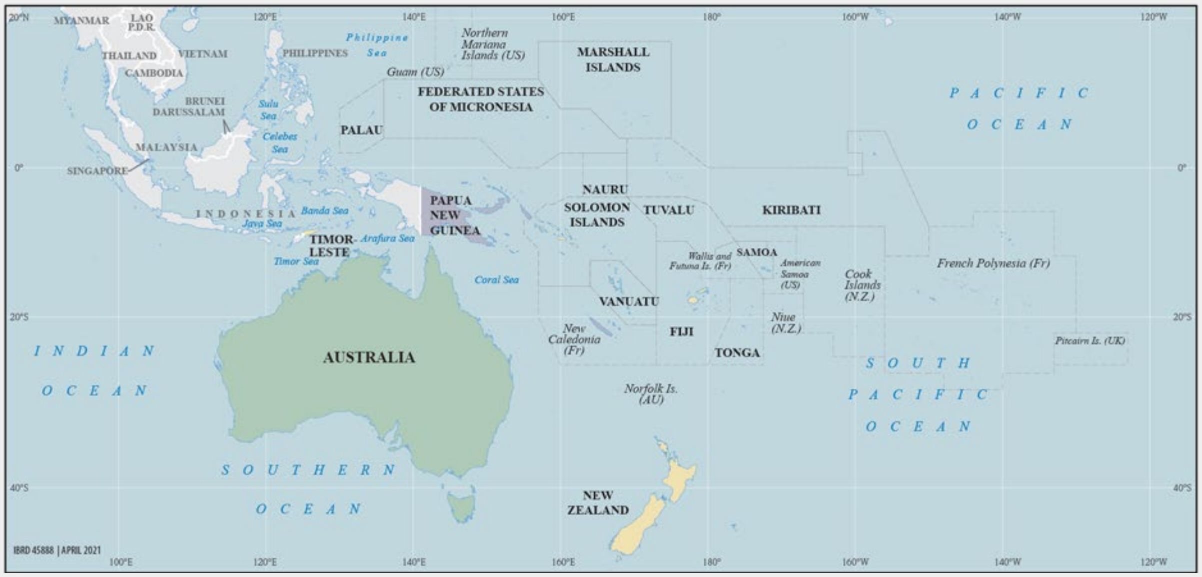
[176] King tides are uncommonly high tides caused by the alignment of solar and lunar gravitational pulls. See the U.S. National Ocean Service's "What is a king tide?" explainer: https://oceanservice.noaa.gov/facts/kingtide.html.

Figure 5.2: Oceania regional map: Micronesia, Melanesia, Polynesia, and Australasia



The tropical Pacific Islands (broadly known as Oceania—see Figure 5.2) range from large landmasses such as New Guinea, which has 83 percent of the region's total land area, to Nauru and Tuvalu at less than 30 square kilometers.[177] The countries' landscapes and the quantity of arable land vary widely. Tuvalu has porous soils of little fertility that can support a narrow range of crops, mostly in subsistence agriculture (Government of Tuvalu 2007). Larger islands such as Fiji, Samoa, and Tonga, however, are more fertile (Becker 2012). The Melanesian islands to the southwest of the Pacific have a higher average elevation than much of the rest of Oceania and make up 98 percent of the total land area (Kumar et al. 2020). Micronesia makes up 0.3 percent of the total land area and a small portion of the population. In contrast, Polynesia makes up only 1 percent of the Pacific land area but is home to over 13 percent of the population.

Climatologically, the SIDS in the western Pacific have a tropical humid or monsoonal climate, whereas the SIDS in Polynesia have a temperate humid climate. In American Samoa, for example, temperatures range from 24° to 30°C throughout the year, dipping slightly during the Austral winter (lowest in August), and rainfall is highest during the Austral summer (October–May). Patterns are similar in the Solomon Islands, but monthly temperatures are lower and the seasonal range in temperatures is more extreme for SIDS such as New Caledonia in more southern latitudes.

As with the Pacific Islands, the tropical Caribbean Islands (Figure 5.3) range in size, with Cuba several orders of magnitude larger than the small islands of the Antilles. The second-largest island is Hispaniola (Haiti and the Dominican Republic). The islands generally have varied topography, including mountains taller than 2,000 meters on the largest islands, and smaller peaks (900–1,500 meters) among some of the Antilles. The larger islands tend to have more arable land for agriculture. The Caribbean region has warm-to-hot tropical climate, with relatively small variations in mean temperature throughout the year: less than 2°C in the south and 5°C in high-elevation areas in the north.[178] Except in the Guianas (Guyana, Suriname, and French Guiana), the region has a single wet season, from May or June, to November or December. This is also when tropical storms and hurricanes occur; heat stress is more common as well. The Caribbean wet season is impacted by the Hadley Call and Intertropical Convergence Zone (ITCZ), with the latter contributing to two peak rainfall periods in the Guianas.

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[177] See World Bank data on land area (square kilometers) at https://data.worldbank.org/indicator/AG.LND.TOTL.K2?locations=NR-TV.

[178] See the Caribbean Regional Climate Center's summary of Caribbean climatology: https://rcc.cimh.edu.bb/caribbean-climatology/.

Figure 5.3: Caribbean regional map

SIDS in the Indian Ocean (Figure 5.4) are part of a vast archipelago of 1,190 coral islands in 26 atolls, of which 200 are inhabited islands and around 110 rely on tourism as a primary economic activity (Kelman et al. 2019). Most SIDS in the Indian Ocean have a low elevation of 0–2.4 meters above sea level. The Indian Ocean SIDS are impacted by ENSO and the Indian monsoon, which produces monsoon winds and storms, while also bringing important contributions to marine life (Roxy et al. 2020). Temperatures are warmer in the Indian Ocean warm pool, a geologic phenomenon with broad effects throughout the Indo-Pacific warm pool.

Figure 5.4: Indian Ocean regional map

5.2 CLIMATE CHANGE IMPACTS IN SIDS

Development, geography, and demographic dynamics can interact with climate change impacts to influence mobility. For SIDS in particular, key factors include geographic isolation, low-lying populated coastal areas, and economic dependence on international markets and on climate-sensitive sectors such as agriculture, fisheries, and tourism. Limited freshwater and cropland availability can affect food security and put further pressure on people—especially small subsistence farmers and those dependent on exports. As noted earlier, SIDS also face exposure to intensifying natural hazards and more frequent and extreme El Niño events over the 21st century. This section expands on climate trends and projections in SIDS to further situate how climate change could affect mobility.

5.2.1 Climate Trends and Projections

SIDS are seeing some of the worst effects of rising sea levels, warmer ocean temperatures, drought, extreme weather patterns, and ocean acidification (Kumar et al. 2020; Hoegh-Guldberg et al. 2018). Under RCP2.6, the lowest-emission trajectory, the Caribbean is projected to see a mean surface temperature increase of 0.5°C–1.5°C (from a 1971–2000 baseline) by 2100, with warm spells during as much as half the year (Hoegh-Guldberg et al. 2018; Taylor et al. 2018), while the western tropical Pacific is expected to see 0.5°C–1.7°C of warming relative to 1961–1990 levels.

Larger changes are projected with higher-emission trajectories. Average rainfall patterns are expected to shift under different emissions scenarios, with variations across subregions (Nurse et al. 2014). Due to regional variation and complexities to reliably capture climate processes over small islands, climate projections should be treated with caution. This is especially the case in the Pacific, where there can be microclimates on islands with larger land mass (Gooley et al. 2014).

SIDS have generally experienced above-average sea-level rise over the last decades. Global mean sea level has significantly accelerated, so although the mean rate for 1901–2010 was 1.5–1.9 millimeters per year, in 1993–2010, it was 2.8–3.6 millimeters per year (Church et al. 2013). There has been significant debate on future global mean sea-level rise, but projections range from about 0.2–0.8 meters above 1986–2005 levels by 2100 with 1.5°C of warming, and 0.3–1.00 meters with 2°C of warming (Hoegh-Guldberg et al. 2018). Actual increases are expected to continue to vary significantly across regions, as they have historically among SIDS. For example, small islands in the tropical western Pacific experienced sea-level rise of up to four times the global average, or 12 millimeters per year, between 1993 and 2009 (Nurse et al. 2014). On the other hand, sea-level rise in the Caribbean was similar to the global average, about 1.8 millimeters per year between 1950 and 2010.

Warming of sea surface temperatures has occurred across all small islands. While global sea surface temperatures have increased at a rate of 0.07°C per decade between 1901 and 2015, the Pacific has warmed more slowly than the Atlantic and Indian Oceans, at a rate of about 0.05°C per decade between 1950 and 2015 (Pringle 2018). Ocean waters have seen a 30 percent increase in acidity since the start of the industrial revolution, with a greater concentration of acidity in surface ocean waters (Kumar 2020). Temperature increases, combined with ocean acidification, have accelerated the degradation of critical ecosystems, especially coral reefs. Coral reefs could decline by 70–90 percent with global warming of 1.5°C, and more than 99 percent would be lost with 2°C of warming (Hoegh-Guldberg et al. 2018).

The frequency and intensity of tropical storms have exacerbated the impacts of sea-level rise and coastal erosion in SIDS. Studies have noted a rise in the magnitude of extreme high sea level events since 1970, which are generally associated with storms and king tides, compounded by rising sea levels (Weir and Pittock 2017; Nurse et al. 2014). Some projections are less confident about observed long-term changes in tropical cyclone activity after accounting for past changes in observation capabilities. There is growing evidence, however, that the number of heavy precipitation events over land has increased globally since the mid-20th century, and this is true of SIDS as well (Hoegh-Guldberg et al. 2018). Extreme precipitation in SIDS is often linked to tropical storms, and these risks are projected to intensify as the climate warms and sea levels continue to rise.

The Pacific Islands, which have only produced 0.03 percent of total global greenhouse gas emissions, are particularly vulnerable to the impacts of climate change—from sea-level rise, to changes in temperature and precipitation, to extreme events (Kumar et al. 2020). Studies have shown an increase in extreme temperatures over time, independent of ENSO events (McGree et al. 2019). Future temperature projections for the Pacific Islands show warming could be below the global average, however, with variations across islands, according to climate models (Gooley et al. 2014). The models also suggest increases in precipitation rates across the western Pacific, heightened by temperature increases, and showing a potential hotspot around the equatorial Pacific region (Westra et al. 2014; Pfahl, O'Gorman, and Fischer 2017; Sohn et al. 2019).

Pacific Islands have also experienced above-average sea-level rise, with associated impacts (Pringle 2018). Salinization of water supplies poses a threat to food and water security, while sea encroachment on coastal areas and extreme sea level events threaten lives and infrastructure (Widlansky, Timmermann, and Cai 2015; Shultz et al. 2016). Annual lost life years and financial losses are already high in Pacific Island SIDS, with income losses due to natural hazards estimated at nearly 5 percent of combined GDP (ESCAP 2020). An estimated 50 percent of these losses are from cyclone impacts, 20 percent from drought, and 15 percent each from floods and earthquakes combined with tsunamis.

Low-lying and predisposed to cyclones and tsunamis, SIDS in the Indian Ocean are also highly vulnerable to the effects of sea-level rise (Stancioff et al. 2018). The Maldives have the lowest-lying territory of any country, with more than 80 percent of the islands less than 1 meter above sea level (Voiland 2021). Salinization and saltwater intrusion into scarce pockets of underground water and the general depletion of freshwater resources pose serious threats for SIDS in this subregion. The Indian Ocean has also seen a faster rate of warming than any other tropical ocean, with temperatures rising by 1°C between 1951 and 2015 (Roxy et al. 2020). The Indian Ocean accounts for a quarter of the increase in global oceanic heat over the past 20 years despite only representing 13 percent of the global ocean surface. This warming threatens key ecosystems, including coral reefs. Average rainfall is also projected to increase substantially in the northern Indian Ocean with patterns also indicating extreme dry and wet periods (Nurse et al. 2014).

SIDS in the Caribbean Islands are set to be impacted by sea-level rise, land and oceanic temperature increases and changes in precipitation patterns, with some intra-regional variation in magnitude and type of change. While average ocean surface temperature changes vary across the region, there has been a warming trend (Stennett-Brown, Stephenson, and Taylor 2019). A recent study modeling ocean and atmosphere changes in the Caribbean under RCP4.5 and RCP8.5 found sea surface temperature could rise by 1.92– 3.01°C by the end of the century, relative to 1976–2005 levels (Bustos Usta and Torres Parra 2021). This, in turn, could extend the hurricane season, increase the frequency of tropical storms, and intensify coral bleaching. Temperature projections for the Caribbean, meanwhile, show that with global warming of 1.5°C (relative to 1971–2000 levels), mean temperatures in the region would rise by 0.5–1.5°C in a 1.5°C world, and with 2°C of global warming, the region would warm by another 0.2–1.0°C (Taylor et al. 2018). Average rainfall is projected to decrease overall (Nurse et al. 2014). Reductions in precipitation could be as high as 20–40 percent for the Caribbean in a 4°C world (World Bank 2014). Modeling and reviews of individual country studies show important variations across countries, however (Stennett-Brown, Stephenson, and Taylor 2019).

The Caribbean islands are also highly exposed to tropical cyclones, many of which have had devastating effects, as noted earlier. Cuba, Puerto Rico, the Dominican Republic, Jamaica, Haiti, the Bahamas, and other Caribbean SIDS have experienced major storms in recent years. Hurricane Dorian, for example, which stalled over the Bahamas in September 2019 and dumped more than 900 millimeters of rain, unleashed massive flooding that resulted in deaths, displaced 9,800 people, and caused major property losses (IDMC 2020a). In 2017, Antigua and Barbuda and Dominica suffered damages from extreme events estimated at 215 percent and 46 percent of GDP, respectively (Eckstein, Hutfils, and Winges 2018).

The Caribbean is particularly vulnerable to these events, as the population of many islands is concentrated within 25 kilometers or less of the coast (Mycoo and Donovan 2017). The Bahamas, Barbados, and Trinidad and Tobago have all their population within 25 kilometers of the coast—and in the Bahamas, 95 percent are within 5 kilometers, and 83 percent are in the low-elevation coastal zone (at less than 10 meters above sea level).

The Caribbean region is also exposed to effects of strong El Niño and La Niña events. Studies indicate a greater likelihood of extreme cyclone rainfall in the Caribbean due to climate change (Vosper, Mitchell, and Emanuel 2020). A 2008 analysis of the potential economic impact of climate change on the Caribbean found that SIDS in the subregion could suffer losses of 5–10 percent of regional GDP from 2025 to 2050 (Bueno et al. 2008). In a 4°C world with 0.89–1.4 meters of sea-level rise, tropical cyclones in the Caribbean alone could cause US$22 billion more in storm and infrastructure damages and tourism losses by 2050 than in a 2°C world (World Bank 2014).

5.2.2 Climate Change Impacts on Key Sectors and Livelihoods

Climate change impacts in SIDS around the world could lead to the loss of livelihoods, deterioration of food systems, economic instability, damage to infrastructure, degradation of ecosystem services, and threats to coastal settlements (Nurse et al. 2014). Table 5.1 provides a summary of projected climate change impacts by SIDS subregion.

Climate change and extreme events may affect agriculture in SIDS, and thus threaten livelihoods and food security (Bell and Taylor 2015). In Vanuatu and the Solomon Islands, for example, climate change poses risks to the production of staple foods such as rice, sweet potato, and yam. Studies in Jamaica suggest that already in the period 1986–2006, agricultural production was impacted by extreme events, highlighting the sector's vulnerability to climate change (Selvaraju et al. 2013). In Fiji, the sugar sector is also expected to decline further as a result of climate change (Bell and Taylor 2015). Overall, agricultural losses from extreme weather events, including tropical cyclones, are only set to become more severe and frequent (Hoegh-Guldberg et al. 2018).

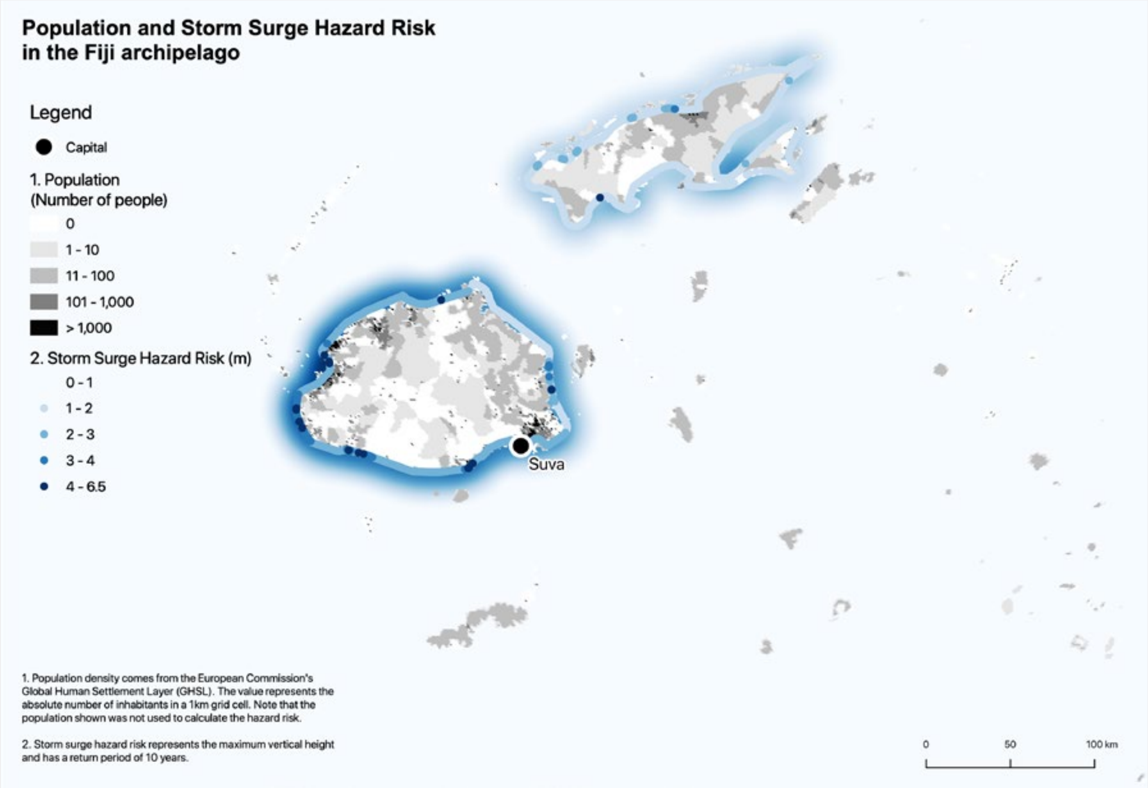
Climate change also amplifies the exposure of SIDS to risks associated with sea-level rise through increased saltwater intrusion, flooding, erosion, and damage to critical infrastructure (Hoegh-Guldberg et al. 2018; Nurse et al. 2014). SIDS stand to lose entire swaths of land and even entire territories as sea-level rise puts them at risk of at least partial inundation. The length of SIDS' coastlines varies considerably, from just 24 kilometers in Tuvalu, to more than 6,000 kilometers for Micronesia, with an average of about 1,000 kilometers—but almost half of SIDS have coastlines in the 100–500 kilometer range (UN-OHRLLS 2013).

With sea-level rise, SIDS could thus potentially lose territorial waters due to physical changes to coastal baselines, possibly resulting in loss of income from rights related to fisheries (Freestone and Cicek 2021). Research has also found that sea-level rise does not necessarily mean the gradual and inevitable erosion of reef islands until they become uninhabitable, as reef islands are dynamic systems that may be able to maintain themselves (Webb and Kench 2010). However, recent studies have concluded that by 2050, in scenarios of intermediate to high sea-level rise, island stability would inevitably deteriorate if no action is taken (Kane and Fletcher 2020).

Critical infrastructure and centers of population are highly exposed to the impacts of sea-level rise, with serious implications for coastal residents and livelihoods in agriculture, fisheries, and tourism, among others. About 57 percent of the infrastructure in the Pacific Islands is in vulnerable coastal areas (Oppenheimer et al. 2019). More than 90 percent of the land area and population in the Maldives, Tuvalu, Marshall Islands, and Kiribati are within 5 meters above sea level (UN-OHRLLS 2013).

More generally, coastal urban centers in SIDS face dual pressures, both exacerbated by rising seas: from limited resources (especially freshwater), and coastal erosion and a high likelihood of floods and storm damage (Mycoo and Donovan 2017). Figure 5.5 shows population and storm surge hazard risk in the Fiji archipelago as an example. Water management on many atolls is already complicated by inadequate sanitation, and not just because of increasing salinization from sea-level rise (Fujita et al. 2013). However, the development of low-lying coastal areas—including expansion of coastal properties, large-scale agriculture, deforestation, mining, and sea walls or groynes that alter coastal sediment flows or change the locus of erosion—can often exacerbate the effects of sea-level rise (Oppenheimer et al. 2019; Weir and Pittock 2017; Green 2016). Ecological features that can contribute to coastal resilience, such as salt marshes, mangroves, and dunes, are often subject to such development pressures.

Figure 5.5: Population and storm surge hazard risk in the Fiji archipelago



1. Population density comes from the European Commission's Global Human Settlement Layer (GHSL). The value represents the absolute number of inhabitants in a 1km grid cell. Note that the population shown was not used to calculate the hazard risk.

2. Storm surge hazard risk represents the maximum vertical height and has a return period of 10 years.

Source: IDMC (2020b).

Climate change is also set to exacerbate the deterioration of critical ecosystems that provide the backbone for livelihoods and key economic sectors. As noted earlier, almost all coral reefs, which constitute an important protective barrier against the sea and also provide critical habitat for marine life, could be lost in a 2°C world (Hoegh-Guldberg et al. 2018). By the year 2040, Caribbean coral reefs are expected to experience annual bleaching events. Such changes could have significant adverse impacts on local communities in SIDS, especially considering that sources of livelihoods (such as tourism and fisheries) are interlinked with ecosystem health.

Opportunities to earn diversified incomes are already limited in some SIDS due to their remote location, and it is common for people to depend heavily on subsistence agriculture, fishing, and/or tourism (Bell and Taylor 2015). The Caribbean coasts are expected to see fishing catch potentially decline by 15–50 percent with just 2°C of global warming, as fish stocks migrate in response to rising water temperatures (World Bank 2014). Luganville, Vanuatu's second-largest city, which relies on tourism, has already seen the degradation of reefs affect tourism through reduced demand for recreational diving (Klint et al. 2012). Sea-level rise and severe storms have also damaged many resorts. Expenditures in the Caribbean tourism sector could decline from US$25 to US$15 billion, with projected losses up to almost US$1.5 billion by 2050.

Similarly, climate change can severely impact terrestrial ecosystems in SIDS, including island biodiversity and water resources, through processes such as desertification or encroachment of invasive species. Ecological niches unique to small island states are seeing widespread degradation as a result of climate change. Over the past 400 years, 724 animal species have gone extinct, and about half were island species (FAO 2019). Climate change challenges exacerbate the localized environmental degradation experienced in many SIDS as a result of economic forces—for instance, phosphate mining on Nauru (Herbert 2019). Anthropogenic activities have precipitated rapid changes to land and water ecologies across the three SIDS subregions (Oppenheimer et al. 2019).

Table 5.1: Key climate change impacts by SIDS subregion

SIDS Subregion	Temperature	Precipitation	Sea-Level Rise	Natural Hazards	Ecosystems	Sectors and Livelihoods
Pacific	Warming below global average, with variations among islands Warming of Pacific Ocean (at lower rate compared with Atlantic and Indian Ocean) Source: Gooley et al. (2014)	Increased rainfall in the western Pacific Potential hotspot of intense rainfall increase in equatorial regions of Pacific Source: Pfahl et al. (2017)	Sea-level rise is a threat to nearly all SIDS Encroachment of sea leading to physical shrinking of islands Especially threatening for low-lying islands in the Indian Ocean and smaller islands in the Pacific Source: Nurse et al. (2014); Stancioff et al. (2018)	High geomorphic sensitivity to natural hazards and high exposure to climate risks; SIDS are considered hotspots for natural hazards Increased extreme weather patterns and sea-level events Cyclones with increased rainfall intensity and wind speed Storms Tsunamis (Indian Ocean) Floods Droughts Heatwaves with high levels of humidity Source: Nurse et al. (2014); Stancioff et al. (2018); Widlansky et al. (2015)	Depletion of freshwater aquifers Saltwater intrusion and salinization of freshwater resources Ocean acidification and degradation of marine ecosystems (incl. coral bleaching) Degradation and damages to coastal wetlands Impacts on terrestrial ecosystems (incl. biodiversity and pests and diseases) Erosion Source: Herbert, 2019; Stancioff, et al. (2018); Schultz et al. (2016)	Economic and livelihood impacts on key sectors incl. fisheries, tourism and agriculture, with increased vulnerability due to high dependency on imports Financial losses due to disasters and shocks, particularly pronounced in more populous islands Extreme events pose a direct threat to people's lives, infrastructure, and ecosystems Food and water security threatened due to changes in precipitation, freshwater availability, high temperatures, extreme events Health threats, including diseases and heat stress Source: Dunne et al. (2013); Nurse et al. (2014); Schultz et al. (2016)
Indian Ocean	Higher than global average warming Warming of Indian Ocean with regional variation of water temperatures Source: Roxy M.K. et al. (2020)	Average rainfall projected to increase in the Northern Indian Ocean Patterns indicating extreme dry and wet periods Source: Nurse et al. (2014)				
Caribbean	Warming below global average Warming of Caribbean Sea with regional variation in water temperatures Source: Taylor et al. (2018)	Projected decrease in average rainfall overall, with variations among countries Source: Nurse et al. (2014); Stennett-Brown et al. (2019)				

5.3 MOBILITY DYNAMICS IN SIDS

5.3.1 Migration Dynamics

This section examines mobility in the context of climate change in SIDS. It covers historical and current patterns of mobility, including both internal and international migration, displacement due to natural hazards, and the role of climate change as a potential driver of migration.

Historically, migration in SIDS has been motivated by a variety of reasons, including family, health, education, livelihoods, a search for a more urban lifestyle, and the opportunity to send remittances (Kelman 2018; King 2009; Hau'ofa 2008). In pre-colonial times and before the establishment of national boundaries, Pacific communities were highly mobile for trade and cultural reasons in what is referred to as a "sea of islands" (Burson and Bedford 2013). In recent years, migration has also been linked to volcanic eruptions, where entire communities and island populations have left suddenly or for longer periods of time without any certainty of return. In recent years, tsunamis have also driven migration; for instance, the 2004 tsunami led to the relocation of communities in the Maldives (Sovacool 2012). The environment, cultures, and livelihood contexts of SIDS have always been dynamic, as necessitated by climatic conditions, natural hazards, and economic activities (Kelman 2018).

Internal migration

Internal mobility in SIDS shows patterns of rural-urban mobility, movement between and away from smaller islands, and disaster-related displacement. Migration out of rural areas and into urban centers has increased in the past few decades, including in Pacific Islands such as Kiribati and Indian Ocean states such as the Maldives. People have left in search of better jobs and educational opportunities (see, e.g., Oppenheimer et al. 2019). This coincides with influxes of people into coastal areas, where urban centers tend to be. In the Maldives, for example, there has been strong migration to Malé, the capital (Speelman, Nicholls, and Dyke 2017). Research has pointed to some structural changes, where temporary rural-urban mobility has gained a more permanent status, for example with Pacific peoples adopting a "pronounced urban focus to their lives" (Haberkorn 2008).

In some SIDS, people move between islands for work, a better place to live, and sustenance (R. Curtain and Dornan 2019). Overall, population dynamics have moved towards heightened movement between and away from smaller islands. For example, for much of Melanesia, studies suggest internal migration for educational and employment opportunities is prominent, with movements from smaller to larger islands, from outer islands to main islands, and from small villages and towns to capital cities (Naidu and Vaike 2016). Yet there are challenges associated with consolidation, particularly with increased pressure on ecological systems, natural resources and existing infrastructure, along with social impacts on mobile populations. Alternatives to consolidation include sustaining economically self-reliant and dispersed populations across various islands (Rasheed and Zakariyya 2017).

Natural hazards can often displace people, temporarily or sometimes permanently—and recurring disasters are particularly likely to drive migration, if the home community is no longer safe, habitable, or able to support livelihoods. Displacement after sudden-onset events is often temporary and to a location within the same country, with people generally able to return to their homes shortly after the disaster (Fornale and Kagan 2017; Petz and Ginnetti 2013). In February of 2013, an earthquake and tsunami in the Solomon Islands displaced an estimated 2,400 people. In 2009, a tsunami hit Samoa, displacing some 5,000 people who had to flee to higher ground. Volcanic eruptions prompted government authorities to evacuate some 400 people on Gaua Island, Vanuatu in 2009. In Papua New Guinea, a 2004 volcanic eruption on Manam Island displaced some 10,000 people, many of whom were still displaced nine years later, despite government efforts to find a durable solution (The Nansen Initiative 2013). Not all displaced persons return home soon after disasters (IDMC 2021), with protracted displacement triggered by disasters and climate change impacts constituting a major knowledge gap. Decisions to migrate in the context of natural hazards depend on multiple factors, including people's understanding of the hazard and both individual and community capacity and vulnerability (The Nansen Initiative 2013).

International migration

Citizens of SIDS are also increasingly migrating in search of educational and economic opportunities, though a large share move only within their countries or to neighboring small islands (R. Curtain and Dornan 2019). People who have been able to attain higher levels of education or access international labor markets may leave in search of greater economic opportunities. Over 40 percent of high-skilled workers in SIDS migrate to high-income countries (Artuc et al. 2015). The yearly net migration rate per 1,000 residents, estimated for 2016, peaked at a high emigration rate of –20.9 per 1,000 residents in Micronesia, –17.8 per 1,000 in Tonga, and –13.2 per 1,000 in Nauru, with very few SIDS experiencing more in- than out-migration (Palau: 0.7 per 1,000, Seychelles: 1 per 1,000, Saint Kitts and Nevis: 1.2 per 1,000, and Antigua and Barbuda: 2.2 per 1,000). Yet some SIDS also have some of the world's largest shares of migrants in their population, such as Samoa, at 60.2 percent, and Jamaica, at 40.4 percent (R. L. Curtain et al. 2017).

Differences in out-migration patterns in SIDS are due to several factors, including history, relative geographic isolation, and the potential for migration between islands or to larger developed countries, which varies by region. Pacific Islanders have deep ties to their land, but nonetheless, they have long migrated for economic opportunities, including to Australia and New Zealand. In Tuvalu, for example, migrants typically move from outer islands to the capital, or to Fiji and New Zealand (ESCAP, ILO, and UNDP 2020). As a baseline, there is a high degree of mobility between Pacific Island states under visa-free or visa-on-arrival privileges available to citizens of Pacific countries (Burson and Bedford 2013).

However, access to labor markets still varies among Pacific islands. The Marshall Islands and the Federated States of Micronesia, for example, have open access to labor markets in the United States (U.S. Congress 2003). Palau has similar arrangements, while Fiji, Tonga, and Samoa can be classified as "high mobility" thanks to historical ties and bilateral agreements providing limited access to New Zealand (World Bank 2017). The Solomon Islands and Vanuatu, in contrast, have some of the lowest rates of outward migration globally due to restricted access to external labor markets and lack of human capital, while Kiribati and Tuvalu have low to moderate levels of labor mobility.

International migration can benefit migrants, sending countries, and receiving countries alike. In the Pacific region, remittance flows, foreign exchange, and investment could benefit Pacific Island states, while migrant workers could help address labor market shortfalls in New Zealand and Australia (World Bank 2017). For Vanuatu, for example, the economic stimulus of remittances, income earned by seasonal workers, and slower population growth due to migration could boost per capita income by about 20 percent. Increased labor market access to Australia and New Zealand for citizens of low-lying atolls could allow for gradual migration and the development of a diaspora for I-Kiribati and Tuvaluans, which would facilitate future migration.

Some Indian Ocean SIDS, meanwhile, have diasporas in India, Sri Lanka, and France (J. R. Campbell 2014). Workers also often migrate for better opportunities both within and across islands, and sometimes to different countries outside the subregion (Hurgobin and Basu 2015). Top destination countries for Maldivians generally include Australia, India, and New Zealand (Kelman et al. 2019), with circular migration being a salient part of island population dynamics.

In the Caribbean, forced movement between islands and even across continents is part of the subregion's complex history, which included colonization as well as the slave trade (Thomas and Benjamin 2018a). Citizens of some Caribbean countries have also migrated to Europe for many generations, especially England and France (J. R. Campbell 2014). In recent decades, migrants have often moved to the United States, Canada, and the United Kingdom, seeking economic and educational opportunities (Thomas and Benjamin 2018a). Throughout the Caribbean, migration is valued for social and economic reasons, contributing to increased income and greater "kin links" over vast areas of the world (Connell and Conway 2000).

5.3.2 Environmental and Climate Migration

As outlined above, there is a long history of mobility in SIDS, due to several factors, some of which are related to environmental pressures, including natural resource degradation and natural hazards. Yet even if climate change intensifies those pressures, people's ability to move, seasonally or permanently, could vary significantly. In Nauru, for example, the depletion of phosphate resources and physical shrinking of the island due to sea-level rise have resulted in considerable outward migration, as large swaths of the country become uninhabitable. The economy has also suffered and is now heavily dependent on foreign aid and on an offshore Australian immigration detention facility (Herbert 2019). Unlike many neighboring islands, Nauru does not have legal arrangements to facilitate migration (R. Curtain and Dornan 2019).

The physical shrinking of some Pacific Islands is a unique threat, as it reduces the habitable land area and makes key resources more scarce (Herbert 2019). Some inhabitants have already had to move, while some have made adjustments within their islands. The community of Vunidogoloa on the island of Vanua Levu, in Fiji, for example, retreated several kilometers inland and uphill in 2014 due to frequent flooding (Green 2016).

Residents of Carteret Islands and Takuu Atoll have already had to move due to land subsidence (sinking) exacerbated by sea-level rise (Connell 2016). Communities in the Solomon Islands have also been relocated due to sea-level rise, coastal erosion, and saltwater intrusion. The provincial government in Choiseul Province has developed a proposal to relocate Taro, the capital, in part due to sea-level rise and the loss of 50 percent of the housing in Nautambu village (Fitzpatrick and Monson 2021). Another example is the case of Honiara, where there are rapid rates of in-migration from other Solomon Islands to informal settlements.

Perceptions of environmental and climate migration

When discussing environmental migration in SIDS, it is important to consider the perspectives of their peoples, many of whom continue to find ways to live in or near their places of birth. Notably, despite what are sometimes highly adverse environmental conditions, surveys of SIDS residents cite not those conditions, but rather economic opportunities, improved services, food security, and education as key drivers of migration.

Interviews with residents of the Maldives conducted in 2013 over eight islands across three atolls found a general reluctance to move (Kelman et al. 2019). Most interviewees expecting to move cited job opportunities and improved public services, not environmental factors. A study conducted in Tuvalu similarly noted economic opportunity as a major driver of migration, with 63 percent of respondents identifying financial hardship as a primary stressor and 55 percent identifying food insecurity (McCubbin, Smit, and Pearce 2015). Forty-two percent of the respondents did identify water shortages as an issue. While these economic and sustenance-based stressors could be linked to climate change, people were likelier to cite financial, cultural and political issues as primary concerns.

At the same time, the consequences of climate change on economies and livelihoods are significant in SIDS, with impacts felt at the individual and community levels. A relatively recent analysis of local perceptions of climate change impacts in two small island settings (Malé Island in the Maldives and St. Kitts) found that sea-level rise, coastal erosion, and climate variability were among issues of concern, but they were not the most alarming ones. In Malé, environmental impacts are among the main migration drivers, though the degree to which they are cited varies by age, sex, education level, and occupation (Stancioff et al. 2018). In another study, Maldivians were found to perceive future sea-level rise as a serious challenge, and migration as a potential way to address it; still, decision-making about migration was dominated by other cultural, religious, economic, and social factors (Stojanov et al., 2016; Speelman et al., 2017).

Even if islanders do not cite climate change as a major reason for leaving, among Marshall Islanders in the United States, anticipated climate change impacts *do* seem to negatively affect emigrants' willingness to return to their homeland (van der Geest et al. 2020). Recent research on three atolls within the Marshall Islands did not find that climate change caused migration, but did find "several significant relations, particularly between migration intentions and perceived trends in the ecosystem services of food provision, fuel wood provision and protection against storms and floods" (ibid., p. 123).

One of the worst potential consequences of climate change across SIDS is the risk of the loss of customary land, an integral part of individual and community identity, particularly in Pacific Islands (ESCAP, ILO, and UNDP 2020). In the Pacific, the indivisibility of the person-community-land bond and the ramifications of the loss of customary land have immense implications for those who move, including dislocation, loss of homeland, and disruption of culture. Customary forms of tenure limit ownership and transfer of land ownership, and the permanent movement of people can even disrupt the link between community and traditional land for host communities (J. Campbell 2010).

The Tuvaluan concept of *fenua,* a set of customary practices and territorial markers, defines people's identity in place (Oakes 2019). *Fenua* may explain people's reluctance to relocate, as attachment to place leads to the perception that their cultural identity and sovereignty may be at risk. Customary land tenure holders are also particularly vulnerable in cases of migration as their holdings and assets tend not be recorded. They may face challenges in making the case for compensation of losses, support programs or relocation, or a right to return to their holdings as their holdings are protected by presence, use and customs, but not by legal registration in many cases.

People's perceptions of the links between climate change impacts and mobility are also influenced by faith and how islanders relate to the land (Oakes 2019). For example, in Tuvalu, depending on the individual, faith-based narratives or resilience narratives such as "a resourceful people will adapt" suggest that many believe they will be able to remain in place despite climate change, while others believe that migration may be inevitable, but should be conducted on people's own terms.

Migration can also be considered part of local-level adaptation, as mobility has long been an element of islanders' way of life, even as a way of coping with and adjusting to social and environmental changes (Klöck 2015). Adaptation decisions in Pacific SIDS such as Samoa are also steeped in traditional knowledge systems. Climate risk management approaches should ensure the integration and role of traditional knowledge, in order to ensure that adaptation measures are appropriate for the Pacific context (Handmer and Nalau 2019).

The notion of fleeing as climate refugees is a complex and sensitive issue and is generally rejected by the people of SIDS, many of whom find the term "climate refugee" incompatible with notions of human dignity and agency (Thomas and Benjamin 2018a; Perumal 2018; McAdam 2011; McNamara and Gibson 2009).[179] Instead, SIDS are aiming to control the process of moving to make self-determined decisions and seeking outside assistance for particular processes, such as to find land to move to (Kelman 2018). To be effective, policies addressing climate and migration will need to account for this complexity, understanding of objective risks, people's material ability to cope with these risks, and their perceptions of these risks and mobility (Oakes 2019).

5.4 Recent Policy Directions for Mobility in the Context of Climate Change in SIDS

Given the climate change vulnerabilities shared across most SIDS, many have taken proactive leadership roles in integrating climate resilience and climate-related mobility in global and regional dialogues. Embedding mobility in the context of climate change into inclusive and resilient development planning also means accounting for all phases of migration—before, during, and after moving.

A number of international frameworks are addressing mobility in the context of climate change, relevant to SIDS broadly in the global agenda. The Global Compact for Safe, Orderly, and Regular Migration

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[179] Under the 1951 UN Refugee Convention, a refugee is defined as "someone who is unable or unwilling to return to their country of origin owing to a well-founded fear of being persecuted for reasons of race, religion, nationality, membership of a particular social group, or political opinion." See the UN Refugee Agency's "What is a refugee?" web page: https://www.unhcr.org/en-us/what-is-a-refugee.html. This definition does not include people who leave their home states for climate-related reasons, or people who migrate internally (Freestone and Cicek 2021).

and Global Compact on Refugees call for deeper understanding of climate change as a driver of migration. The Compacts provide specific commitments to address the drivers of environmental mobility and develop policies aimed at ensuring greater protection for those affected by these movements (Martin et al., 2018). Focused on disaster displacement, the Sendai Framework outlines “targets and priorities for action to prevent and reduce disaster risks, including through governance, investment in disaster reduction for resilience, and disaster preparedness, recovery, rehabilitation, and reconstruction” (United Nations 2015). SIDS have spearheaded the loss and damage agenda, which considers compensation and insurance for losses linked to sea-level rise (see Box 5.1).

Box 5.1: The Loss and Damage Agenda for SIDS

SIDS have long recognized that even with ambitious mitigation and adaptation measures, some severe climate change impacts may be unavoidable, especially for vulnerable small islands. Thus, as part of the negotiations on the establishment of the United Nations Framework Convention on Climate Change (UNFCCC), Vanuatu submitted a proposal on behalf of the Alliance of Small Island States on compensation and insurance for losses linked to sea-level rise (AOSIS 1991).

Two decades later, amid mounting evidence of the potential for very large losses due to climate change, as well as the potential for significant displacement, AOSIS stepped up its efforts to address “loss and damage” under the UNFCCC through a mechanism that would help affected SIDS manage financial risks from increasingly frequent and severe extreme weather events, and could provide compensation for losses that could not be avoided.

The Warsaw Mechanism on Loss and Damage associated with Climate Change Impacts was established as part of COP19 in 2013, and Article 8 of the Paris Agreement provided the Warsaw Mechanism with a permanent legal basis. However, the obligations are only of a cooperative and facilitative nature, without any legal or financial obligations (Freestone and Cicek 2021).

There is no universal definition of loss and damage, but it is generally understood to include adverse climate-related impacts and residual costs not avoided through mitigation and adaptation (Handmer and Nalau 2019; Thomas and Benjamin 2018a). This could include both economic (loss of assets and crops) and non-economic losses such as loss of biodiversity, heritage, and health. Non-economic losses could also include some forms of mobility, displacement, loss of territory, loss of cultural heritage and loss of local knowledge (UNFCCC 2013). Traits associated with loss and damage include attributability to climate change, irreversibility, unavoidability, intolerability (Vulturius and Davis, 2016).

A review of NDCs found that a majority of Pacific Islands discuss loss and damage, with some governments (such as the Cook Islands and Fiji) addressing the need for loss and damage to be assessed on a national scale. Other islands, such as Vanuatu and Dominica, have stated in their NDCs that loss and damage will need to be factored in policy and planning in the future (Thomas and Benjamin 2018a).

There are multiple studies that document existing loss and damage experienced by SIDS, with evidence showing that small islands have experienced impacts to a wide variety of coastal, terrestrial and human systems despite mitigation and adaptation efforts (see, e.g., Thomas and Benjamin 2018b; Lashley and Warner 2015). In the Pacific SIDS, there are already cases where communities face “intolerable climate-related risk” (Handmer and Nalau 2019). Yet much more work remains to be done to quantify loss and damage in SIDS, especially with regard to the slow-onset impacts of climate change (Thomas and Benjamin 2018b).

Scholars suggest that loss and damage compensation would mean an acknowledgement of harms, a justifiable source of funding for rehabilitation, relocation and resettlement, and a form of corrective justice (Adelman 2016). The Warsaw International Mechanism’s Taskforce on Displacement has also raised the profile of discussions of climate-related migration. Looking ahead to COP26 in Glasgow, more than 100 countries, including SIDS, are urging the international community to further advance the loss and damage agenda.[a]

[a] Loss and damage is one of five elements in the “COP26 Five-Point Plan for Solidarity, Fairness and Prosperity,” available at https://climatenetwork.org/resource/cop26-five-point-plan-for-solidarity-fairness-and-prosperity/.

At the regional level, the Framework for Pacific Regionalism, the Framework for Resilient Development in the Pacific (FDRP) and the SAMOA Pathway offer an overarching approach to strengthen resilience to climate change and disaster risk management, including displacement (Wewerinke-Singh and Van Geelen 2018). The FDRP7 in particular, adopted by the Pacific Islands subregion in 2016 as voluntary guidelines, calls for Pacific countries to integrate mobility aspects into national policies and actions. The goal is to protect individuals and communities vulnerable to climate change and disaster-related displacement and migration, including through relocation and labor migration policies. The United Nations Pacific Strategy prioritizes addressing the links between migration and climate change and protecting migrants' rights and facilitating safe, well-managed migration.

A number of bilateral and regional labor migration programs could also serve as vehicles for climate change adaptation. This includes the development of free movement agreements such as the Temporary Movement of Natural Persons provisions in the Pacific Island Countries Trade Agreement (Fornale and Kagan 2017; Weir and Pittock 2017). In the Pacific, a "highly-textured migration landscape" sitting within existing immigration policy mechanisms offers potential leverage to enable states to respond to mobility linked to environment and climate change (Burson and Bedford 2013).

Two free movement agreements in the Caribbean Community (CARICOM) and Organization of Eastern Caribbean States (OECS) economic integration schemes granted displaced Caribbean nationals protection benefits after catastrophic hurricanes, including a right of entry in other islands and easing access to foreign labor markets through a mutual recognition of skills scheme and/or a waiver of work permit requirements (Francis 2019). The region is working on similar free movement mechanisms in the future (Cantor 2018). The facilitation of safe and orderly migration could also involve reforms for receiving countries to expand labor mobility for low-mobility and small island states where migrants are likely to originate (World Bank 2017).

Many SIDS are also embedding climate-induced mobility in national policy frameworks and climate priorities. The Republic of Vanuatu's 2018 National Policy on Climate Change and Disaster-Induced Displacement addresses both displacement and disaster in an integrated manner and within the country's broader mobility context (Republic of Vanuatu 2018). In its updated NDC, the Republic of the Marshall Islands commits to producing a National Adaptation Plan and Adaptation Communication that explicitly covers relocation and emphasizes the need to design new policies and plans for elevated settlements for future consolidation of the population (The Republic of the Marshall Islands 2018). The NDC acknowledges that while relocation should be considered a last-resort option, it is likely that some Marshallese will choose to relocate as many have already done. It highlights the need for the government to simultaneously assure the rights of citizens to remain as best it can, and ensure continued opportunities for migration for those who choose to relocate.

Recent efforts by the government of the Republic of Kiribati have focused on in-situ adaptation and for i-Kiribati to remain in the islands (Farbotko et al. 2018). In the past, the Republic of Kiribati had developed a "migration with dignity" policy to manage population movement on the country's own terms (Kelman 2018; Wyett 2014). The country's NDC and National Framework for Climate Change and Climate Change Adaptation aimed to establish host country agreements to government-sponsored and self-sponsored emigration to resettle I-Kiribati overseas as well as assist migration due to climate change (Republic of Kiribati 2016). See Box 5.2 for further country-level examples.

Box 5.2: Integrating climate change and mobility in national policy frameworks in SIDS

Additional illustrative examples on the integration of climate change and mobility in national policy frameworks across SIDS include:

Fiji has indicated that its adaptation efforts include relocating communities to higher ground (Government of Fiji 2018), and it is the process of drafting guidelines to better plan and prepare for future planned relocations (ESCAP, ILO, and UNDP 2020).

Jamaica's Climate Change Policy Framework references migrants in relation to human security, stating that "the negative impacts on livelihoods that may result from the impacts of climate change can lead to changes in migration patterns and a rise in both internal and external migration" (Government of Jamaica 2015).

In **Papua New Guinea**, an "Atolls Resettlement Scheme" from the Carteret Islands has been in place since 1984, with resettlement on previously alienated government land in Kuvesria. A recent plan targeted the resettlement of about 1,500 residents by 2020. Political, economic and cultural challenges have constrained the resettlement effort, including disagreements over land tenure and land registration, differences of ethnicity and culture, and lack of access to off-farm employment (Connell 2012).

The **Solomon Islands**' National Adaptation Programme of Action highlights the need to identify and support vulnerable communities to adapt to climate change. The country's Climate Change Policy identifies relocation of communities as a last resort (Fornale and Kagan 2017).

Tuvalu has acknowledged the possible need for international migration, yet also stated a preference for adapt-in-place measures, asserting its people's "right to pursue any and all means to ensure their nation survives and the legacy remains, with future generations living productive lives on these islands" (Government of Tuvalu 2015, 9).

Vanuatu's National Adaptation Programme of Action explicitly refers the relocation of the Lateu settlement to Lirak, a site in inland Tegua, an island in the Torba province in the Northern Part of Vanuatu (Republic of Vanuatu 2007).

Consideration is also being actively given to the long-term habitability of islands—particularly atolls and other low-lying islands—and the recognition of the need to plan for an uncertain future. Among options actively being considered are spontaneous or planned movements inland on larger islands (Weir and Pittock 2017); planned relocation from outer islands to higher elevation or climate-reinforced islands, such as from the Carteret Islands to Papua New Guinea; or the new island of Hulhumalé in the Maldives (Miller 2020; Edwards 2013).

Forced evacuations and arbitrary displacement are generally prohibited under international law. However, states' existing human rights obligations to protect the right of life may oblige states to relocate affected persons when it is impossible or unsafe to return (Freestone and Cicek 2021). The United Nations High Commissioner for Refugees recommends that planned relocation be considered as a measure of last resort, and that it take into account relevant human rights principles, such as free, prior, and informed consent of affected communities; effective and meaningful participation; appropriate and fair compensation; the right to an adequate standard of living including adequate housing; and the right to an effective remedy (UNHCR 2015). See Box 5.3 for how the government in São Tomé and Príncipe managed a voluntary retreat strategy for coastal communities after heavy flooding.

Analysis of existing cases of relocations in the context of climate change has found that secure access to land is one of the most significant factors in ensuring successful relocations and integration with host communities, with movement to land not owned by the community making integration much more complex (Fornale and Kagan 2017).

Box 5.3: Voluntary coastal retreat in São Tomé and Príncipe

In São Tomé and Príncipe, the government designed and piloted voluntary population retreat from coastal areas at risk to safer, higher ground for its coastal communities in Malanza, Sta. Catarina, and Sundy (Koskinen-Lewis et al. 2016; Leighton, Michelle 2012). Changes in wave action and river flood patterns, combined with sand extraction, caused extensive coastal erosion and flooding.

The relocation was requested by coastal populations after unusually heavy and damaging flooding in the early 2010s. The communities opted for planned relocation over coastal protection infrastructure, perceiving relocation as the best long-term solution (Trzaska et al. 2020). In the pilot, some coastal communities actively participated in various steps of the strategy. Old topographic maps were compared with current high-resolution satellite imagery to examine changes in settlement and the rate of retreat of the coastline. In the community of Malanza, the coastline had receded by more than 100 meters in 60 years, putting at risk a significant portion of housing.

Projections of future flood patterns helped identify the most vulnerable areas, while members of communities also conducted an exercise to identify the poorest households. The government worked with members of communities to achieve agreement on who is vulnerable, priority groups for assistance, and to discuss the possible impacts and options for relocation (Koskinen-Lewis et al. 2016). It also secured expansion areas adjacent to community land, where rural areas were converted to urbanized land. The most vulnerable households were given formal rights to earmarked lots.

For households, the decision to relocate to the expansion area was voluntary, and no compensation was provided (except for lost assets for farmers and private landowners such as crops and fruit trees). A Resettlement Action Plan was prepared to establish a formal framework for these affected people to secure fair and timely compensation for losses (Koskinen-Lewis et al. 2016). To prevent return to at-risk areas, there was community involvement in determining what should be done in the beach side areas such as prohibiting construction, self-monitoring by the communities, and demolishing abandoned structures.

Internal relocations have the potential to work more effectively, as communities could experience less trauma in familiar places, have time to plan, and are in control of movement in an orderly manner (Kench, Ford, and Owen 2018). In addition, small-scale displacement occurring on or across customary lands and written agreements involving customary groups and informal settlement can also be integrated within national displacement response frameworks (Fitzpatrick & Monson, 2021). Culture, communal unity, and traditional obligations also play important roles in deliberations relating to relocation and, in extreme cases, could even prevent communities from moving, highlighting the need to incorporate social and cultural parameters in relocation policies (Charan, Kaur, and Singh 2017). All dimensions of relocation—human, environmental, and economic—are critical to consider (McMichael, Barnett, and McMichael 2012; J. Campbell 2010). See Box 5.4 for further examples of national level policies addressing climate, mobility, and relocation in the cases of Vanuatu and Fiji.

Box 5.4: Policies and frameworks addressing climate, mobility, and relocation in Vanuatu and Fiji

Vanuatu is one of the first countries to develop a policy on internal displacement from disasters and climate change which includes actions on return and reintegration, local integration and planned relocation, and integrating mobility into development planning in its National Policy on Climate Change and Disaster-Induced Displacement (Republic of Vanuatu 2018).

The Vanuatu Climate Change and Disaster Risk Reduction Policy 2016–2030 incorporates many aspects of the Sendai Framework into Vanuatu's domestic policy with specific actions to address mobility needs in the face of climate change and disasters (Republic of Vanuatu 2018). The country's NDC, meanwhile, focuses on strategic priorities related to climate vulnerability and multi- sector impact assessments, integrated climate change adaptation and disaster risk reduction, community-based adaptation, and ecosystem-based approaches (Republic of Vanuatu 2016).

Studies investigating local perceptions of ni-Vanuatu people show an unwillingness towards resettlement, and a preference for adaptation in place measures (Perumal 2018). Relocation is seen as an option of last resort, with a preference for internal migration to preserve cultural ties and ways of life. Yet Bonnemaison's (1985) work on ni-Vanuatu mobility conjures the metaphor of "the tree and the canoe," which both links ni-Vanuatu to their land and enables them to "migrate with the knowledge that they always will have a home to which to return." Internal mobility is common in Vanuatu as a deliberate adjustment strategy in response to many factors, including non-climatic events such as volcanic eruptions.

The 2018 National Policy on Climate Change and Disaster-Induced Displacement addresses a policy gap in terms of reducing the triggers of displacement, protecting displaced people, and addressing long-term recovery and needs of communities affected by displacement. It includes people at risk of displacement, internal migrants, and host communities (Republic of Vanuatu 2018). The policy considers both displacement and disaster holistically, aiming to address displacement risks in the broader mobility context of Vanuatu.

The disasters covered by the policy are not limited to natural hazards, but also include crises such as evictions, land conflicts and development-induced displacement that can affect communities (Republic of Vanuatu 2018). Mobility is conceptualized on a continuum, with slow-onset, economic migration and sudden onset-disasters seen as drivers of displacement. Wewerinke-Singh and van Geelen (2018) suggest that many of Vanuatu's policies on climate change adaptation and disaster risk relocation are the first of their kind in the Pacific region. They note that the country is among the few with a dedicated climate ministry and a national policy that is one of the world's most progressive policies on climate-related displacement. Still, a lack of institutional capacity, combined with low development, can increase the risk of displacement in disasters, and more investment in resilience measures, climate-smart land use, and planning is necessary.

In Fiji, the government's Displacement Guidelines view environmental change (including environmental degradation, climate change, and disasters), human rights, and mobility as interrelated and interconnected. They focus on preventative measures to avert and minimize the impacts of displacement on affected populations. The guidelines outline measures for the Fijian government and other stakeholders for three stages of displacement: pre-displacement, in displacement, and the post-displacement stage, with the decision to move being initiated by affected communities, households and/or individuals (Government of Fiji 2019).

The village of Vunidogoloa in Vanua Levu was the first community in Fiji to be relocated—moving two kilometers inland after years of inundation, coastal flooding and storm surges (Government of Fiji 2018). The relocation was a "harrowing" experience for villagers who retreated from their ancestral lands, despite moving to land within the community's customary boundaries (Charan, Kaur, and Singh 2017). The government's Department of Fisheries provided fish ponds, as the community could no longer easily access the ocean for subsistence needs (Fornale and Kagan 2017).

Even though the relocation involved 130 people, the discussion of moving inland started seven years before the actual relocation. The relocation project was funded by both government funds and community contributions. Fijians view land as more than a resource, with islanders possessing instinctive and spiritual attachment to their land and viewing it as inseparable from concepts of personhood and identity (Charan, Kaur, and Singh 2017). Further, many communities embrace distinctive sets of traditional knowledge and abilities that provide opportunities for both adapt-in-place and relocation.

Box 5.4. (cont)

The government of Fiji has addressed relocation in its Planned Relocation Guidelines to provide a blueprint for engaging communities and ensuring coordination amongst agencies, in addition to a Climate Relocation and Displaced Peoples Trust Fund for communities and infrastructure (Government of Fiji 2018). The Planned Relocation Guidelines define relocation as a last resort and as part of adaptation strategies in relation to disasters and slow-onset events occurring on Fiji.

The guidelines lay emphasis on inclusive and gender-responsive community engagement and ownership of relocation processes, recognizing traditional knowledge when addressing communities experiencing uncertainty about their future due to climate change. Migration is considered an adaptation strategy, with an emphasis on livelihoods- and rights-based approaches when planning or implementing relocation processes.

At the same time, many SIDS are exploring options to adapt in place and to build the resilience of population centers and livelihood systems. Adaptation with dignity requires a focus on sustainable livelihoods and allowing people to live with human rights respected. Existing obligations for procedural rights (the right to information and ability to participate in decision-making) can play a key role in enabling affected people to make informed decisions (McAdam and Saul 2010).

Land tenure, use, and management options can be affected by adaptation strategies that focus on land and population consolidations, as in the case of the Marshall Islands, where land ownership and use rights are based on strips of land extending from lagoon to ocean—which might not be possible when built-up islands are created and population consolidation takes place (World Bank 2020). The Marshall Islands have the highest proportion of land held under customary tenure of any small island nation, and the creation of new elevated land island settlements could present challenges to the continuation of tradition and custom.

In the Maldives, coastal protection and land reclamation are also emerging priorities for adaptation, while Jamaica's Vision 2030 National Development Plan focuses on risk reduction from natural hazards and adaptation to climate change to reduce existing and future vulnerability. See Box 5.5 for further details.

Box 5.5: Adapting in place in the Maldives and Jamaica

The Maldives are 188 dispersed islands with average elevations ranging from 0.23 to 0.5 meters above sea level (Gussmann and Hinkel 2021). Sea level-driven flood risk is perceived as the main adaptation challenge in the Maldives, with long-term annual sea level data for the past 20 years showing a rise of 3.75 and 2.93 millimeters per year in Malé and Gan, respectively.

The Maldives has given high priority to coastal protection, with a guideline established in 2014 identifying islands that require immediate coastal protection measures based on the "rate of erosion, population, potential for population consolidation, economic activity, critical infrastructure, extent of direct impacts to community and mitigation measures undertaken by the community" (Government of Maldives 2016). Some communities in the Maldives have shown active participation and willingness to design and implement both soft and hard coastal protection measures (Ratter, Hennig, and Zahid 2019). The Maldives Climate Change Policy Framework mode broadly prescribes policies for responding to climate change impacts, focusing on adaptation actions and opportunities for climate-resilient infrastructure and communities.

The Government of the Maldives has initiated a major land reclamation project, raising the new island of Hulhumalé 2.1 meters above mean sea level, 0.6 meters above the average elevation in Malé (Bisaro et al. 2020). Maldivians migrating from either Malé or peripheral islands are expected to populate Hulhumalé, reducing the flood risk of the Maldivian population. Research has found that raising land on Hulhumalé has been beneficial in reducing long-term flood risk and aiding development; it is likely to be safe from flooding as long as sea-level rise is less than 0.6 meters (Brown et al. 2020).

The country has implemented a "reclamation fortification model" for coastal protection, shoreline and island fortification, which focus on hard engineering methods. There are potential implications, however, for the capacity of the reef-island system to naturally adjust to sea-level rise, and cause detrimental effects to the local, reef-based fish supply (Duvat 2020). Of additional concern are technical and financial implications including structural maintenance and upgrading of infrastructure. Several islands have reclaimed mangrove and inter-tidal marshy areas, with over 1,300 hectares of reef and lagoon areas reclaimed from inhabited islands (Government of Maldives 2016).

In Jamaica, extreme events made more frequent and more severe by climate change could threaten the sustainability of agriculture, one of Jamaica's most important economic sectors.

Jamaica's Vision 2030 National Development Plan aims to improve the agricultural sector by providing increased access to technologies to increase productivity (Planning Institute of Jamaica 2017). Adaptation initiatives include institutional strengthening within the Ministry of Agriculture and Fisheries through the development of a comprehensive database management system on livelihoods, production, and climate change impacts to increase access to data for adaptation planning (Selvaraju et al. 2013). Priority areas of action include providing climate information services for agriculture along with scaling up community-based adaptation initiatives.

The Government of Jamaica has received a grant from the Climate Investment Funds to improve the quality and use of climate related data and information for effective planning and action at local and national levels, including strengthening Jamaica's meteorological observation and data collection systems and enabling effective planning and design of adaptation initiatives (Government of Jamaica 2021).

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Appendix A

Inter-Sectoral Impact Model Intercomparison Project (ISIMIP) Water and Crop Model Results

Climate change impacts on water availability and crop productivity will have important impacts on the population potential of given locations in the gravity model. This Appendix provides the water and crop indices for each of the subregions and countries of focus. This is important background information for the modeling results described in Chapters 2 and 3. This is because the climate change impacts are an input to the gravity model and, when combined with parameters derived from the development scenarios (the Shared Socioeconomic Pathways), directly affect the population potential of areas within countries. Thus, these results aid in the interpretation of results related to population redistribution and internal climate migration (climate migration).

In each section, Inter-Sectoral Impact Model Intercomparison Project (ISIMIP) average index values for annual surface water availability and crop productivity during the period 2010–2050, and 2050–2100 are discussed, with reference to respective map figures. White (blank) areas on maps representing crop model results are areas where there is no current crop production. While crop areas may change in the future, our modeling is based on the assumption of constant crop areas. As described in Equation B.1 in Appendix B, the index represents the deviation from the long-term average, with values such as 0.2 representing 20 percent above the baseline average, and –0.6 representing 60 percent below the baseline average. Positive and negative values are represented in blue scale and red scale, respectively, with increasing color saturation representing higher values (more positive or negative values, respectively) on both scales.

In each section, tables also display the coefficients derived from the calibration of the model for each subregion. To produce the coefficients, decadal deviations from the baseline in past crop productivity and water availability were used in a model that sought to predict changes in the historical population distribution over two decades (1990-2000 and 2000-2010), accounting for factors such as the agglomeration effect that are traditionally used in population gravity models to predict shifts in population distribution. Through this process, coefficients were derived that minimized the error in each historic prediction for both decades and both variables, for urban and rural areas separately, which were then averaged. The coefficients represent the sensitivity of the population to climate change impacts on crops and water, and are used in conjunction with the ISIMIP projections of crop productivity and water availability deviations from baseline for each 10-year increment (we only present maps of the average deviations from baseline for the 40-year period from 2010–2050 in the map figures).

The long-term averages depicted in the map figures are useful to consider in the context of projected population outcomes, as differences across population distribution scenarios and relative to the no climate scenarios are driven in part by these indicators. It is important to remember, however, that the modeling approach explicitly considers 10-year time steps, not one 40-year time stretch. Over each period the projected change in urban and rural population is influenced by decadal deviation from baseline conditions in water availability and crop productivity. Thus, this 40-year index could mask, for example, above average results in the first two decades, and below average results in the last two decades.

It is also important to remember that these model results represent plausible scenarios of future changes in water resources and agriculture, which are consistent with the scientific literature; but they do not represent predictions, nor the most likely outcomes. Consequently, the same is true for the population model results based on these scenarios. The reader is referred to *the IPCC's Working Group 1 Fifth Assessment Report* (especially Chapters 11 and 12) for a comprehensive account of uncertainties and likelihood estimates of future climatic changes.

A.1 ISIMIP WATER AND CROP MODEL RESULTS FOR NORTH AFRICA

ISIMIP average index values for water availability and crop productivity for 2010–2050 are presented in Figures A.1 and A.3, respectively, and for the period 2050–2100 in Figures A.2 and A.4, respectively.

Table A.1 displays the coefficients derived from the calibration of the model for the subregion, based on Morocco. For both urban and rural areas, water is a slightly stronger predictor, yet the coefficients are not that different from those for crop productivity—the main difference being that deviations in water availability affect the entire subregion whereas deviations in crop productivity only affect crop growing areas, which are limited to a relatively narrow band along the coast. Yet, unlike in many other regions, the differences among the parameter estimates are not that great, and all are relatively high, suggesting high historical sensitivity of population distribution to climate factors.

Table A.1: Model coefficients for North Africa (based on Morocco)

	Urban	Rural
Crop productivity	0.599	1.077
Water availability	0.712	1.111

Overall, the ISIMIP water model shows a mostly drying trend on the northwest and west areas of the subregion, and a mostly wetter trend on the eastern zone (Figure A.1). Large areas of the Sahara show dramatic changes—both positive and negative—in water availability, but these are against an extremely low baseline in water availability, and thus must be interpreted with caution.

Crop model results are less informative, as large parts of the subregion do not have crop production (Figure A.3). The Nile valley shows a modest increase in some of the models, similar to oasis areas in the southwest of Libya. Results for the coastal areas of Tunisia and Algeria, and for Morocco west of the Atlas Mountains display areas of increased productivity and patches of decline, some of them significant.

Looking out to the last half of this century, the RCP8.5 scenarios for water in the northern areas (with a more Mediterranean climate) are dire, with declines of 70–90 percent over much of the area (Figure A.2). The crop productivity models for 2050–2100 show declines in the western portion of 30–50 percent under RCP8.5 in the northwest of the subregion (Figure A.4).

Figure A.1: ISIMIP average index values during 2010-2050 against 1970-2010 baseline for water availability, from LPJmL/water and WaterGap, forced with the HadGEM2-ES climate model (left) and IPSL-CM5A (right) under RCP2.6 and RCP8.5, North Africa

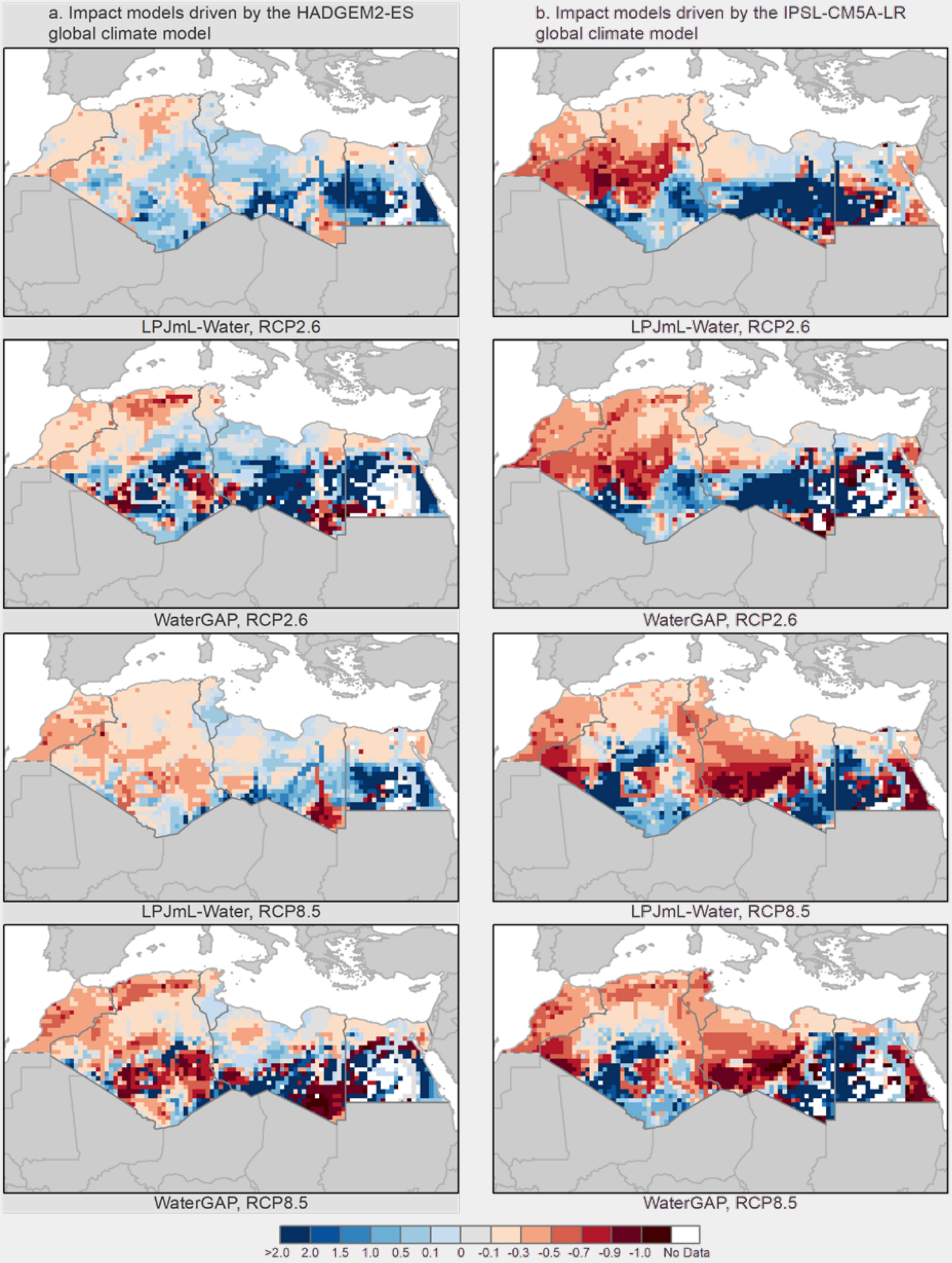
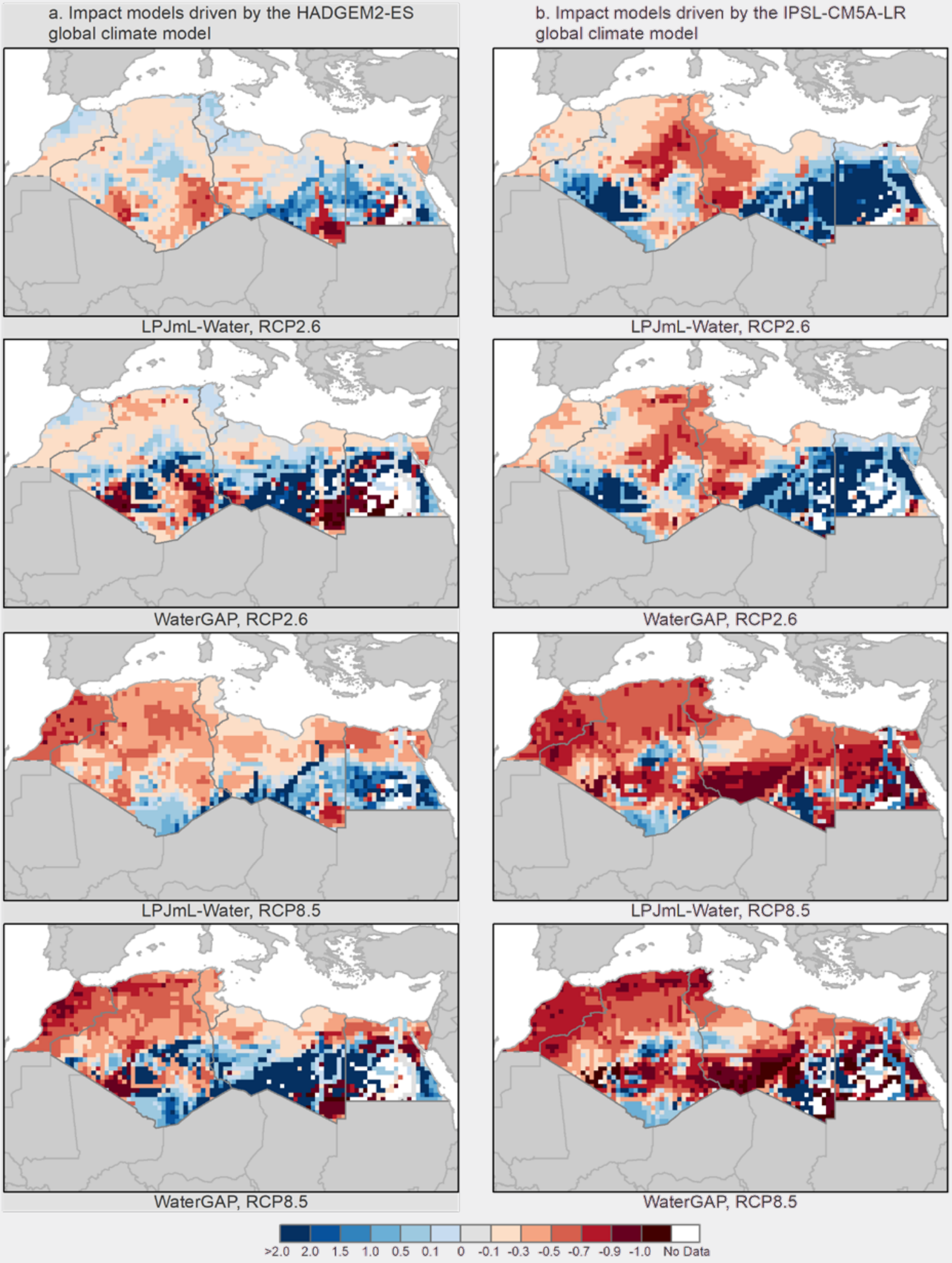


Figure A.2: ISIMIP average index values during 2050-2100 against 1970-2010 baseline for water availability, from LPJmL/water and WaterGap, forced with the HadGEM2-ES climate model (left) and IPSL-CM5A (right) under RCP2.6 and RCP8.5, North Africa


a. Impact models driven by the HADGEM2-ES global climate model

b. Impact models driven by the IPSL-CM5A-LR global climate model

LPJmL-Water, RCP2.6

LPJmL-Water, RCP2.6

WaterGAP, RCP2.6

WaterGAP, RCP2.6

LPJmL-Water, RCP8.5

LPJmL-Water, RCP8.5

WaterGAP, RCP8.5

WaterGAP, RCP8.5

Figure A.3: ISIMIP average index values during 2010-2050 against 1970-2010 baseline for crop productivity, from LPJmL/crop and WaterGap, forced with the HadGEM2-ES climate model (left) and IPSL-CM5A (right) under RCP2.6 and RCP8.5, North Africa

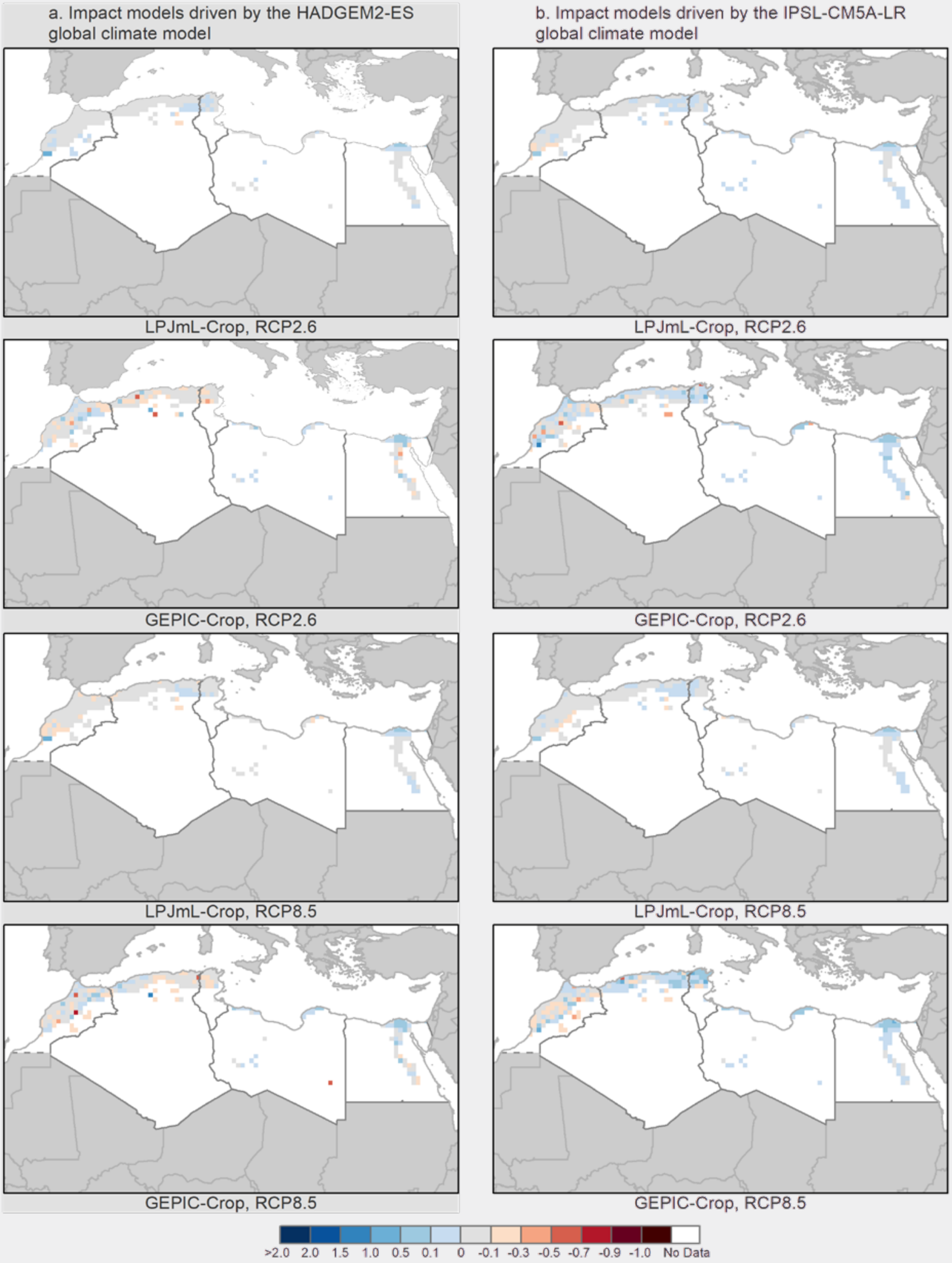
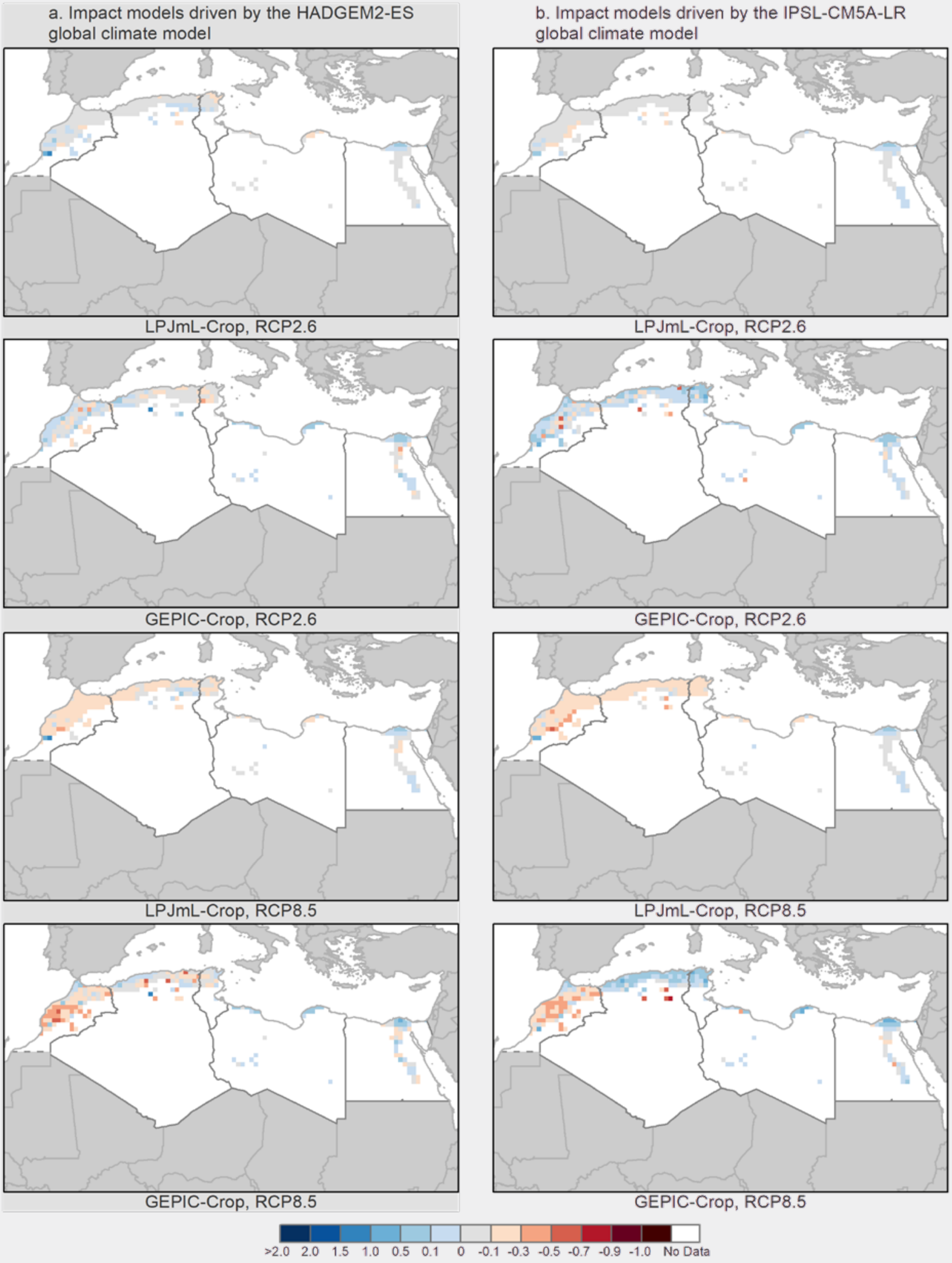


Figure A.4: ISIMIP average index values during 2050-2100 against 1970-2010 baseline for crop productivity, from LPJmL/crop and WaterGap, forced with the HadGEM2-ES climate model (left) and IPSL-CM5A (right) under RCP2.6 and RCP8.5, North Africa



a. Impact models driven by the HADGEM2-ES global climate model

b. Impact models driven by the IPSL-CM5A-LR global climate model

LPJmL-Crop, RCP2.6

LPJmL-Crop, RCP2.6

GEPIC-Crop, RCP2.6

GEPIC-Crop, RCP2.6

LPJmL-Crop, RCP8.5

LPJmL-Crop, RCP8.5

GEPIC-Crop, RCP8.5

GEPIC-Crop, RCP8.5

A.2 ISIMIP WATER AND CROP MODEL RESULTS FOR THE LOWER MEKONG

ISIMIP average index values for water availability and crop productivity for 2010–2050 are presented in Figures A.5 and A.7, respectively, and for the period 2050–2100 in Figures A.6 and A.8, respectively.

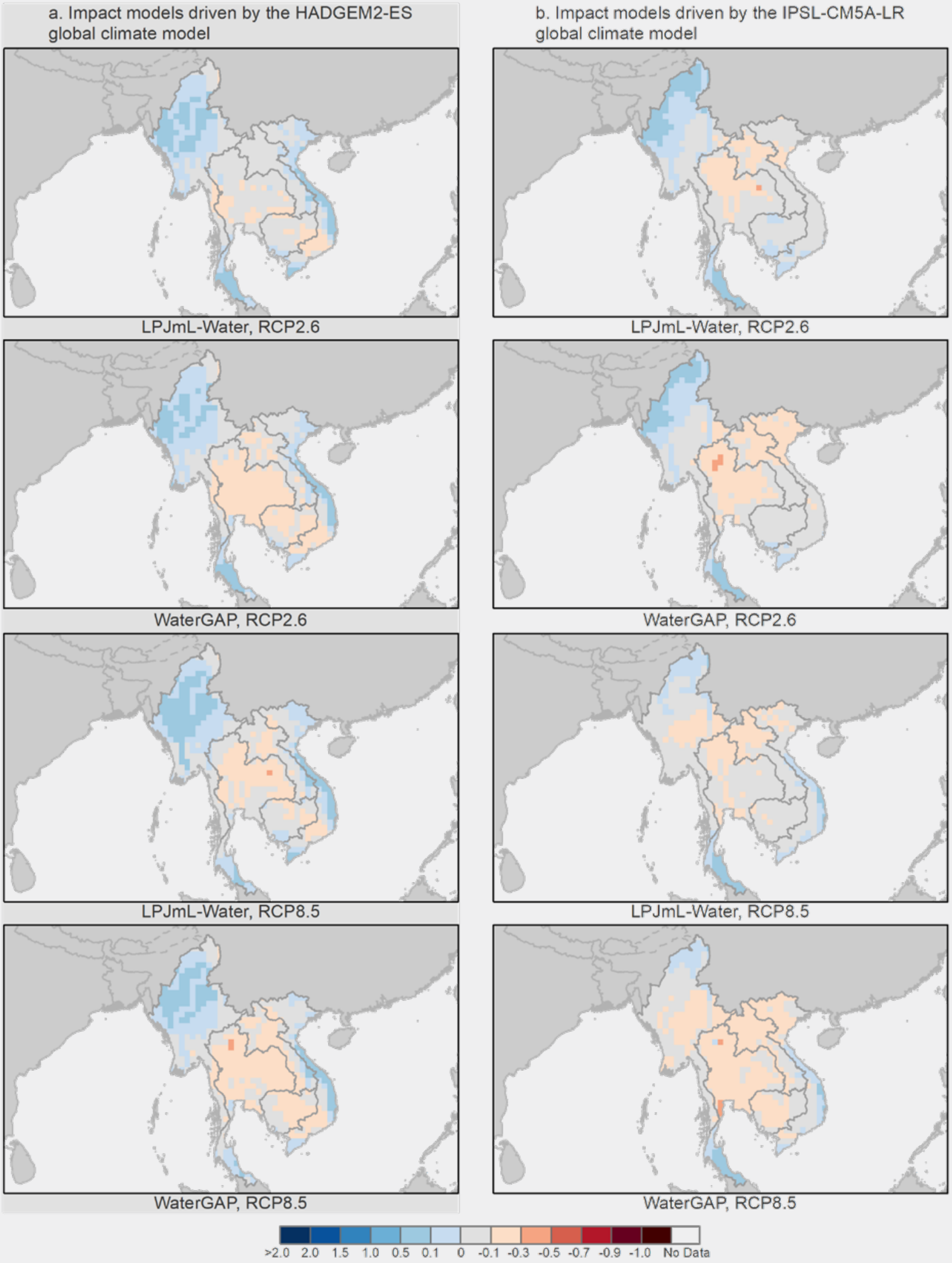
Table A.2 displays the coefficients used in the calibration of the model for the subregion. Thailand was used for the entire Lower Mekong subregion owing to the availability of consistent input population data across the 20-year time period for calibration. For both rural and urban areas, crop productivity is the strongest predictor, and is much stronger for rural compared to urban areas. Water availability is also important in rural areas.

Table A.2: Model coefficients for the Lower Mekong (based on Thailand)

	Urban	Rural
Crop productivity	0.587	1.509
Water availability	0.143	0.846

ISIMIP projections for water availability and crop productivity from 2010–2050 are found in maps below. Figure A.5 shows modest (–10 to –30 percent) declines in water availability in the central portions of the Lower Mekong subregion, with pockets of potentially high (30–50 percent) declines in northern Thailand. The coastal areas and mountains of Vietnam largely see increases, as do the Malay Peninsula of Thailand and western portions of Myanmar. Figure A.7 shows that rainfed and irrigated agriculture is widespread in the subregion, and that crop productivity is projected to be mostly stable or slightly higher as a result of climate change, though depending on the model (particularly under RCP8.5) parts of central Thailand, Lao PDR, northern Vietnam and northern Myanmar could experience modest (10–30 percent) declines. The GEPIC model shows a greater stippling of results, with pockets of extremely high increase or decrease. Projections are also available from 2050–2100 (Figures A.6 and A.8), and generally just show a slight accentuation of the impacts in the first half of the century.

Figure A.5: ISIMIP average index values during 2010-2050 against 1970-2010 baseline for water availability, from LPJmL/water and WaterGap, forced with the HadGEM2-ES climate model (left) and IPSL-CM5A (right) under RCP2.6 and RCP8.5, Lower Mekong



a. Impact models driven by the HADGEM2-ES global climate model

b. Impact models driven by the IPSL-CM5A-LR global climate model

LPJmL-Water, RCP2.6

LPJmL-Water, RCP2.6

WaterGAP, RCP2.6

WaterGAP, RCP2.6

LPJmL-Water, RCP8.5

LPJmL-Water, RCP8.5

WaterGAP, RCP8.5

WaterGAP, RCP8.5

Figure A.6: ISIMIP average index values during 2050-2100 against 1970-2010 baseline for water availability, from LPJmL/water (left) and WaterGap (right), forced with the HadGEM2-ES climate model (left) and IPSL-CM5A (right) under RCP2.6 and RCP8.5, Lower Mekong

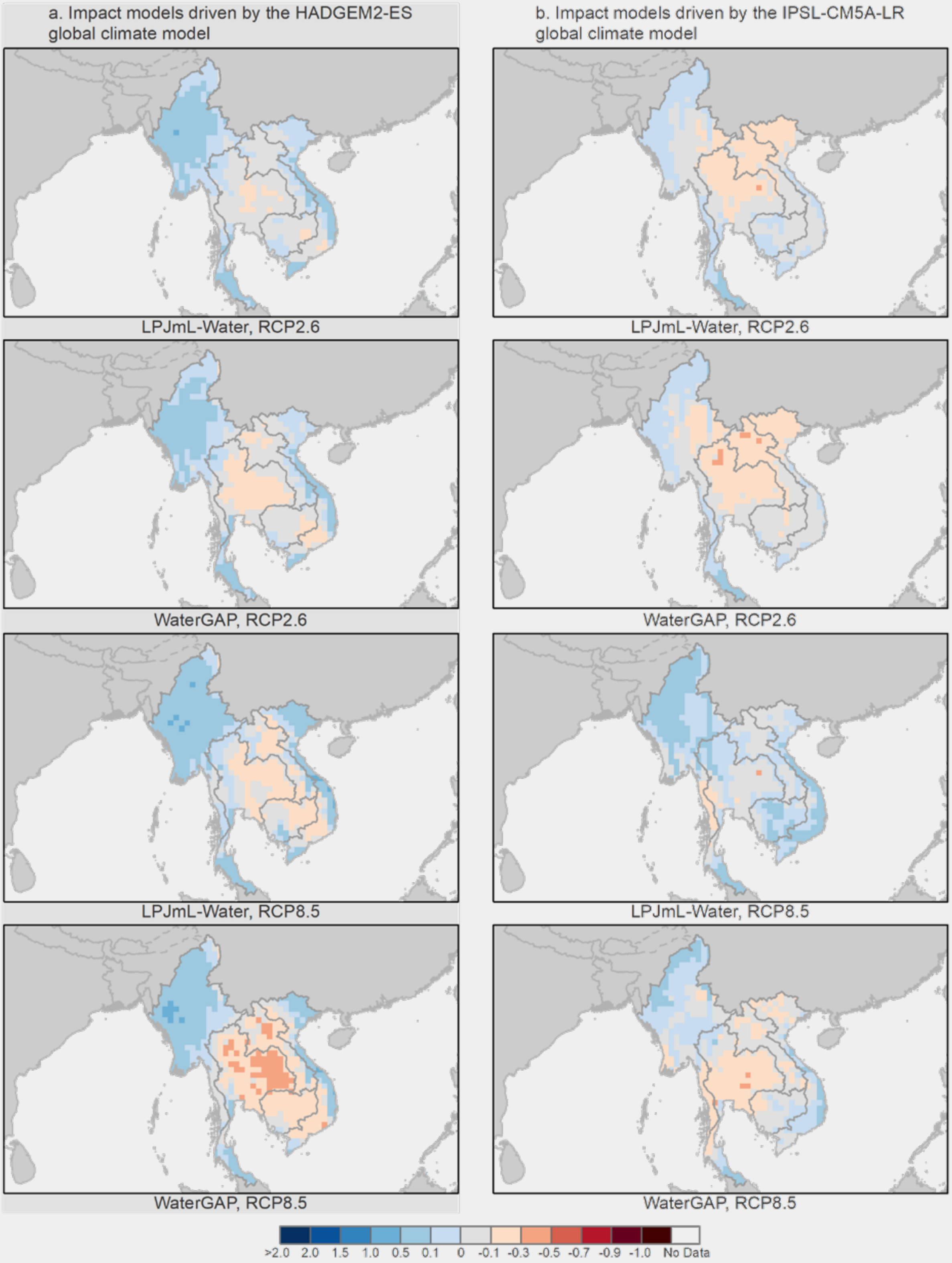


Figure A.7: ISIMIP average index values during 2010-2050 against 1970-2010 baseline for crop productivity, from LPJmL/crop and WaterGap, forced with the HadGEM2-ES climate model (left) and IPSL-CM5A (right) under RCP2.6 and RCP8.5, Lower Mekong

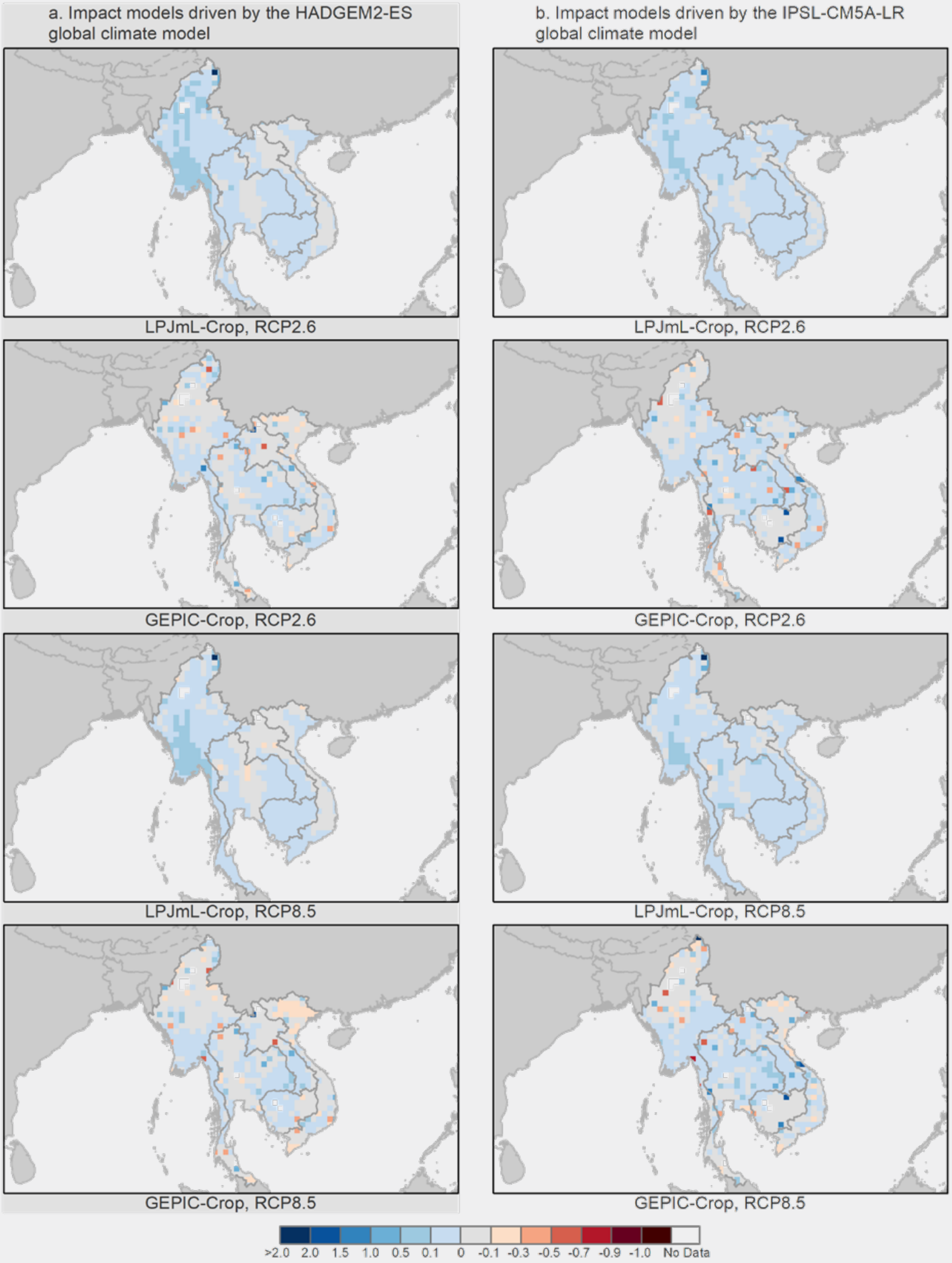
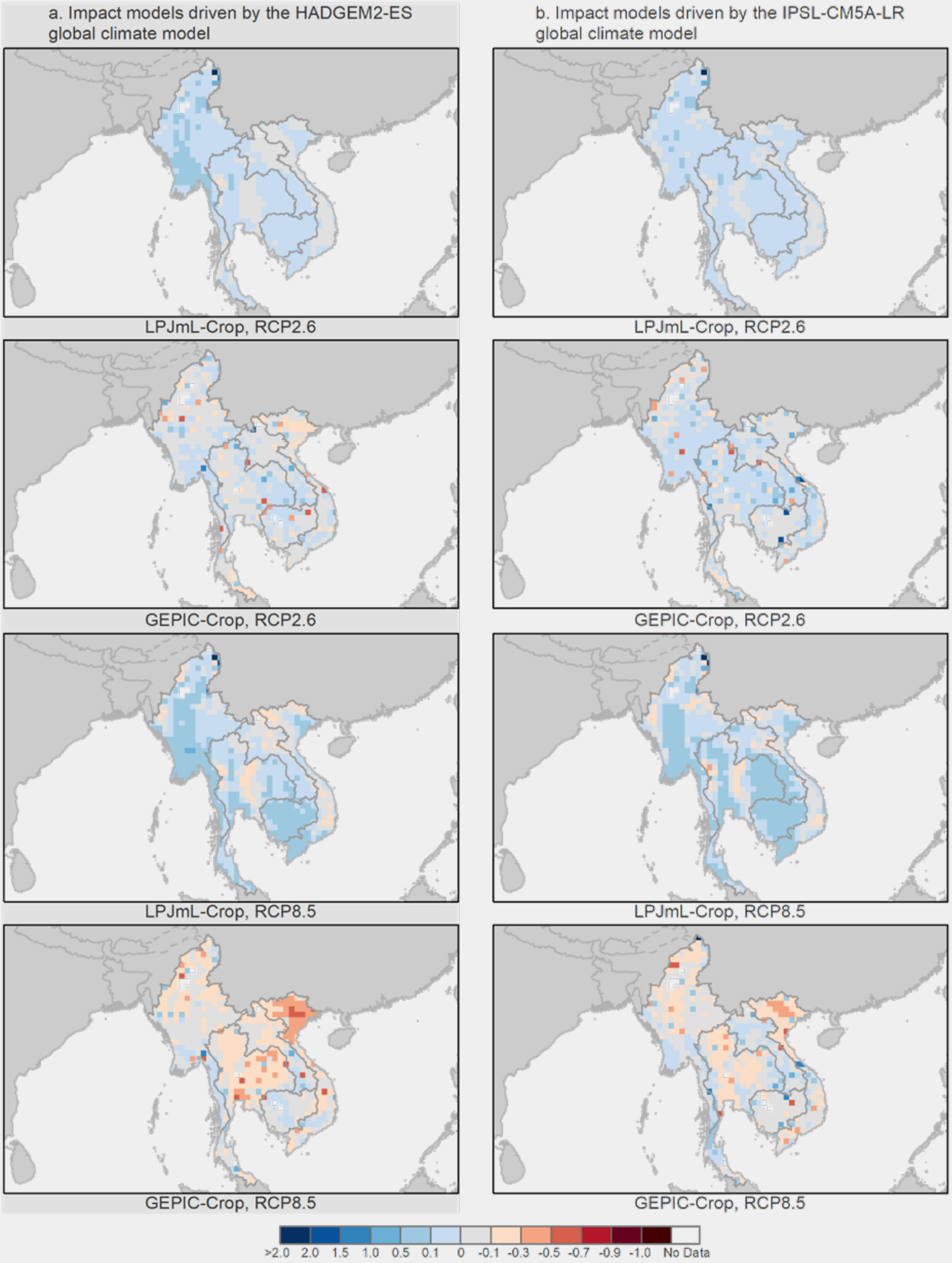


Figure A.8: ISIMIP average index values during 2050-2100 against 1970-2010 baseline for crop productivity, from LPJmL/crop and WaterGap, forced with the HadGEM2-ES climate model (left) and IPSL-CM5A (right) under RCP2.6 and RCP8.5, Lower Mekong



a. Impact models driven by the HADGEM2-ES global climate model

b. Impact models driven by the IPSL-CM5A-LR global climate model

A.3 ISIMIP WATER AND CROP MODEL RESULTS FOR CENTRAL ASIA

ISIMIP average index values for water availability and crop productivity for 2010–2050 are presented in Figures A.9 and A.11, respectively, and for the period 2050–2100 in Figures A.10 and A.12, respectively.

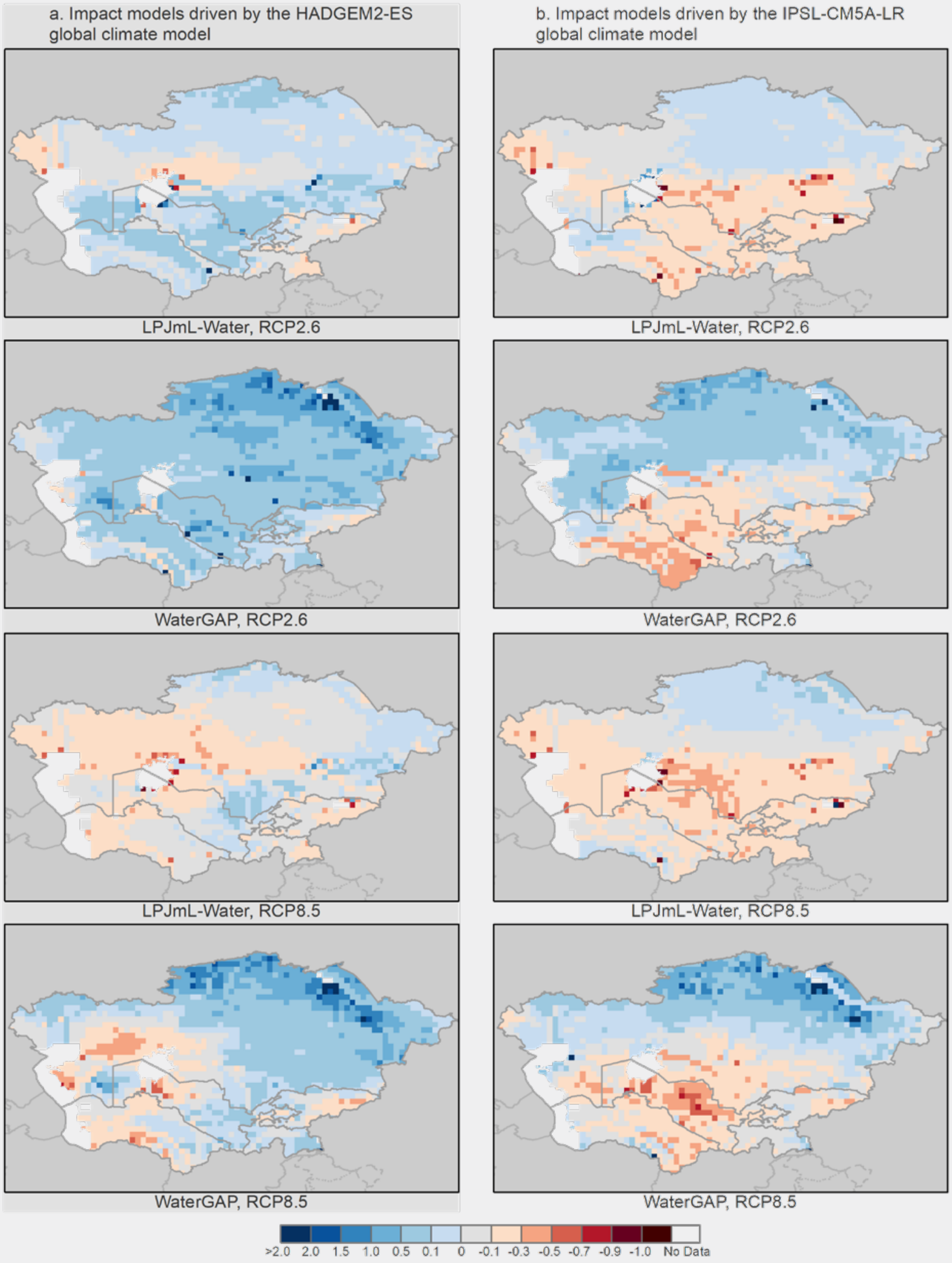
Table A.3 displays the coefficients used in the calibration of the model for the subregion, based on the Kyrgyz Republic. For both urban and rural areas, water is the strongest predictor, and is much stronger for urban compared to rural areas.

Table A.3: Model coefficients for Central Asia (based on the Kyrgyz Republic)

	Urban	Rural
Crop productivity	0.030	0.197
Water availability	1.600	0.239

ISIMIP projections for water availability and crop productivity from 2010–2050 are found in the maps below. Water availability drives the climate migration modeling results to a greater extent than crop productivity. Figure A.9 shows declines in water availability relative to the historical baseline in the southern and particularly the southwestern portions of the subregion, areas that are already semi-arid. Figure A.11 shows that for the relatively limited areas suitable for rainfed agriculture, crop growth is projected to decline. Projections are also available from 2050–2100, and generally show the subregion projected as hotter and drier (Figures A.10 and A.12), but with some combinations of global climate models and water impact models showing increases in water availability in selected areas.

Figure A.9: ISIMIP average index values during 2010-2050 against 1970-2010 baseline for water availability, from LPJmL/water and WaterGap , forced with the HadGEM2-ES climate model (left) and IPSL-CM5A (right) under RCP2.6 and RCP8.5, Central Asia



a. Impact models driven by the HADGEM2-ES global climate model

b. Impact models driven by the IPSL-CM5A-LR global climate model

LPJmL-Water, RCP2.6

LPJmL-Water, RCP2.6

WaterGAP, RCP2.6

WaterGAP, RCP2.6

LPJmL-Water, RCP8.5

LPJmL-Water, RCP8.5

WaterGAP, RCP8.5

WaterGAP, RCP8.5

Figure A.10: ISIMIP average index values during 2050-2100 against 1970-2010 baseline for water availability, from LPJmL/water (left) and WaterGap (right), forced with the HadGEM2-ES climate model (left) and IPSL-CM5A (right) under RCP2.6 and RCP8.5, Central Asia

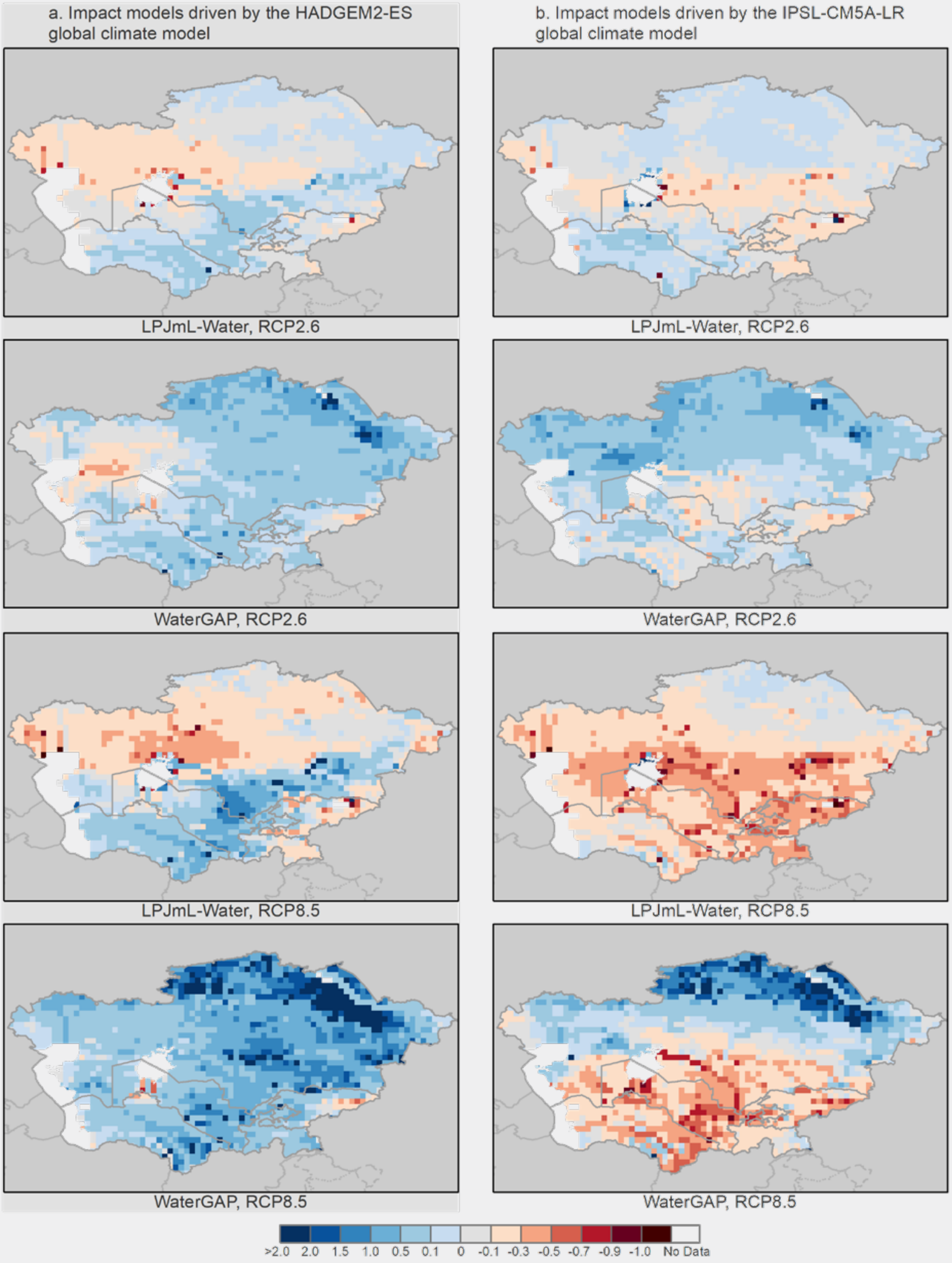


Figure A.11: ISIMIP average index values during 2010-2050 against 1970-2010 baseline for crop productivity, from LPJmL/crop and WaterGap, forced with the HadGEM2-ES climate model (left) and IPSL-CM5A (right) under RCP2.6 and RCP8.5, Central Asia

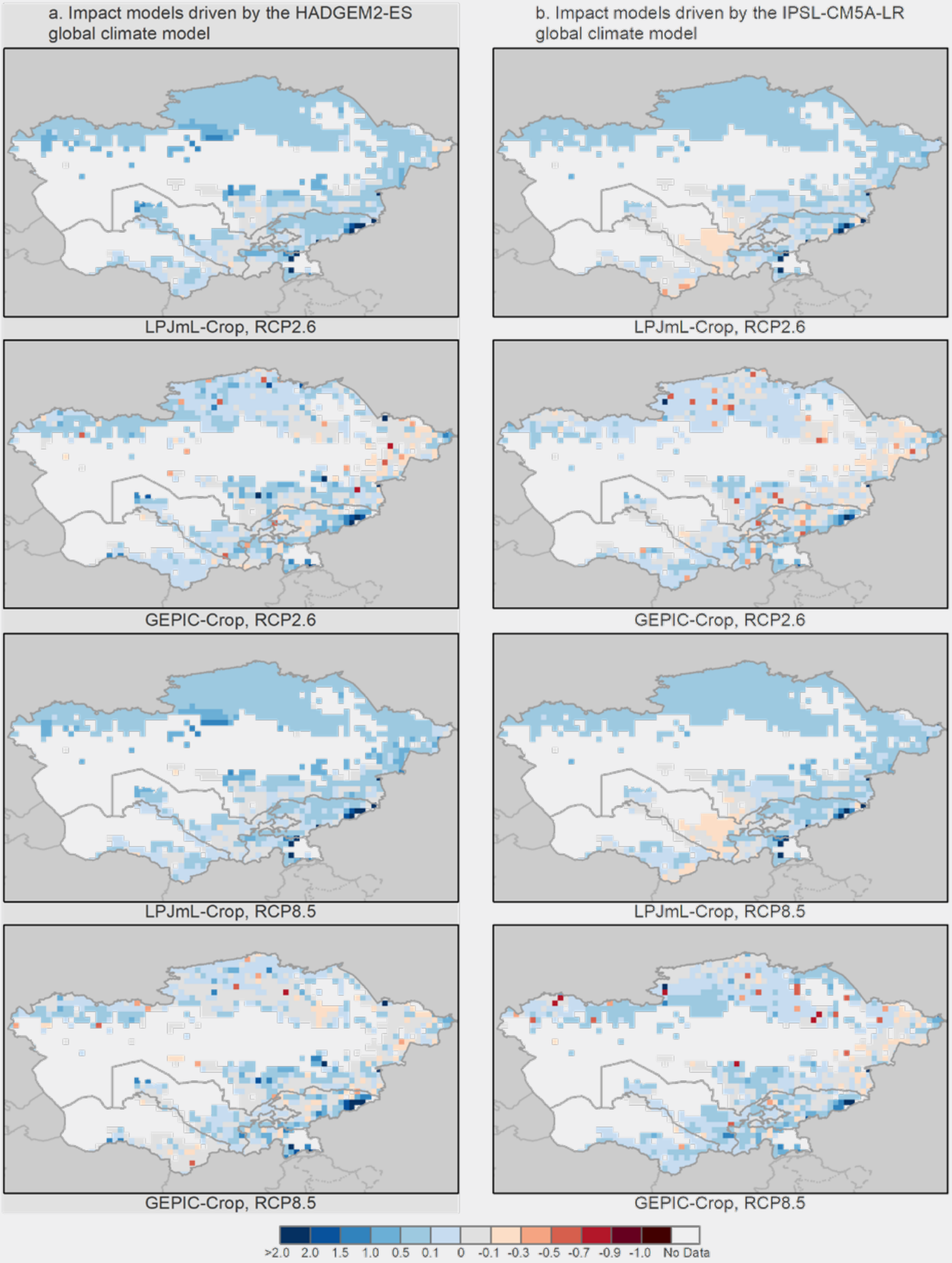
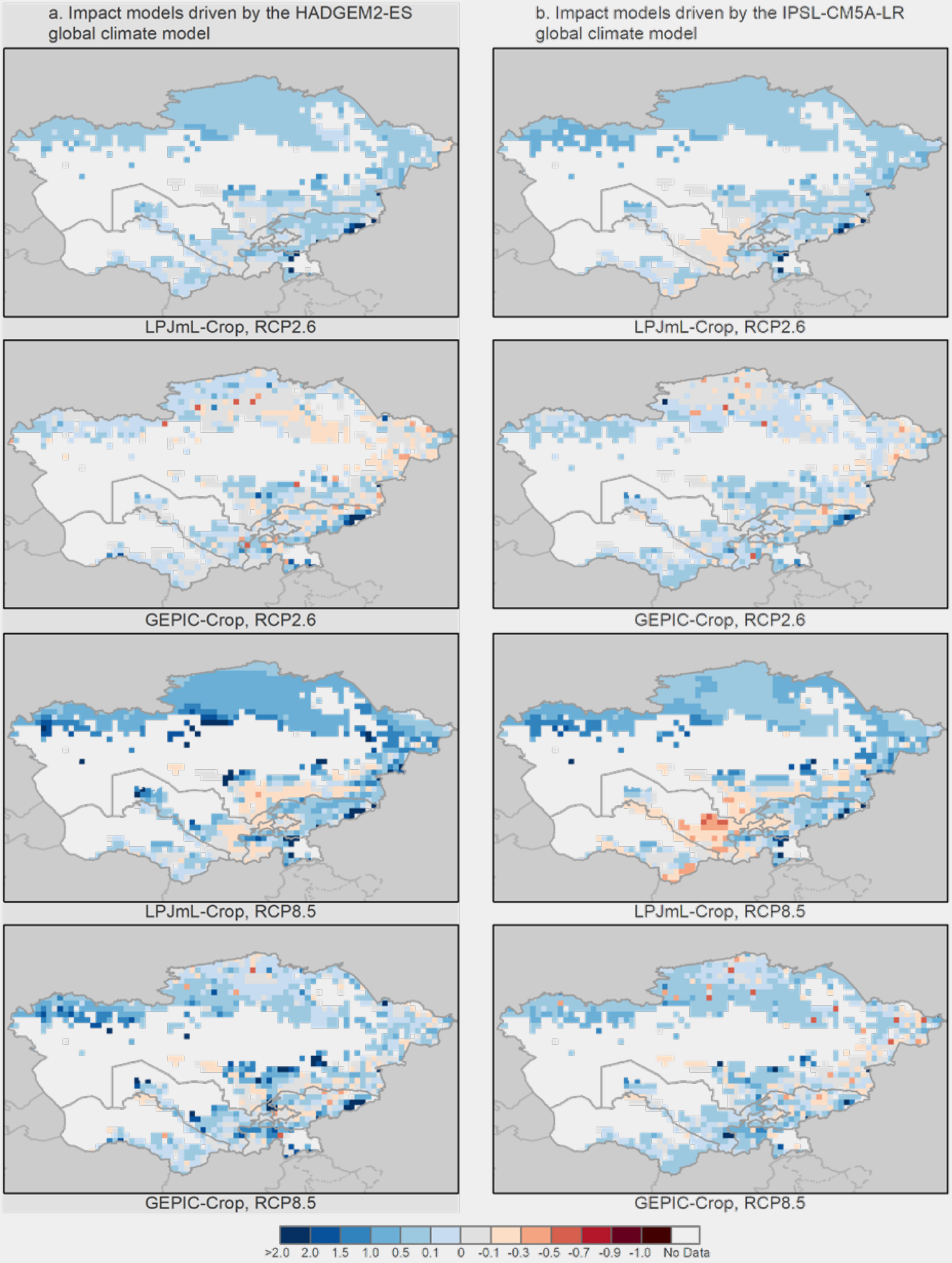


Figure A.12: ISIMIP average index values during 2050-2100 against 1970-2010 baseline for crop productivity, from LPJmL/crop and WaterGap, forced with the HadGEM2-ES climate model (left) and IPSL-CM5A (right) under RCP2.6 and RCP8.5, Central Asia



A.4 ISIMIP WATER AND CROP MODEL RESULTS FOR MOROCCO

ISIMIP average index values for water availability and crop productivity for the period 2010–2050 are presented in Figures A.13 and A.15, respectively, and for the period 2050–2100 in Figures A.14 and A.16, respectively.

Table A.4 displays the coefficients derived from the calibration of the model for Morocco. During the calibration process, water was found to be a slightly stronger predictor of past changes in population distribution, yet the coefficients are not that different from the those for crop productivity. The main difference is that deviations in water availability affect the entire country whereas deviations in crop productivity only affect crop growing areas, which are limited to the northern part of the country. Yet, unlike many other regions of the world, the differences among the parameter estimates are not that great, and all are relatively high – suggesting high historical sensitivity of population distribution to climate factors.

Table A.4: Model coefficients for North Africa (based on Morocco)

	Urban	Rural
Crop productivity	0.599	1.077
Water availability	0.712	1.111

In Figure A.13, water availability shows a consistent decline across models, and this is most intense in the western and southern areas of the country. The only exception is the LPJmL HadGEM2-ES model under RCP2.6, which shows a modest increase on the west coast. Regarding crop productivity, in Figure A.15, the LPJmL models show little or no change, while WaterGap models indicate some areas of both increase and decrease in a checkered pattern.

Looking out to the end of the century, it is notable that under the RCP8.5 model runs (Figure A.14) water availability declines precipitously across most of the country, with declines of 70–90 percent common over much of the country. Crop productivity is also more severely impacted under high emissions scenarios (Figure A.16).

Figure A.13: ISIMIP average index values during 2010-2050 against 1970-2010 baseline for water availability, from LPJmL/water and WaterGap, forced with the HadGEM2-ES climate model (left) and IPSL-CM5A (right) under RCP2.6 and RCP8.5, Morocco

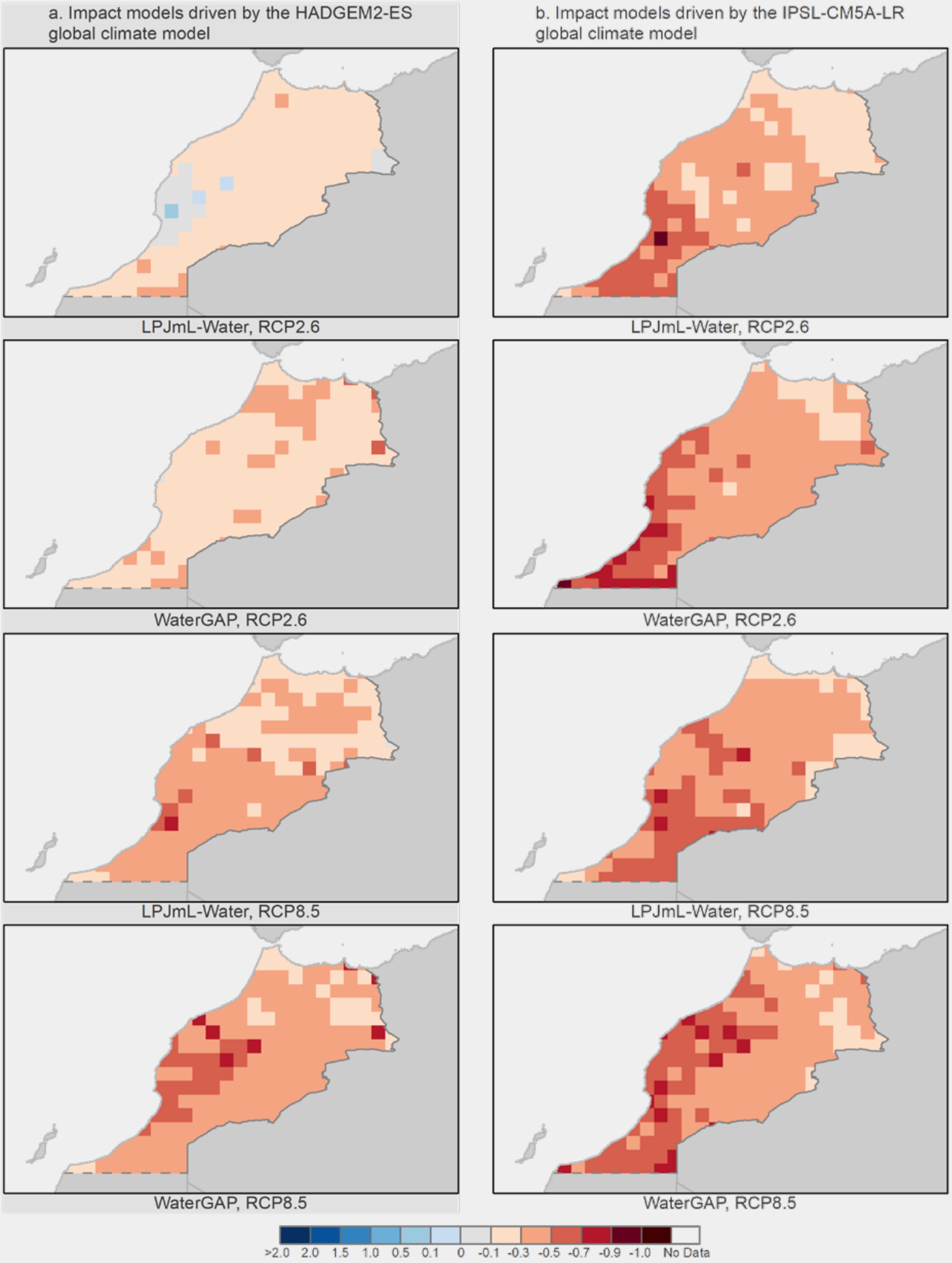


Figure A.14: ISIMIP average index values during 2050-2100 against 1970-2010 baseline for water availability, from LPJmL/water and WaterGap, forced with the HadGEM2-ES climate model (left) and IPSL-CM5A (right) under RCP2.6 and RCP8.5, Morocco

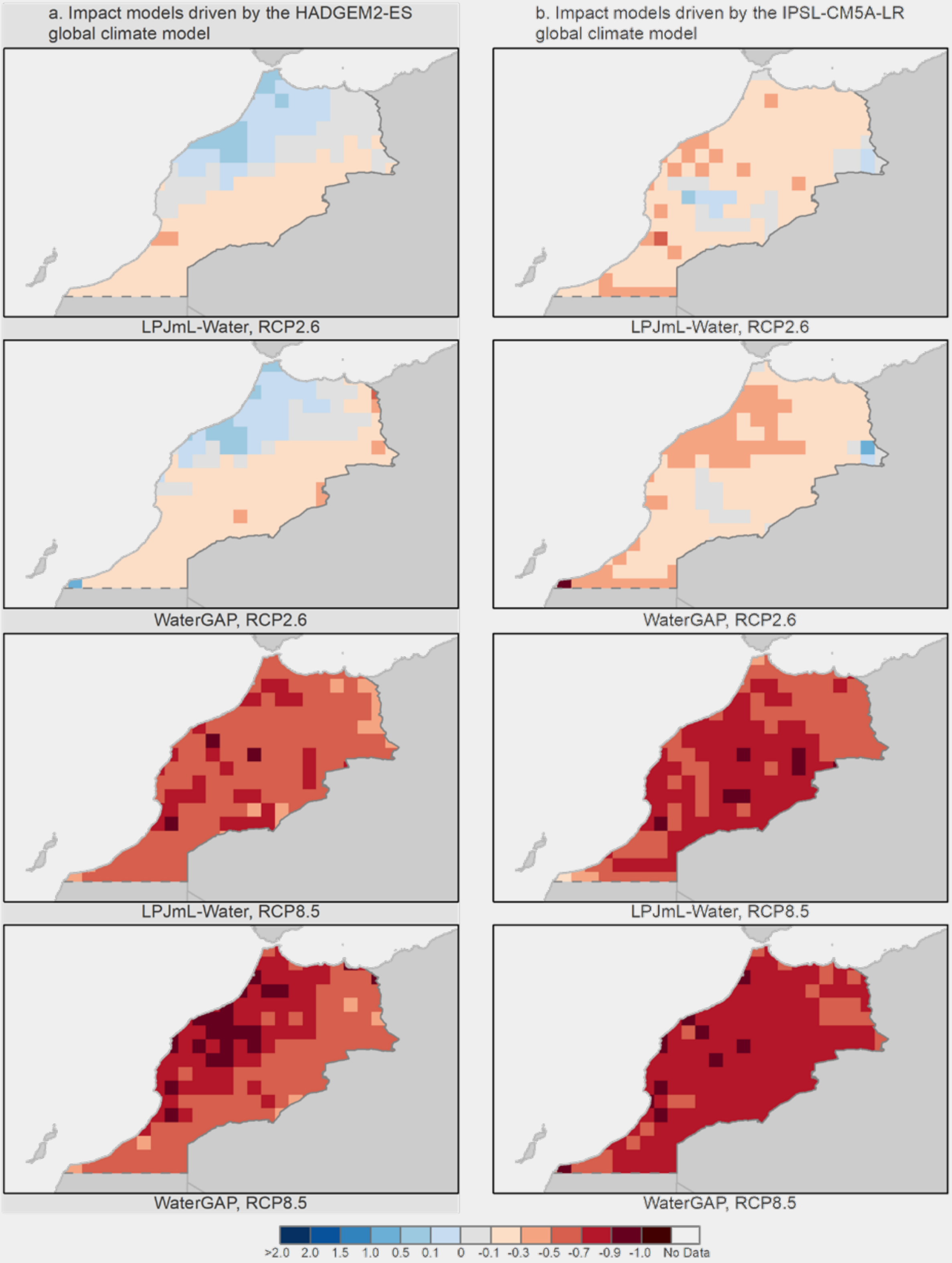


Figure A.15: ISIMIP average index values during 2010-2050 against 1970-2010 baseline for crop productivity, from LPJmL/crop and WaterGap, forced with the HadGEM2-ES climate model (left) and IPSL-CM5A (right) under RCP2.6 and RCP8.5, Morocco

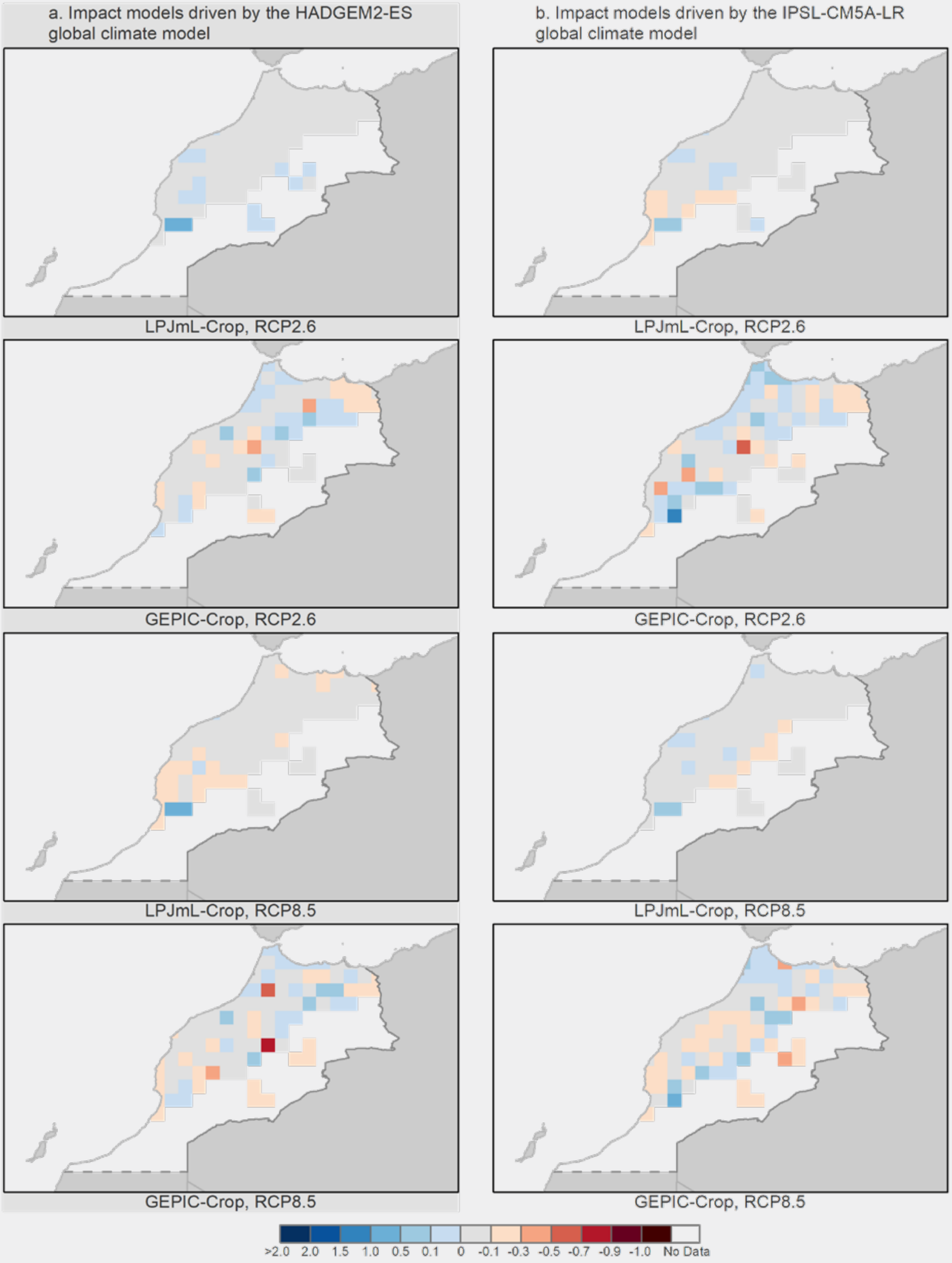
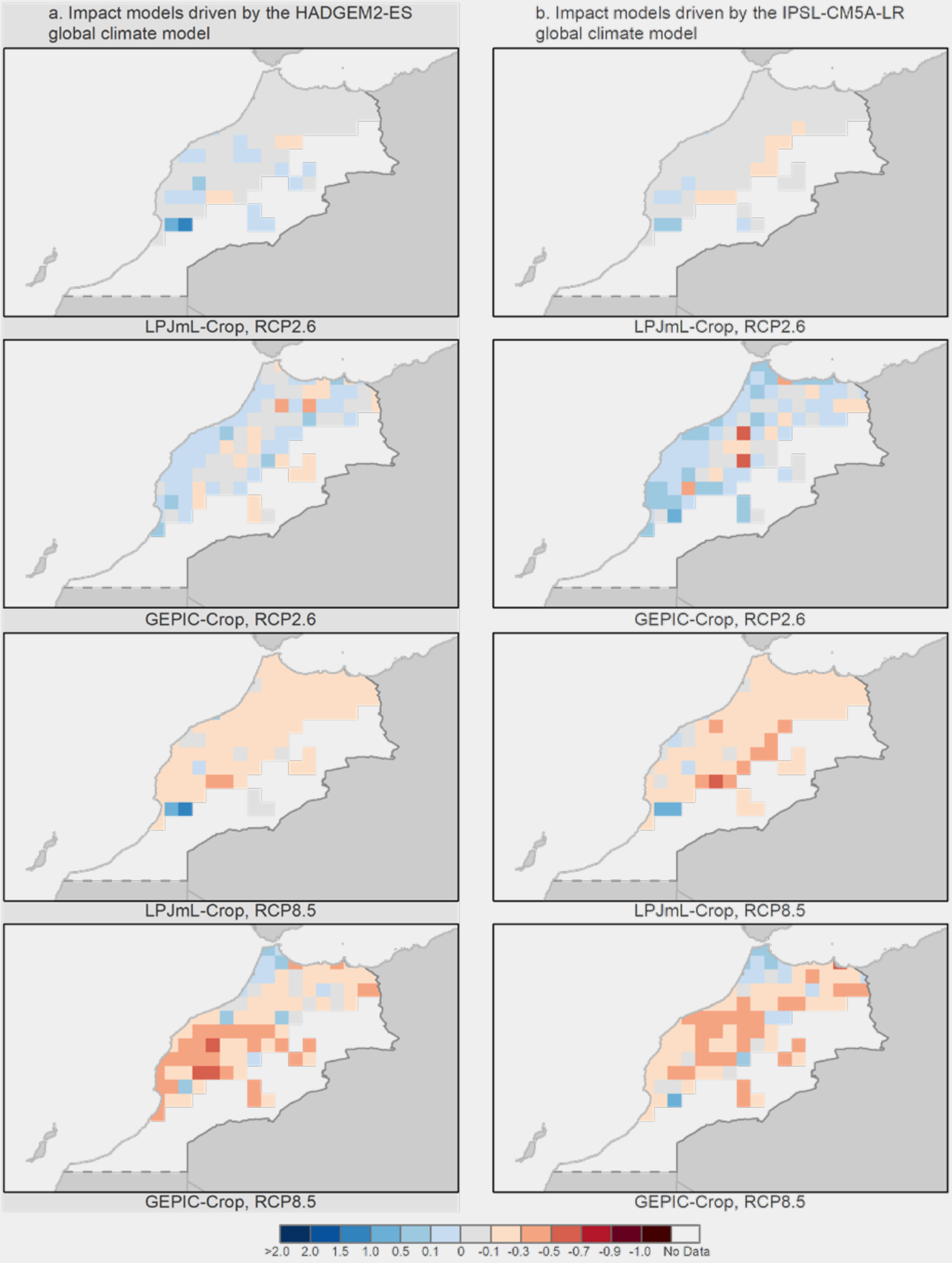


Figure A.16: ISIMIP average index values during 2050-2100 against 1970-2010 baseline for crop productivity, from LPJmL/crop and WaterGap, forced with the HadGEM2-ES climate model (left) and IPSL-CM5A (right) under RCP2.6 and RCP8.5, Morocco



A.5 ISIMIP WATER AND CROP MODEL RESULTS FOR VIETNAM

ISIMIP average index values for water availability and crop productivity for the period 2010–2050 are presented in Figures A.17 and A.19, respectively, and for the period from 2050–2100 are in Figures A.18 and A.20, respectively.

Table A.5 displays the coefficients derived from the calibration of the model for Thailand. Thailand was used for the entire Lower Mekong subregion owing to the availability of consistent input population data across the 20-year time period for calibration. Rural and urban population distributions in Vietnam will be most heavily impacted by crop productivity changes followed by changes to water availability, with rural areas generally more sensitive than urban areas.

Table A.5: Model coefficients for the Lower Mekong (based on Thailand)

	Urban	Rural
Crop productivity	0.587	1.509
Water availability	0.143	0.846

Almost all ISIMIP model runs averaged over 2010–2050 reproduce the historic trend of increasing rainfall (and therefore water availability) in the central coastal region and drying in the north and in the southern mountainous regions (Figure A.17). Crop productivity changes are patchier (particularly under the GEPIC model), but generally central areas will see slight declines, with more significant declines in the far north in some model runs (Figure A.19). The crop productivity changes in the central region offset increases in water availability (at least inland from the coast), whereas declines in the north reinforce the signal of declining water availability in that region. Apart from the GEPIC model under the high emissions RCP8.5 scenario, the southern portion of the country, including the Mekong Delta, is projected to see increases in crop productivity.

Looking ahead to the second half of the century (2050–2100), changes in water availability are not drastically different from 2010–2050, except for perhaps the WaterGAP model run forced by the HADGEM2-ES, which shows a greater drying in the southern highlands (Figure A.18). Trends in crop productivity (both positive and negative) generally also remain stable or slightly increase in intensity, with the exception of the GEPIC model under RCP8.5, where northern Vietnam sees more significant declines in productivity of 30–70 percent (Figure A.20).

Figure A.17: ISIMIP average index values during 2010-2050 against 1970-2010 baseline for water availability, from LPJmL/water and WaterGap, forced with the HadGEM2-ES climate model (left) and IPSL-CM5A (right) under RCP2.6 and RCP8.5, Vietnam

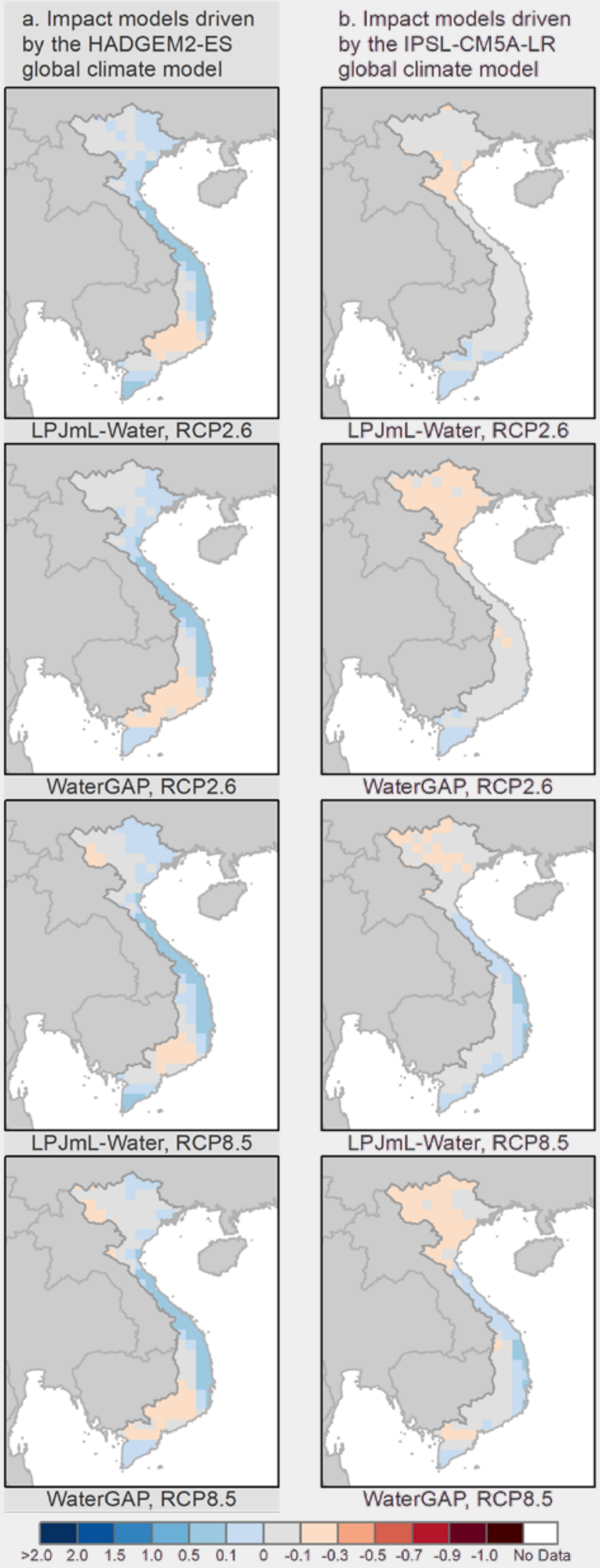


Figure A.18: ISIMIP average index values during 2050-2100 against 1970-2010 baseline for water availability, from LPJmL/water and WaterGap, forced with the HadGEM2-ES climate model (left) and IPSL-CM5A (right) under RCP2.6 and RCP8.5, Vietnam

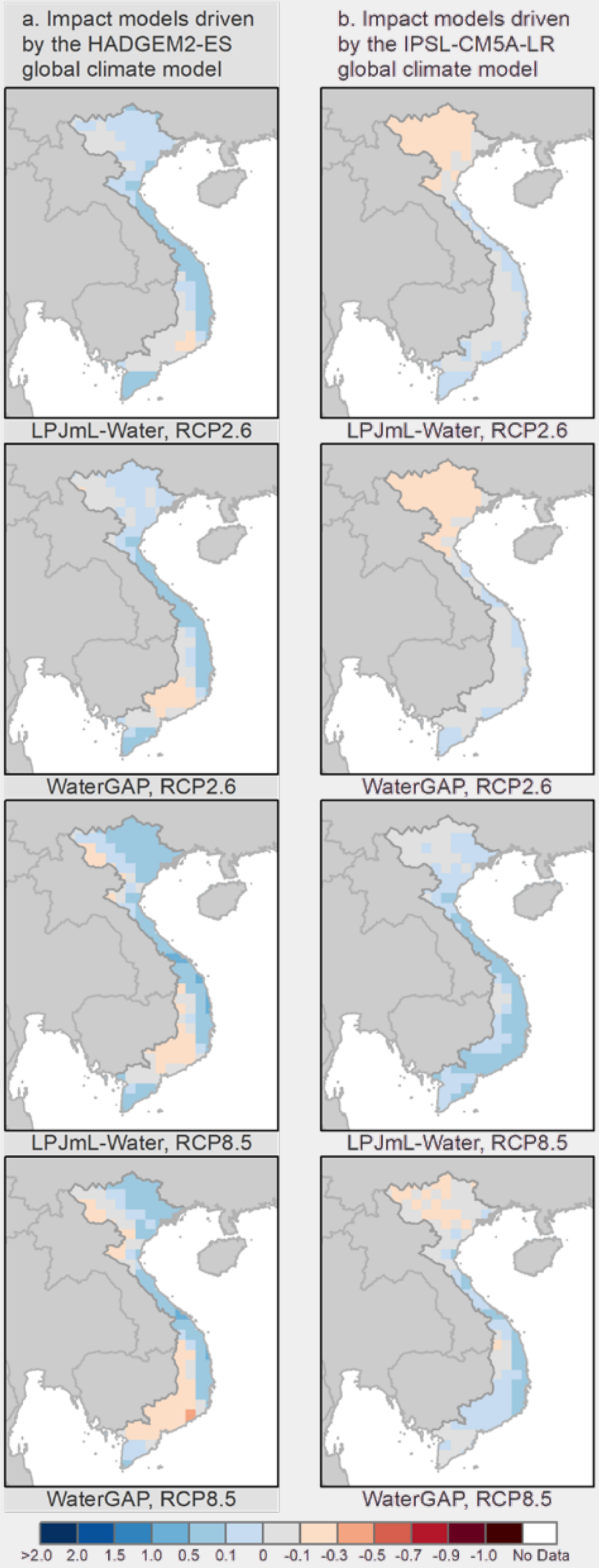


Figure A.19: ISIMIP average index values during 2010-2050 against 1970-2010 baseline for crop productivity, from LPJmL/crop and WaterGap, forced with the HadGEM2-ES climate model (left) and IPSL-CM5A (right) under RCP2.6 and RCP8.5, Vietnam

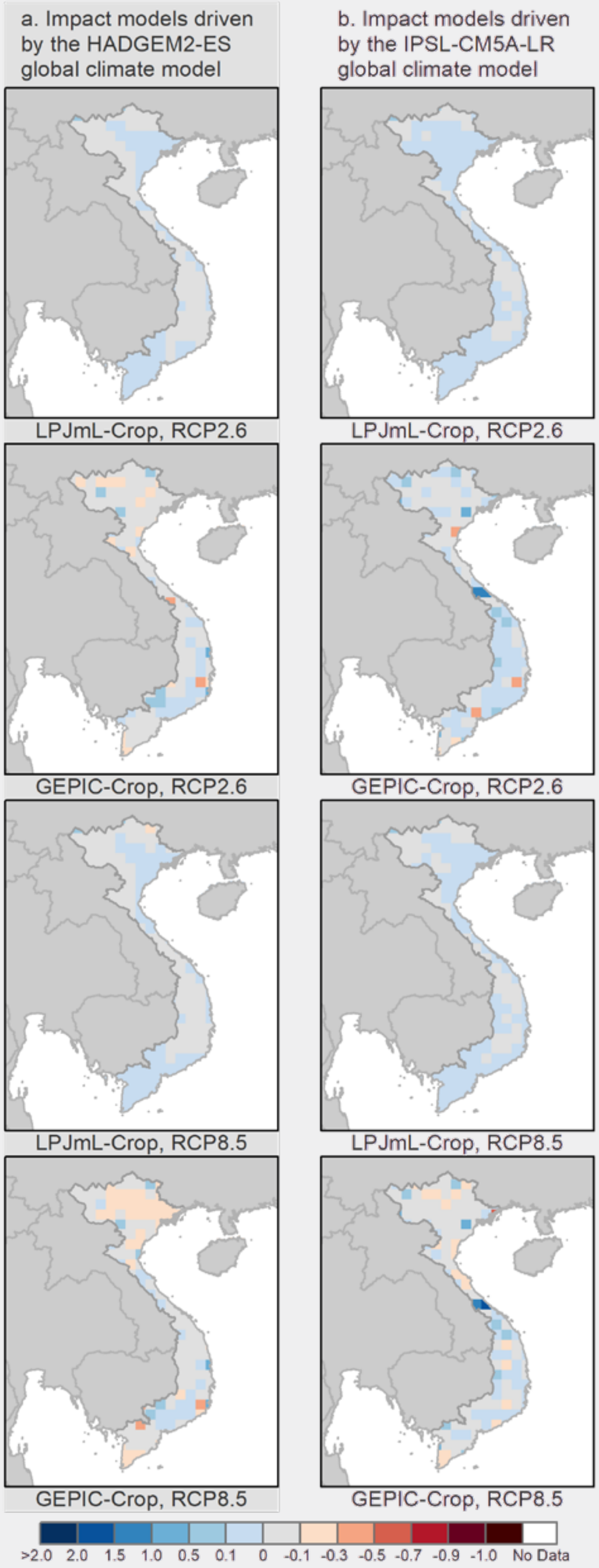
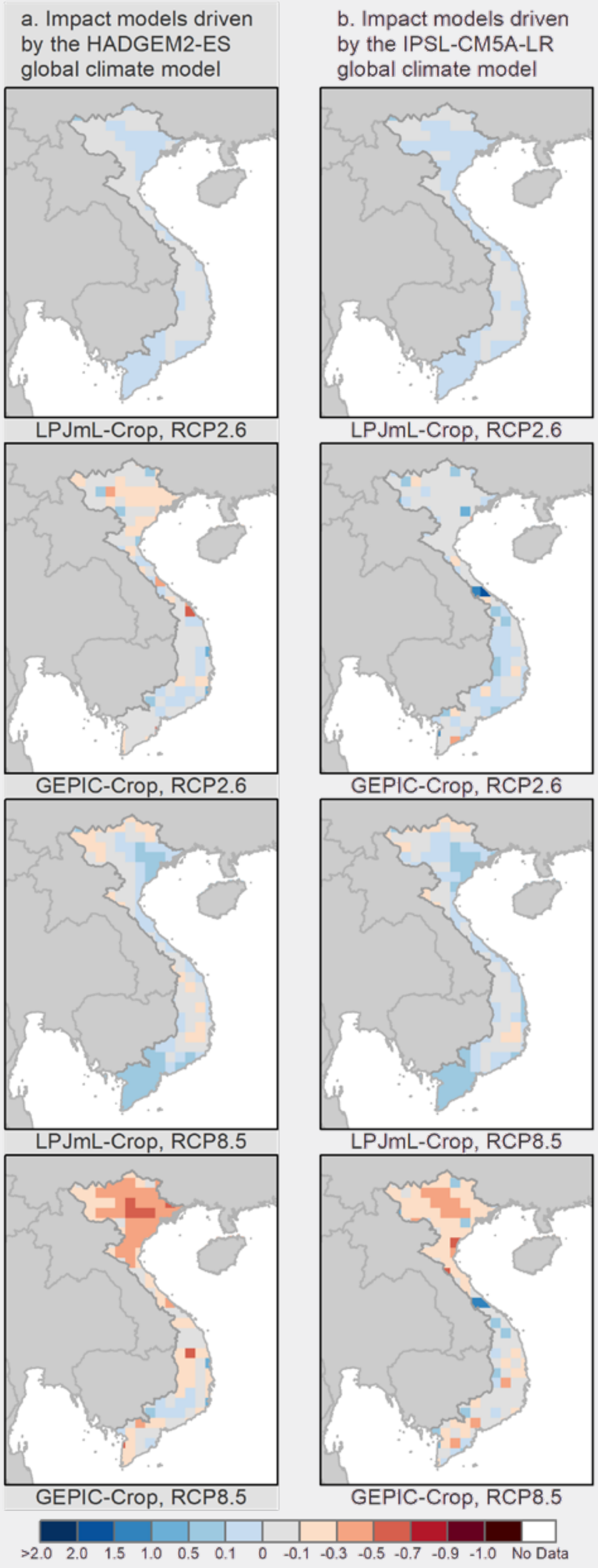


Figure A.20: ISIMIP average index values during 2050-2100 against 1970-2010 baseline for crop productivity, from LPJmL/crop and WaterGap, forced with the HadGEM2-ES climate model (left) and IPSL-CM5A (right) under RCP2.6 and RCP8.5, Vietnam



A.6 ISIMIP WATER AND CROP MODEL RESULTS FOR THE KYRGYZ REPUBLIC

ISIMIP average index values for water availability and crop productivity for the period 2010–2050 are presented in Figures A.21 and A.23, respectively, and projections from 2050–2100 in Figures A.22 and A.24, respectively.

Table A.6 displays the coefficients derived from the calibration of the model for the Kyrgyz Republic. For both urban and rural areas, change in water availability is the strongest predictor of changes in population distribution, especially in urban areas.

Table A.6: Model coefficients for Central Asia (based on the Kyrgyz Republic)

	Urban	Rural
Crop productivity	0.030	0.197
Water availability	1.600	0.239

Projections of water availability are particularly important in explaining future changes in climate migration for the Kyrgyz Republic (Figure A.21). Water availability projections to 2050 across two GCM-ISIMIP model combinations and the two emissions pathways generally show a gradient from wetter conditions in the southwest to drier conditions in the northeast. The Ferghana Valley presents wetter conditions in almost all models. Beyond this general trend, models diverge in the intensity of the changes, with RCP8.5 scenarios displaying significantly drier conditions than RCP2.6 scenarios in some areas. Drying is projected to intensify in the second half of the century (Figure A.22), particularly under the IPSL climate model.

The ISIMIP crop models mostly indicate increases in productivity, especially in the eastern part of the country, in both the near-term to 2050 and in the second half of the century (Figure A.23 and A.24). This is likely the result of increasing temperatures in the higher elevation regions of the country. Crop productivity in the breadbasket of the Ferghana Valley may remain constant or decline slightly under future climate change impacts.

Figure A.21: ISIMIP average index values during 2010-2050 against 1970-2010 baseline for water availability, from LPJmL/water and WaterGap, forced with the HadGEM2-ES climate model (left) and IPSL-CM5A (right) under RCP2.6 and RCP8.5, Kyrgyz Republic

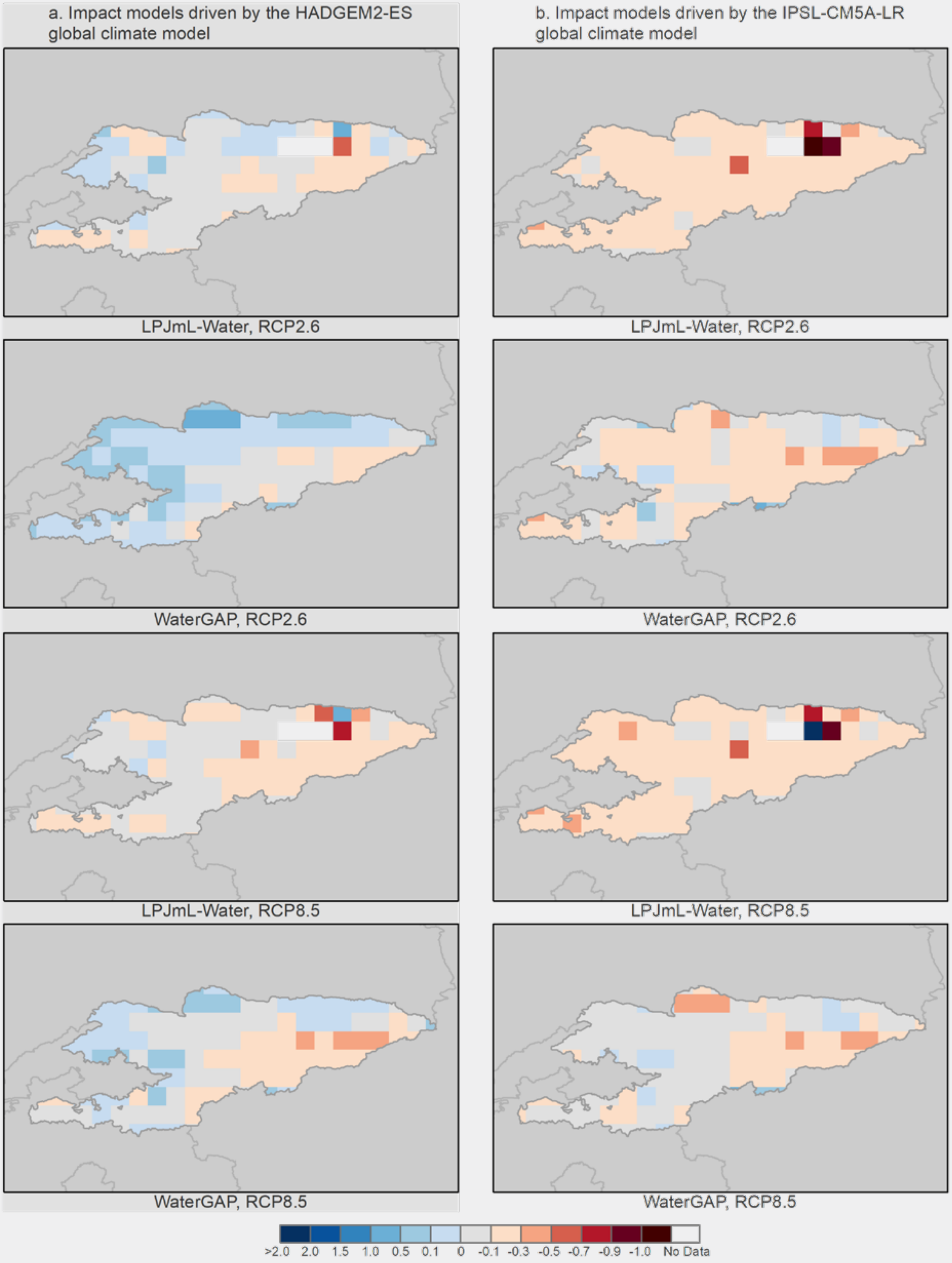
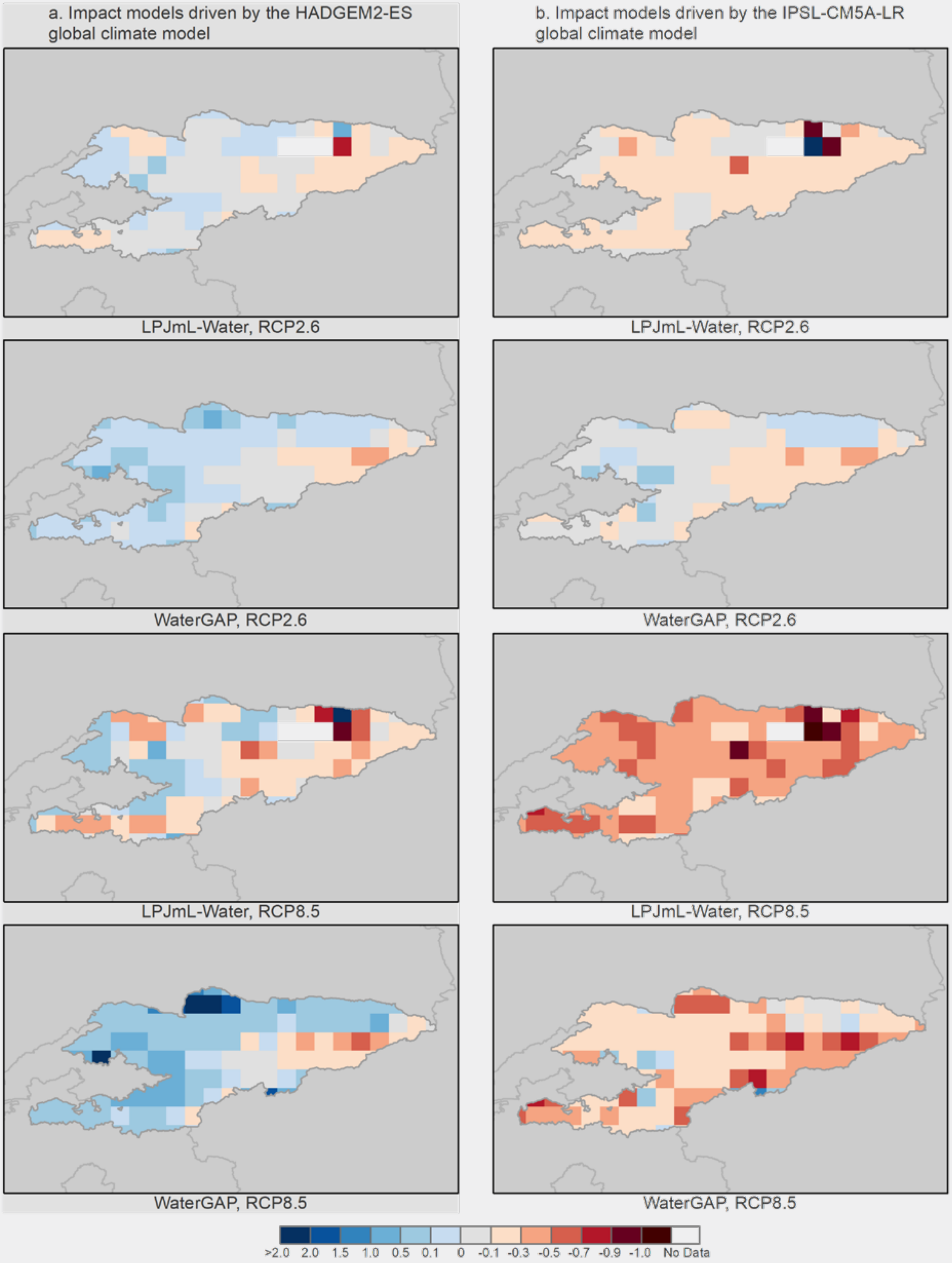
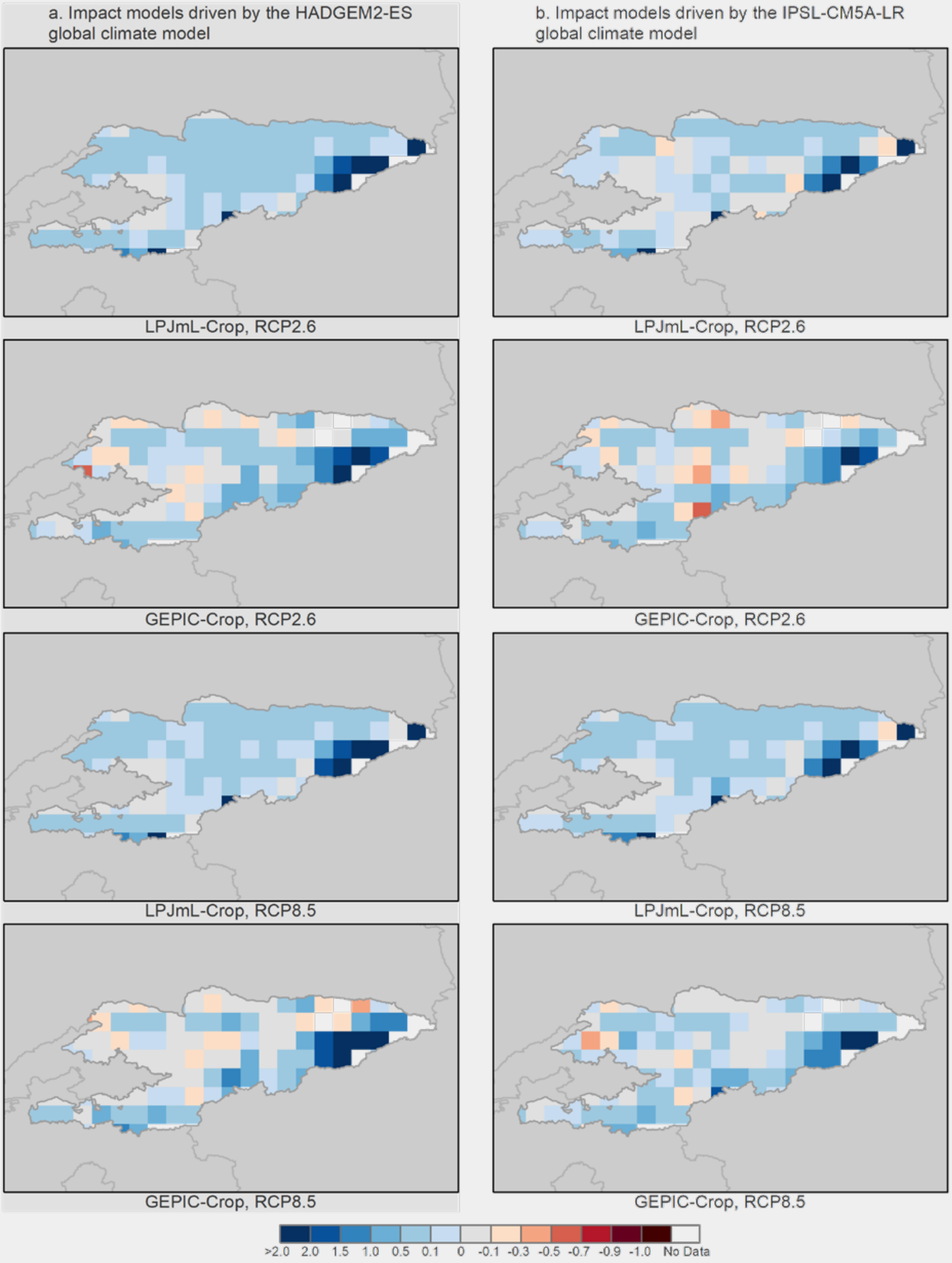


Figure A.22: ISIMIP average index values during 2050-2100 against 1970-2010 baseline for water availability, from LPJmL/water and WaterGap, forced with the HadGEM2-ES climate model (left) and IPSL-CM5A (right) under RCP2.6 and RCP8.5, Kyrgyz Republic


a. Impact models driven by the HADGEM2-ES global climate model

b. Impact models driven by the IPSL-CM5A-LR global climate model

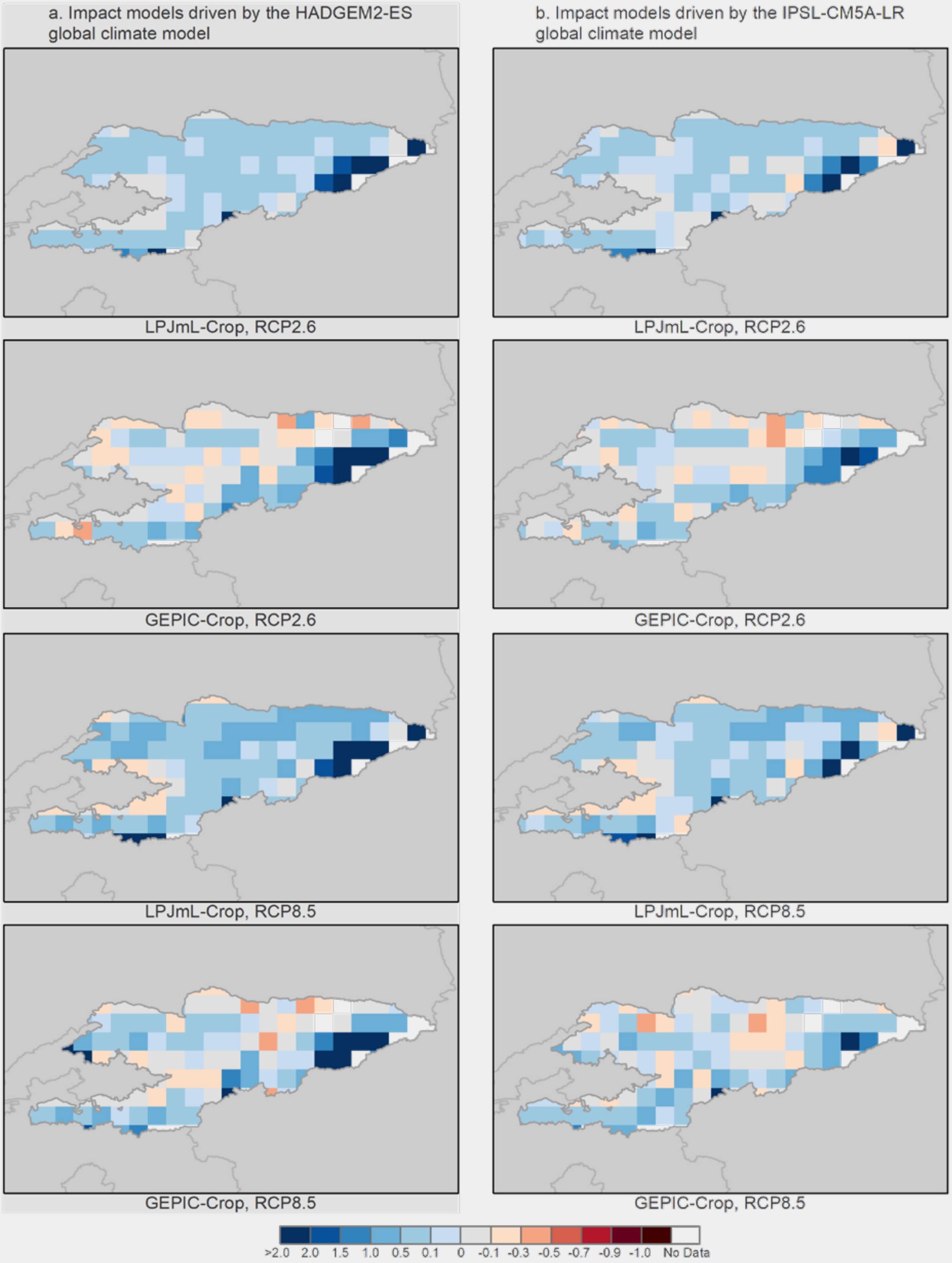
Figure A.23: ISIMIP average index values during 2010-2050 against 1970-2010 baseline for crop productivity, from LPJmL/crop and WaterGap, forced with the HadGEM2-ES climate model (left) and IPSL-CM5A (right) under RCP2.6 and RCP8.5, Kyrgyz Republic



a. Impact models driven by the HADGEM2-ES global climate model

b. Impact models driven by the IPSL-CM5A-LR global climate model

Figure A.24: ISIMIP average index values during 2050-2100 against 1970-2010 baseline for crop productivity, from LPJmL/crop and WaterGap, forced with the HadGEM2-ES climate model (left) and IPSL-CM5A (right) under RCP2.6 and RCP8.5, Kyrgyz Republic



a. Impact models driven by the HADGEM2-ES global climate model

b. Impact models driven by the IPSL-CM5A-LR global climate model

Appendix B

Modeling Internal Climate Migration: A Refresher on the Groundswell Methodology

Climate migration is already taking place, and as climate change impacts grow in the coming decades, the scale of that migration is expected to increase. The *Groundswell* reports examine how much climate migration within countries may grow, over what time frame, and where. This Appendix provides an overview of the methodology used to model climate migration in the six World Bank regions: Sub-Saharan Africa, East Asia and the Pacific, South Asia, the Middle East and North Africa, Latin America, and Eastern Europe and Central Asia.

The methodology takes a pioneering approach to introducing climate change impact projections into a model of future population distribution over large areas. It focuses on key factors that are particularly important as potential drivers of migration—water availability, crop productivity, and sea level rise augmented by storm surge. The modeling uses a scenario-based approach to isolate the portion of future changes in population distribution that could be attributed to climate migration. Sources of uncertainty and the possibilities for expanding the scope of the work are discussed. Figure B.1 summarizes the basic steps of the modeling process. Box B.1 describes the methodology in a nutshell.

Figure B.1: Modeling approach to estimating internal climate migration

MODELING INPUTS

Development pathways
Shared Socioeconomic Pathways (SSPs)—SSP2 (moderate development) and SSP4 (unequal development).

GHG emission pathways drive climate change impacts using ISIMIP water and crop model results, and sea level rise augmented by storm surge. Two Representative Concentration Pathways (RCPs) are used: RCP2.6 (low emissions) and RCP8.5 (high emissions).

PLAUSIBLE INTERNAL CLIMATE MIGRATION SCENARIOS UP TO 2050

Pessimistic/ Reference (RCP8.5/SSP4)	**More inclusive development** (RCP8.5/SSP2)	**More climate-friendly** (RCP2.6/SSP4)
🟨	🟩	🟩

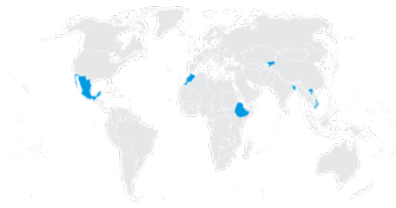
GRAVITY MODEL

Accounts for demographic and socioeconomic (or development) trends, geographic factors and climate impacts applied at grid cell level for modeling shifts in population distribution at country level

ESTIMATES OF INTERNAL CLIMATE MIGRANTS PRESENTED FOR SELECT REGIONS

Estimates of climate migrants derived by comparing grid-cell level population for each of the three “climate impact” scenarios with that of the “no climate impact” scenario (derived from the development only pathway i.e. SSP2, SSP4). The positive difference across all grid cells are aggregated to the national level (and then regional) to produce the estimated number of climate migrants under each of the three scenarios

Six regions with subregional focus for deeper analysis: East Africa (Sub-Saharan Africa), **Lower Mekong** (East and Asia and the Pacific), **South Asia, North Africa** (Middle East and North Africa), **Mexico and Central America** (Latin America), and **Central Asia** (Eastern Europe and Central Asia)

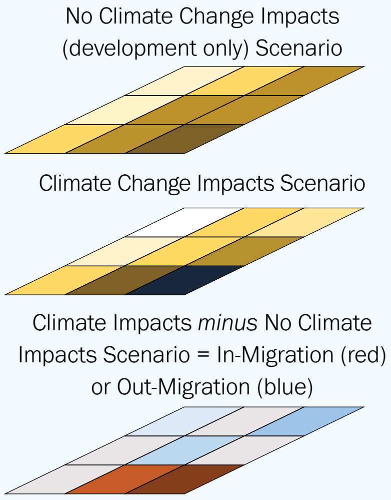


Six illustrative country examples for deeper narrative: Ethiopia (Sub-Saharan Africa), **Vietnam** (East and Asia and the Pacific), **Bangladesh** (South Asia), **Morocco** (Middle East and North Africa), **Mexico** (Latin America), and the **Kyrgyz Republic** (Eastern Europe and Central Asia)

Note: ISIMIP = Inter-Sectoral Impact Model Intercomparison Project; SSP = Shared Socioeconomic Pathway; RCP = Representative Concentration Pathway.

Box B.1: The modeling approach in a nutshell

A population gravity model is used to project future population distribution for each country based on two development scenarios: an unequal development scenario representing a divided world with poor development prospects in low-income countries, versus a moderate development scenario representing a more equitable future world. Climate change impacts on water availability and crops/pasturage for two potential climate futures are added to the two development scenarios, which affect the relative attractiveness of areas within countries. Areas projected to see higher water availability and crop productivity attract people; areas projected to see lower water availability and crop productivity will tend to repel people. Areas impacted by sea level rise augmented by storm surge are “masked” out in a way that people cannot move into them. The climate change impacts are included with the development scenarios in three combinations: a pessimistic reference scenario with high emissions and poor development prospects, a more inclusive development scenario with high emissions and more equitable development prospects, and a more climate-friendly scenario with low emissions and poor development prospects. The diagram at right reflects the process for a hypothetical model run for one of the scenarios, where higher population densities in 2050 are reflected by darker shades. Future population projections without climate change impacts are subtracted from population projections with climate change impacts in order to yield a map of population differences. Positive differences are assumed to reflect net in-migration and negative differences are assumed to reflect net out-migration due to climate change impacts. The model is calibrated by looking at the relationship between past climate change impacts and changes in historical population distributions between 1990 and 2010 (in two 10-year increments), which generates parameter estimates used to project future changes (see Appendix C.2). Multiple model runs are combined to create an average (or ensemble mean) for each scenario (see Figure B.3).



B.1 STATE OF THE ART ON CLIMATE MIGRATION MODELING

Climate migration modeling is a new but growing field (de Sherbinin and Bai 2018; McLeman 2013). This section overviews recent developments in the field, describes the approach to gravity modeling, and reviews the antecedents to this report’s work.

B.1.1 Review of Climate Migration Modeling Efforts

The simplest approach to modeling climate migration is exposure mapping. This approach usually involves overlaying a climate-related hazard on a population distribution map. In some cases, assumptions are made about the number of people who will be displaced if that hazard occurs. Hazards that have been mapped in this way include sea level rise, for which there is a large and growing body of literature (for example, Andrew et al. 2019; Neumann et al. 2015; CIESIN 2013; Mondal and Tatem 2012; McGranahan, Balk, and Anderson 2007); floods (Hirabayashi et al. 2013); multiple climate hazards (B. KC et al. 2021; Christensen et al. 2014); and multiple climatic and non-climatic hazards (Peduzzi et al. 2009; Dilley et al. 2005). Although useful to illuminate the potential risks to human populations, these approaches generally make fairly simplistic assumptions about who will stay or go.

Empirical and theoretical advances from studies of the influence of climate variability and change on recent migration have helped ground recent modeling efforts. These studies generally employ statistical models of migration as it relates to environmental phenomena (for example, Gray and Wise 2016; Backhaus, Martinez-Zarzoso, and Muris 2015; Nawrotzki, Hunter, and Dickinson 2012; Feng, Krueger, and Oppenheimer 2010; Massey, Axinn, and Ghimire 2010; Afifi and Warner 2008; Henry, Schoumaker, and Beauchemin 2004) to develop coefficients related to climate parameters as they influence migration.

These studies need to carefully control for known determinants of migration. Field studies and surveys that delve into household decision making can illuminate perceptions of environmental change and the appropriateness of a decision to migrate (or not).

Agent-based models build on this empirical and theoretical understanding of environmental and other influences on human migratory behavior. They model the behavior of autonomous decision makers when confronted with environmental, economic, or other changes. The theory of planned behavior, coming out of cognitive psychology, provides a basis that can be used to break down the reasoning process relating to the development of a behavioral intention. In this theory, a decision to take an action is related to three factors: the individual's attitude toward the behavior, subjective norms governing the behavior in that society, and the individual's perceived capacity to act on the desired behavior (Ajzen 1991). Agent-based models consider the migration decision in terms of the rules of behavior that govern the response of individuals to complex combinations of multilevel stimuli. They are often parameterized using extensive household survey research and data on migration.

Agent-based models for environmental migration have been developed for Burkina Faso (Kniveton, Smith, and Wood 2011) and Thailand (Entwisle, Verdery, and Williams 2020; Walsh et al. 2013). In the Burkina Faso model, agents decide whether to migrate as an adaptation to changes in rainfall; the likelihood of migrating is affected by both the agent's individual attributes and their placement in a social network in which changes in rainfall are discussed. That study (Kniveton, Smith, and Wood 2011), which incorporates climate scenarios and different demographic, economic, and governance scenarios, finds that gradual rainfall reductions lead to the most total and international migration when combined with changes to social systems and governance.

The Thai study focuses on population-environment interactions in the Nang Rang District, an agricultural area in northeastern Thailand (Walsh et al. 2013). Its model includes social and land use modules. The social modules simulate changes in human population and social networks, including migration and household assets; the land use modules simulate changes in land use and suitability, as well as crop yields. In the agent-based model, individual agents have unique IDs, age, gender, migration status, marriage status, and education. Because the researchers focus on the interactions between population and environment, they also evaluate how human activities affect the ecological system. In the face of high climate variability and extremes, with attendant impacts on crop yields, farmers in Nang Rang adopt a portfolio diversification strategy that includes cultivation of lands with different characteristics, as well as reliance on migration and remittances.

A significant strength of agent-based models is the explicit modeling of micro-level demographic behavior based on theory and empirical evidence (Entwisle, Verdery, and Williams 2020). This feature is a strength for local analyses with enough available data, but it is a limitation for regions with scarce empirical evidence on migration and intent to migrate. Another limitation of agent-based models is the limited spatial definition (or resolution) of the migration pathways. Models typically produce volumes of flows out of one location. They may identify flows into alternative locations, but they do not typically identify source or destination areas with spatial precision, making it difficult to map changes in population that may result from the migration decision making of individual actors.

System dynamics models have been developed to examine environmental migration and displacement. The International Displacement Monitoring Center (IDMC) developed a model that simulates the impacts of droughts, floods, and climate change on the displacement of pastoralists in northern Kenya. It simulates what happens when different measures are implemented to prevent, mitigate, or respond to displacement (Ginnetti 2015). They can be used to develop "what if?" scenarios involving complex econometric models and utility functions. Work on system dynamics models of climate migration is still in its early stages.

Radiation models, a newer class of models, start from the assumption that migration becomes less likely the greater the distance and with more intervening opportunities (Robinson and Dilkina 2018). Thus, migrants will tend to go to the nearest suitable location rather than go farther to pursue similar opportunities. Simini et al. (2012) were the first to apply a radiation model, contrasting its approach with the gravity model (below). According to the authors, it is able to reproduce mobility fluxes with only information on the population distribution and no data on population migration, and the model predicts mobility patterns in good agreement with long-term migration patterns between different regions. So far radiation models are only beginning to be used to project climate migration and have been limited to the case of sea level rise (for example, Robinson, Dilkina, and Moreno-Cruz 2020; Davis et al. 2018). Radiation models do include a spatial component, so results can be mapped.

B.1.2 Gravity Modeling

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 behavior. 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 (Kim, Horner, and Marans 2005; Gustafson 2001; Clark and Withers 1999). Changes in spatial distributions over time reflect changing perceptions. The tendency of populations to gravitate toward larger urban agglomerations, reflected in high rates of urbanization globally, supports the notion that the presence of population is indicative of relative attractiveness.

Gravity modeling has been carried out for the United States using population and land use change scenarios (Bierwagen et al. 2010), which were used to estimate land-based emissions from certain settlement patterns. Also for the United States, McKee et al. (2015) projected population to 2030 and 2050 using a spatial population projection model that incorporates gravity and multivariate methods. Their model considers factors that affect population distribution, such as land cover, the steepness of local terrain, distances to larger cities, and a moving average of the current population. A novelty of their model is the inclusion of population projections, variables, and weights that are adapted to address local characteristics of each of the 3,109 counties in the United States. Their model has the ability to examine "what if" scenarios, such as significant economic decline or climate change impacts. The work described here shares in common with McKee et al. (2015) the introduction of environmental factors into gravity models that affect the relative attractiveness of locations and, by extension, the implicit migration that contributes to population distribution.

The work in this report builds on Jones and O'Neill (2016), who produced scenario-based global population projections to 2100 by downscaling national-level projections of urban and rural population change to a 7.5 arc-minute grid framework. The population projections include explicit international and domestic migration modules. For domestic migration, they downscaled projected national-level urban and rural population change using the National Center for Atmospheric Research (NCAR) gravity-based approach (Bryan Jones and O'Neill 2013). This model is described below.

Gravity model approaches over large geographic areas are largely silent on the question of individual motivations for migration. These models can help illuminate the relative importance of push factors (environmental or economic factors at origin that influence the decision to migrate) versus pull factors (factors at destination such as higher wages that influence the decision to migrate), because modeling the attractiveness of locations in terms of economic or demographic agglomeration factors fits with existing theory.

B.1.3 Climate Migration Modeling: Conclusions

Each approach to modeling meets different purposes and faces different constraints. Agent-based models and systems dynamics models depend on rich data on individual and household-level decision-making processes as well as empirical grounding. They generally lack a strong spatial definition of movements. Radiation and gravity models address some of these constraints and are based on either current population distribution or on past aggregate shifts in population distributions, respectively. For the gravity model, it can be difficult to tease out the specific factors—job opportunities, social amenities, or social networks—that result in population redistributions, or the relative contribution of factors, including environmental change, that may attract or repel populations from given locations. Nevertheless, gravity modeling is one of the few approaches available to take climate migration modeling to scale.

B.2 MODELING INPUTS

B.2.1 The Representative Concentration Pathways

The magnitude of future global warming can be framed through Representative Concentration Pathways (RCPs). Developed in advance of the IPCC *Fifth Assessment Report*, RCPs represent the latest generation of global scenarios for climate change research (see Riahi et al. 2017; van Vuuren et al. 2014) risks and other consequences. RCPs are trajectories of greenhouse gas concentrations resulting from human activity, which result in a specific level of radiative forcing in 2100.[180] The two selected trajectories used in this report are based on the low greenhouse gas concentration RCP2.6 and high greenhouse gas concentration RCP8.5. These imply futures where radiative forcing of 2.6 and 8.5 watts/m^2, respectively, are achieved by the end of the century.[181]

Notably, 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 characterized 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. A previous process (the Special Report on Emissions Scenarios) specified the socioeconomic conditions that drove the climate change models, from which impacts were then calculated. The two RCPs used in this analysis drive the indicators of water and agriculture sector change, which are incorporated in projections of future population distributions.

In RCP2.6, greenhouse gas emissions begin to decline by 2020, and radiative forcing peaks by midcentury before declining to near current levels by 2100. To achieve RCP2.6, new technologies would need to be widely deployed over the next 5–10 years. The extended RCP2.6 scenario assumes “negative emissions” by 2070, meaning that humans remove more carbon dioxide (CO_2) and methane (CH_4) from the atmosphere than they release. RCP2.6 is thus consistent with the Paris Agreement, which keeps the global temperature increase “well below” 2°C.

RCP8.5 is characterized by increasing greenhouse gas emissions, leading to high atmospheric concentrations. It is a future consistent with scenarios of energy-intense development, continued reliance on fossil fuels, and a slow rate of technological development. Pathways characterized by rapid population

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[180] 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.

[181] 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. Technically, low to moderate emissions could produce RCP8.5 should the climate system prove to be more sensitive to emissions than anticipated. Climate sensitivity reflects the degree of warming associated with a doubling of atmospheric CO_2 from pre-industrial levels. The potential range is 1.5°–4.5°C.

growth and land use intensification (croplands and grasslands) are also consistent with this scenario. RCP8.5 implies little to no climate policy. It is characterized by significant increases in carbon dioxide (CO_2) and methane (CH_4) emissions. Some have characterized it as at the high end of business-as-usual scenarios, and maybe even unrealistic, since it implies both larger future populations and a heavy dependence of the energy sector on coal (Hausfather and Peters 2020). Yet this is an area of active debate within the climate community, and there are valid reasons to see RCP8.5, which tracks closely to historic emissions, as a realistic scenario out to 2050, even if beyond mid-century there are increasing uncertainties (Schwalm, Glendon, and Duffy 2020).

The IPCC estimates that in RCP2.6, temperatures are projected to peak at 0.4°–1.6°C above baseline levels by 2050 and then stabilize (IPCC 2013, Table SPM.2). In RCP8.5, temperatures rise by 1.4°–2.6°C by 2050, and by 2.6°–4.8°C by 2100. In this report, the lower emissions scenario is a world in which temperatures are likely to peak at 0.25°–1.5°C above recent baseline levels by 2050 and then stabilize through the end of the century. In the higher emissions scenario, temperatures rise by 0.5°–2°C by 2050 and by 3°–5.5°C by 2100. The slight variation in the projected range of temperature change associated with each RCP between AR5 and our report, reflects the choice of two general circulation models used to drive the ISIMIP climate impact models, whereas the AR5 figures represent the entire Climate Model Intercomparison Project (CMIP5; see Taylor, Stouffer, and Meehl 2012) model ensemble.

B.2.2 Shared Socioeconomic Pathways

To create scenarios illuminating different possible development pathways, this analysis builds on spatial population projections by Jones and O'Neill (2016) that are based on Shared Socioeconomic Pathways (SSPs). SSPs represent a set of scenarios—or plausible future worlds—that underpin climate change research and permit the integrated analysis of future climate change impacts, vulnerabilities, adaptation, and mitigation (Ebi et al. 2014). They can be categorized by the degree to which the different scenarios represent challenges to mitigation (greenhouse gas emissions reductions) and societal adaptation to climate change.

The analysis uses SSPs as story lines to guide the development of spatial population projections at 7.5 arc-minute resolution (grid cells of about 14 square kilometers at the equator). The five SSPs developed by Jones and O'Neill (2016) span a wide range of possible future development pathways and describe trends in demographics, human development, economy, lifestyles, policies, institutions, technology, the environment, and natural resources. They are the scenario benchmarks used for adaptation planning purposes. Table B.1 summarizes the SSP narratives; Figure B.2 relates the SSPs to one another. National-level estimates of population, urbanization, and GDP have been released for each SSP and are available through the SSP database.[182]

The model used in this report builds on SSP2 "moderate development" and SSP4 "unequal development". SSP2 is a development scenario between SSP1 ("sustainability") and SSP3 ("fragmentation"). In SSP2, both low- and middle-income countries experience moderate population growth, urbanization, income growth, and educational progress and with a slow reduction in inequalities among world regions. In SSP4, low- and middle-income countries follow different pathways. Low-income countries have high population growth and urbanization rates and low GDP and education levels. Middle-income countries have low population growth, high urbanization rates, moderate GDP, and low education levels. In both country groups, inequality remains high, and economies are relatively isolated, leaving developing regions highly vulnerable to climate change, with limited adaptive capacity. These scenarios were chosen because they represent divergent development pathways. They were also selected for consistency, or the ability to be paired, with the high and low emissions scenarios (RCPs) used in this report. The high emissions scenario (RCP8.5) can be paired with both SSP4 and SSP2; the low emissions scenario (RCP2.6) can be paired with SSP4.

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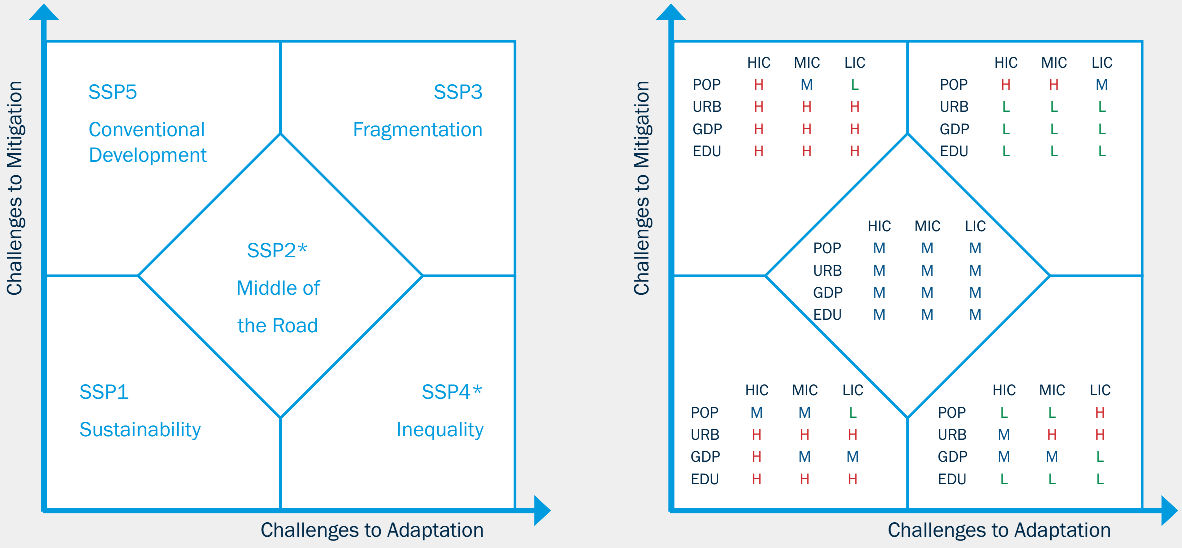
[182] See IIASA's website https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=about.

Table B.1: Shared Socioeconomic Pathway narratives

SSP	Illustrative starting points for narrative	Level of challenge
SSP1	Sustainable development proceeds at a reasonably rapid pace, inequalities are reduced, and technological change is rapid and directed toward environmentally friendly processes, including lower carbon energy sources and higher productivity of land.	Low for mitigation and adaptation
SSP2*	Intermediate case between SSP1 and SSP3.	Moderate
SSP3	Unmitigated emissions are high, as a result of moderate economic growth, rapid population growth, and slow technological change in the energy sector, making mitigation difficult. Investments in human capital are low, inequality is high, a regionalized world leads to reduced trade flows, and institutional development is unfavorable, leaving large numbers of people vulnerable to climate change and many parts of the world with low adaptive capacity.	High for mitigation and adaptation
SSP4*	A mixed world, with relatively rapid technological development in low-carbon energy sources in key emitting regions, leading to relatively large mitigative capacity in places where it matters most to global emissions. However, in other regions, development proceeds slowly, inequality remains high, and economies are relatively isolated, leaving them highly vulnerable to climate change with limited adaptive capacity.	High for adaptation, low for mitigation
SSP5	In the absence of climate policies, energy demand is high and most of this demand is met with carbon-based fuels. Investments in alternative energy technologies are low, and there are few readily available options for mitigation. Economic development is relatively rapid, driven by high investments in human capital. Improved human capital also produces a more equitable distribution of resources, stronger institutions, and slower population growth, leading to a less vulnerable world better able to adapt to climate impacts.	High for mitigation, low for adaptation

Source: Based on O'Neill and others (2014).
Note: * SSP2 and SSP4 used in the model for this report.

Figure B.2: Qualitative Shared Socioeconomic Pathway narratives (left) and the underlying assumptions (right) on various indicators for countries by income group



	HIC	MIC	LIC
POP	H	M	L
URB	H	H	H
GDP	H	H	H
EDU	H	H	H

	HIC	MIC	LIC
POP	H	H	M
URB	L	L	L
GDP	L	L	L
EDU	L	L	L

	HIC	MIC	LIC
POP	M	M	M
URB	M	M	M
GDP	M	M	M
EDU	M	M	M

	HIC	MIC	LIC
POP	M	M	L
URB	H	H	H
GDP	H	M	M
EDU	H	H	H

	HIC	MIC	LIC
POP	L	L	H
URB	M	H	H
GDP	M	M	L
EDU	L	L	L

Source: Jiang (2014).
Note: H = high, M = medium, L = low, POP = population, URB = urbanization, GDP = gross domestic product, EDU = education, HIC = high income countries, MIC = medium income countries, LIC = low income countries; * = SSPs used in the model for this report.

The SSP population projections include cross-border movements, but these do not reflect the potential role of climate change in driving future migration flows. As this study builds on the SSPs, by definition, it also includes the bilateral migration flows included in the national-level population projections that correspond to each SSP (S. KC and Lutz 2017). For both SSP2 and SSP4, these flows are in the middle of the range.[183] They are based on an existing global-level matrix of in- and out-migration (Abel et al. 2019) that is adjusted to reflect assumptions regarding, for example, conflict and political changes and the degree of openness of national borders in each SSP (O'Neill et al. 2014).

B.2.3 Scenario Combinations Used in the Model

Three plausible future internal climate migration scenario combinations are examined:

- A pessimistic reference scenario (SSP4 and RCP8.5), in which low-income countries are characterized by high population growth, high rates of urbanization, low GDP growth, and low education levels. High emissions drive greater climate change impacts. This scenario poses high barriers to adaptation because of the slow pace of development and isolation of regional economies.

- A more inclusive development scenario (SSP2 and RCP8.5), which holds emissions as they are in the pessimistic reference scenario but combines them with reduced inequalities among world regions and more moderate trends in population growth, urbanization, income, and education than under SSP4. Population growth is lower than in SSP4 for low income countries and higher for middle income countries.

- A more climate-friendly scenario (SSP4 and RCP2.6), which has a lower emissions pathway, but holds the development scenario as it is in the pessimistic reference scenario.

Note that at the time of the first *Groundswell* report, these combinations were considered plausible. Some now argue that only SSP5 (not included here) can be combined with RCP8.5.[184] Notwithstanding the evolving knowledge base regarding the plausibility of certain SSP–RCP combinations, a significant value of the approach taken in this report lies in the observed differences relative to the pessimistic reference scenario along the constant development and constant emissions pathways, each of which allows us to assess the impact of improved climate and socio-economic futures independently and relative to one another.

B.2.4 Climate Change Impact Scenarios

Many studies seeking to understand the effects of climate change on mobility have used climate variables such as temperature and precipitation rather than actual climate change impacts on different sectors. The key innovation of this research project is that, rather than simply incorporating likely future climate trajectories, it incorporates actual impacts on two critical sectors: water and agriculture, as well as sea level rise in coastal zones, augmented by storm surge.

Inter-Sectoral Model Intercomparison Project

The Inter-Sectoral Impact Model Intercomparison Project (ISIMIP) is a climate-impact modeling initiative aimed at contributing to a quantitative and cross-sectoral synthesis of the differential impacts of climate change, including uncertainties. The ISIMIP project uses a subset of the general circulation models used in the IPCC AR5 process. This leads to slight variations in the projected temperature range associated with RCP2.6 and RCP8.5 used in this report as described above. ISIMIP has compiled a database of state-of-the-art computer model simulations of biophysical climate change impacts. It offers a framework for consistently projecting the impacts of climate change across affected sectors and spatial scales.

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[183] Migration flows are considered medium across all SSPs except SSP3 ("fragmentation"), where they are low, and SSP5 ("conventional development"), where they are high. A more sophisticated set of SSP projections is under development.

[184] See Benefits of Reduced Anthropogenic Climate Change (BRACE) project, at https://www.cgd.ucar.edu/projects/chsp/brace.html.

The analysis for this study used outputs of the ISIMIP Fast Track modeling effort, which covers 1970–2010, as well as projections for 2010–2050 (Piontek et al. 2014).[185] Under the Fast Track, the future sectoral impact models are driven by a range of general circulation models. This project used 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 IPSL-CM5A-LR climate model developed by the Institut Pierre Simon Laplace Climate Modeling Center (in France) (see Appendix C for details).

Climate change impacts addressed in the model

The ISIMIP 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 water availability and crop productivity, as well as sea level rise scenarios that were developed outside the ISIMIP framework. The global simulations—at a relatively coarse spatial scale (0.5 degrees or roughly 55 kilometers 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. These climate change impacts were selected because the literature shows that water scarcity and declining yields, along with sea level rise, are among the slow-onset climate change impacts with the greatest relevance to rural livelihoods and habitability, particularly in low-income countries, and these impacts will also be very important drivers of migration. In the ISIMIP models, water availability is influenced by rainfall, rising temperatures, dams and reservoirs, and management practices, while crop productivity is a function of rainfall, temperature, CO_2 concentrations, irrigation, and management practices. These technologies and management practices are held static after 2005; in other words, technologies remain fixed, and there is no adaptation to future climate change impacts in either the water or agricultural sectors.

It is important to note that countries face many other climate change impacts that are not modeled, such as increasingly frequent and severe floods, drought, and cyclones (except to the extent that they affect water availability and crop yields). As devastating as these may be, short-duration, fast-onset events are not directly included, as the focus is on slow-onset climate change impacts that drive more permanent migration. The full range of factors are beyond the scope of this analysis but should be examined in studies at scale, as they could significantly affect livelihoods and mobility in some places (for example, urban heat stress effects, salination expanding the area affected by sea level rise and related effects on surface and groundwater used for irrigation). These factors are difficult to capture in global models, and therefore require more localized study. The model presented here should be seen as a first step in quantifying the potential impact of climate change on migration within countries; future efforts could incorporate more sectoral models. Thus, the results should be seen as a lower-bound estimate of the likely impact of climate change on migration.

As mentioned above, the focus of this work is not on short-term climate variability or extremes—which are not as well captured by the impact models—but on deviations from baseline conditions over decades. There are compelling theoretical reasons to focus on trends rather than extremes.

- Extremes are more likely to result in short-term displacement (followed by population return to affected areas) (Brzoska and Fröhlich 2016; Black et al. 2011; Kälin 2010).

- Longer-term trends in crop yields or water availability are more likely to contribute to out-migration (Nawrotzki et al. 2017; Bohra-Mishra, Oppenheimer, and Hsiang 2014).

- The impact of successive climate shocks may erode household assets and therefore the ability to adapt locally, eventually affecting decisions to migrate (IDMC 2015; Warner et al. 2012).

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185. See https://www.isimip.org/gettingstarted/fast-track-simulation-protocol/. Note that only the Fast Track model runs were available in 2017, at the time of the original preparation of the original *Groundswell* report. New impact model runs are now available under ISIMIP2b.

- Successive shocks over several years will affect the index values described below, because they represent more prolonged deviations from the mean.

The analysis also uses sea level rise projections under RCP2.6 and RCP8.5 from the IPCC *Fifth Assessment Report*, as shown in Table B.2 (J. A. Church et al. 2013). The IPCC estimates do not take storm surge into account, but as Dasgupta et al. (2007) note, "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" (p. 6). A detailed assessment of the likely levels of storm surge for all covered coastal areas was beyond the scope of this project, but in the model, increments have been added to the sea level rise projections shown in Table B.2 to account for storm surge. Under RCP2.6, the increment was 0.85–0.9 meters, for a total of 1 meter; under RCP8.5, the increment was 1.68–1.85 meters, for a total of 2 meters. These assumptions are applied to all coastlines for 2050; they represent the loss of habitable land as a result of sea level rise plus storm surge in each coastal grid cell.

Both the 1- and 2-meter sea level rises are based on NASA Shuttle Radar Topography Mission data, as modified by the Center for International Earth Science Information Network (CIESIN 2013). Although the addition of the increments is technically sound and based on past work (Hallegatte et al. 2011; Dasgupta et al. 2007), the 1- and 2-meter bands were chosen partly as an expedient (the global sea level rise layers were developed in earlier work) and partly because at the 14-kilometer modeling resolution, smaller sea level rise increments would have barely registered.

Table B.2: Projected rise in sea level under low and high Representative Concentration Pathways (meters above current mean sea level)

	RCP 2.6			RCP 8.5		
Year	Lower	Middle	Upper	Lower	Middle	Upper
2030	0.092	0.127	0.161	0.098	0.132	0.166
2050	0.157	0.218	0.281	0.188	0.254	0.322

Source: Church et al. (2013).
Note: Sea level rise was augmented with storm surge increments under RCP 2.6 (0.85-0.9m); and RCP 8.5 (1.68-1.85m).

Water and crop models used in the gravity model

Data on water availability and crop productivity were integrated into the gravity 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° x 0.5° grid cell resolution. Crops include maize, wheat, rice, and soy beans; for regions with multiple cropping cycles, yield reflects only the major crop production period.[186] The data were converted to decadal average water availability and crop productivity (in tons) per grid cell.[187] An index was then calculated that compares those values with the 40-year average for water availability and crop productivity for 1970–2010:

$$Index = (D_{\text{avg}} - B_{\text{avg}}) / B_{\text{avg}} \qquad \text{(Equation B.1)}$$

where D_{avg} is the decadal average crop productivity/water availability and B_{avg} is the baseline average crop productivity/water availability for the 40-year period 1970–2010. The indexes for water availability and crop productivity represent deviations from the long-term averages (0.2 indicates 20 percent above the baseline average, –0.6 indicates 60 percent below the baseline average).

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[186] 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.

[187] 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 rainfed and irrigated yields, to obtain grid cell-level production (in metric tons) (Portmann, Siebert, and Döll 2010).

The ISIMIP models 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 modeling process is time consuming and computationally intensive, it was important to work with a reduced set of ISIMIP inputs.[188] The modeling employed the HadGEM2-ES and IPSL-CM5A-LR global climate models, which drive combinations of the two water models and two crop models: the LPJmL water and crop models, the WaterGAP2 water model, and the GEPIC crop model (Table B.3). Appendix C provides detailed information on model selection.

The crop and water models were 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 fast-track) simulations. Table B.3 presents the combinations of models used.

For each of the three climate migration scenarios (Figure B.1)—pessimistic reference, more inclusive development, and more climate-friendly—model outputs were averaged to generate a mean or "ensemble." Figure B.3 shows how the four model results for the pessimistic reference scenario (SSP4-RCP8.5) were averaged to create an ensemble for Ethiopia.

Table B.3: Matrix of global climate models and crop and water model combinations used in this report

	Crop simulation			
Water simulation	**GCM1, LPJmL (crop)**	**GCM1, GEPIC**	**GCM2, LPJmL (crop)**	**GCM2, GEPIC**
HadGEM2-ES, LPJmL (water)	Model 1			
HadGEM2-ES, WaterGAP2		Model 2		
IPSL-CM5A-LR, LPJmL (water)			Model 3	
IPSL-CM5A-LR, WaterGAP2				Model 4

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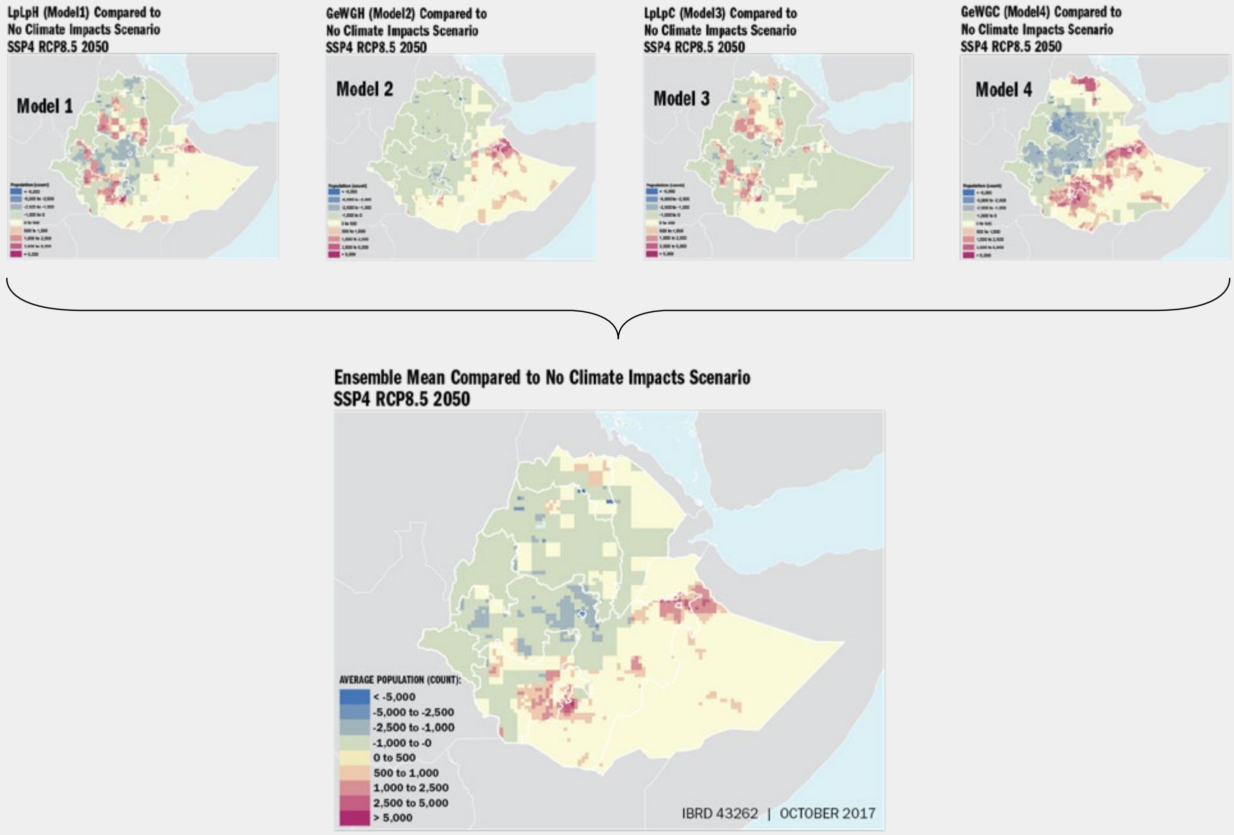
188. Feeding all potential ISIMIP water and crop model outputs into the gravity model would have yielded 12,500 model runs: 2 RCPs * 5 GCMs * 25 crop model outputs * 50 water model outputs = 12,500.

Figure B.3: Illustrative example for Ethiopia: Combining four model outputs into one ensemble



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ISIMIP water and crop model results

Climate change impacts on water availability and crop productivity have important impacts on the population potential of locations in the gravity model. Appendix A presents the water availability and crop productivity indexes in the context of climate trends and projections for each of the three new regions of focus. The climate change impacts are an input to the gravity model; when combined with parameters derived from the development scenarios (the SSPs), they directly affect the population potential of locations within countries. Chapters 2 and 3 translate this information into regional and country-specific estimates of climate migration.

Population data

The population gravity model used to project future climate migration is calibrated based on the historical sensitivity of past shifts in population distribution to the effects of deviations in water availability and crop productivity from long-term baselines. These relationships are then assumed to hold into the future, so changes in each of the sectoral impacts will result in increasing or decreasing attractiveness of areas for human settlement in the future. The calibration process, carried out on changes in actual population distribution in two decadal increments—1990 to 2000 and 2000 to 2010—revealed that populations are most sensitive to historical deviations in water availability (in both rural and urban areas) followed by historical deviations in crop productivity, although the relative influence of each varies from region to region. This means that positive deviations in water availability and crop productivity are associated with increases in population density in the past, and negative deviations are associated with decreases. Crop productivity is not used to calibrate urban grid cells since populations in these areas are assumed not to be as dependent on agriculture for livelihoods. In any given grid cell, the drivers may either act in concert, reinforcing one another (e.g., rural grid cells with crop productivity and water availability declines), or they may offset each other (e.g., crop productivity may increase but water availability declines).

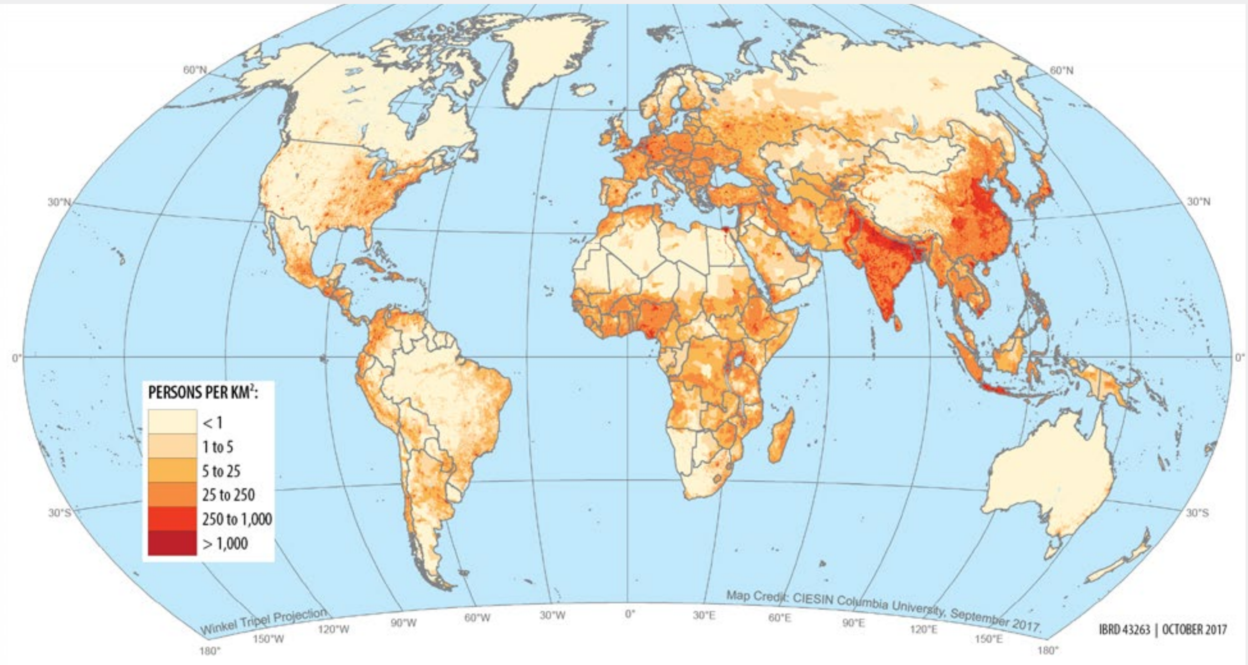
The population baseline used is the 2010 baseline in the Center for International Earth Science Information Network (CIESIN) Gridded Population of the World Version 4 (GPWv4) (CIESIN 2016) (Figure B.4). The gravity model was calibrated based on population change estimates for 1990–2010 derived from GPW version 3 (CIESIN, FAO, and CIAT 2005) and for 2000–2010 from GPWv4. GPW versions 3 and 4 model the distribution of the population on a continuous global surface based on the highest spatial resolution census data available from the 2000 and 2010 rounds of censuses, respectively. In this work, population count grids were used that were adjusted to national-level estimates from the United Nations World Population Prospects reports. GPWv3 and v4 are gridded data products with output resolutions of 2.5 arc-minutes (a square approximately 4 kilometers on a side at the equator) and 30 arc-seconds (a square approximately 1 kilometer on a side at the equator), respectively. For model calibration and the baseline population for the future projections, the data were aggregated to 7.5 arc-minutes (a square approximately 14 kilometers on a side at the equator [i.e. grid cells with an area of 196 square kilometers]). Uncertainties about these data are discussed in Appendix C.

Climate migration in the Middle East countries was not modeled, due to high degrees of uncertainty in baseline (2010) populations, ongoing conflicts in Syria and Yemen, and, in the case of Syria, resulting refugee flows to neighboring countries. Out of an estimated population of 21.4 million in 2010 (UN DESA 2019), 6.6 million people have fled Syria since 2011, and 6.7 million are internally displaced. Yemen, which in 2010 had 23.2 million residents, now has more than 4 million internally displaced people. The baseline figures for both countries are thus no longer reliable, and the same is true for neighboring countries such as Lebanon and Jordan. Libya, however, which has also experienced conflicts since 2011, has been modeled for this report, because the country's population, 6.2 million people, is concentrated in a few coastal urban areas. With about 217,000 internally displaced persons, one can argue that the population distribution has not changed significantly since the onset of the conflict. The other North African countries have also been modeled; though they are also hosting refugees from Syria and other countries, inflows are more modest than in some of the countries of the Mashreq and do not affect baseline population distribution in a substantial way. In no country in North Africa did refugees count for more than 0.5 percent of the population between 2004 and 2020, and for most the refugee population was well under 0.25 percent.

For Eastern Europe and Central Asia, a decision was also taken not to model the Russian Federation, Belarus, Moldova, and Ukraine, because the climate sensitivity of past changes in population distribution in these temperate, higher latitude countries is low. For the same reason, and because they are high-income countries, Poland and Croatia, were not modeled. For Central Asia, the climate migration modeling work was calibrated using data for the Kyrgyz Republic, applying spatial population grids during two-time steps, 1990–2000 and 2000–2010 (as described above). The calibration attributes unexplained variance in population distribution between the actual population distributions in 2000 and 2010 and those distributions modeled by the population gravity model to climate change impact factors, namely changes in water availability and crop productivity. Given the changes in migration dynamics that ensued in Central Asia after the breakup of the former Soviet Union, an advantage of calibrating the model in the Kyrgyz Republic is that while the population was more mobile, there was less emigration than from some other countries in the region (for example Kazakhstan), so there is reasonably high confidence that the calibration was indeed picking up on possible environmental impacts on livelihoods that, in turn, drove migration.

Finally, given the coarse resolution of the ISIMIP inputs (0.5 degree grid cells or 55 kilometers on a side), Small Island Developing States (SIDS) were too small to model successfully. Although an attempt was made to model larger SIDS (for example Fiji), there was very little meaningful variation in population distribution between the no climate impact and climate impact scenarios, and sea level rise had only negligible impacts on future population distributions at the scale mapped, especially where land rises steeply from the shoreline.

Figure B.4: Global population density, 2010



Source: Gridded Population of the World Version 4 (CIESIN 2016).

B.3 POPULATION MODELING METHODS

The modeling work is based on a modified version of the National Center for Atmospheric Research-CUNY Institute for Demographic Research (NCAR-CIDR) gravity model (Bryan Jones and O'Neill 2016).Technical details on the model specification are in Appendix C.

B.3.1 The Gravity Model

The original NCAR-CIDR model is a gravity-based approach that downscales national population projections to subnational raster grids (Bryan Jones and O'Neill 2013; 2016) 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 be described as a function of the characteristics known to correlate with spatial patterns of population change.

The NCAR-CIDR 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. 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 (Rich 1980). 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 (Warntz and Wolff 1971). 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.

B.3.2 Adding Climate Change Impacts

The calculation of potential was modified by adding local characteristics, including climate change impacts. Figure B.5 is a flowchart of the modeling steps; boxes in red show the addition of climate change impacts or results incorporating climate change impacts. Population potential is 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; of assumptions regarding spatial development patterns (for example, sprawl vs. concentration); and of certain geographic characteristics of the landscape.

Beginning with the 2010 gridded urban/rural population distribution for each country, the modeling done for this report incorporated the influence of climate change 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.

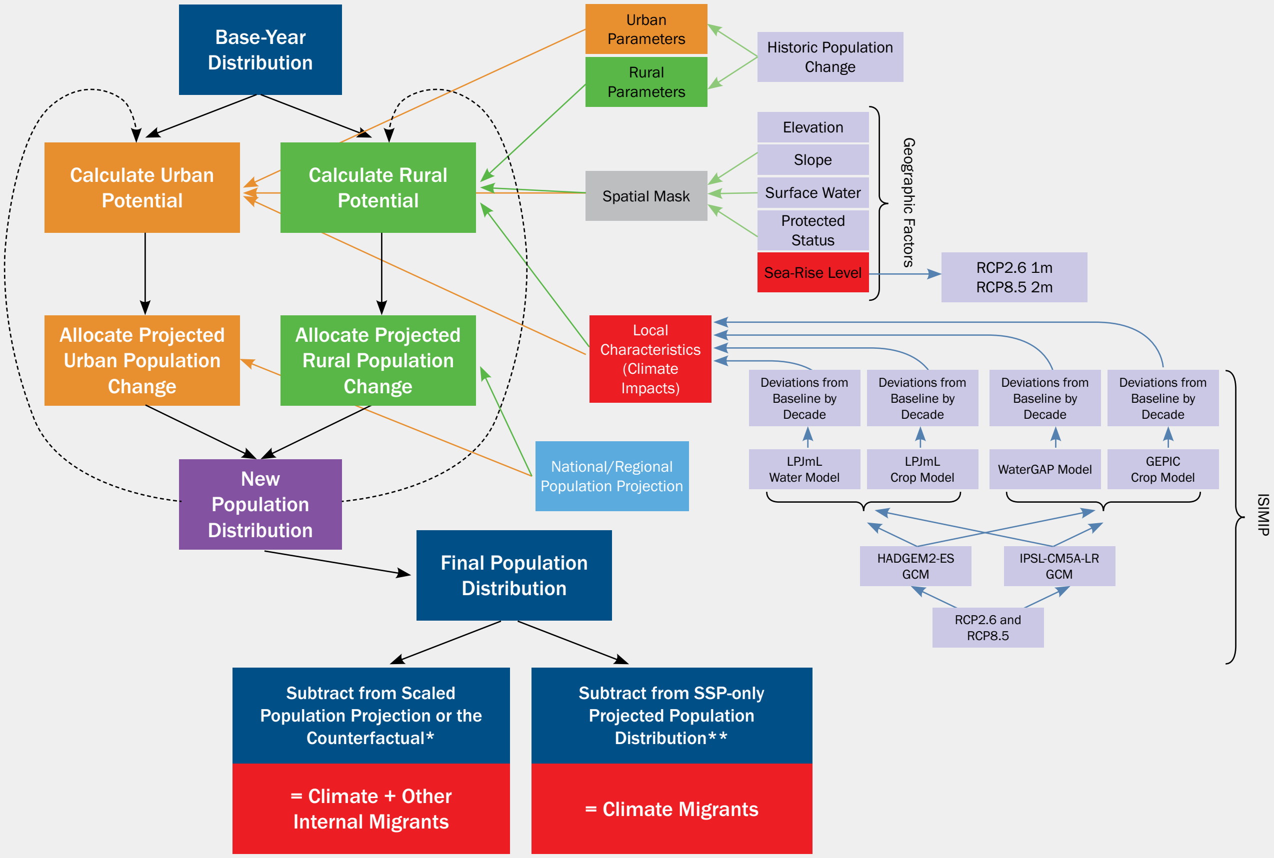
3. Allocate projected urban population change to grid cells proportionally based on their urban potentials.

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.

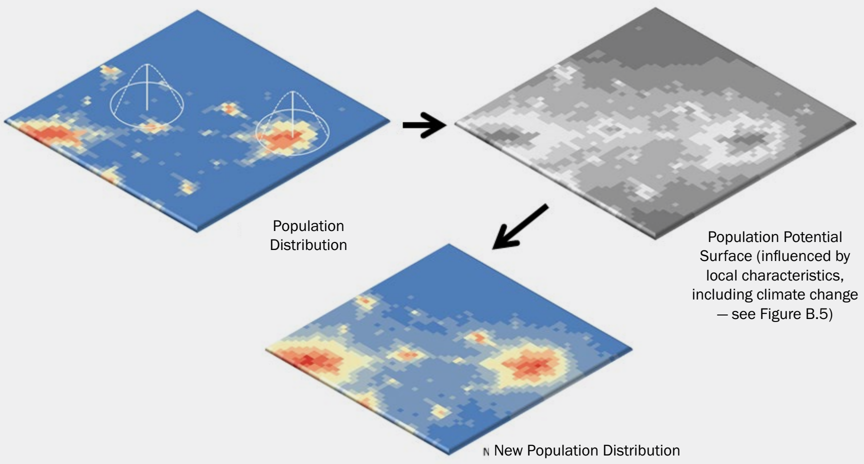
These steps are then repeated for each decadal time interval. Figure B.6 illustrates steps 3 and 4 for a hypothetical population distribution. Note that population potential surfaces, urban and rural, are continuous across all cells; each cell may thus contain urban and rural populations.

Figure B.5: Flowchart of modeling steps



Note: Boxes in red represent the addition of climate change impacts into the modeling framework or results that reflect climate change impacts.
* The counterfactual population projection simply scales the population distribution in 2010 to country-level population totals appropriate to each SSP.
** The SSP-only population projection represents the population projection without climate change impacts (i.e. based only on the development trajectories embodied in the SSPs).

Figure B.6: Hypothetical example of gravity-based population projection model for single time step



Based on the modified NCAR-CIDR population potential (vi) is calculated as a parametrized negative exponential function:

$$\mathrm{v_i} = \mathrm{A_i l_i} \sum_{j=1}^{m} P_j^{\alpha} e^{-\beta d_{ij}} \qquad \text{(Equation B.2)}$$

Where:

$\mathrm{A_i}$ = Local characteristics
$\mathrm{l_i}$ = Spatial mask
a = Population parameter etc.
P = Population
β = Distance parameter
d = Distance

It is weighted by a spatial mask[189] (*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 sea level rise between 2010 and 2050. P_j is the population of grid cell j; d is the distance between two grid cells. The distance and population parameters (α and β) are estimated from observed patterns of historical population change. The β parameter is indicative of the shape of the distance–density gradient describing the broad pattern of the population distribution (for example, sprawl versus concentration). The α parameter captures returns on agglomeration externality, interpreted as an indicator of the socioeconomic, demographic, and political characteristics that make a place more or less attractive.

The primary reason for relying on the "agglomeration effect", characterized by the population and friction-of-distance parameters, as opposed to some of the known drivers of migrations, such as employment opportunity and wage rates, is the difficulty associated with gathering historic data in a consistent fashion over a large portion of the globe, and projecting these indicators (that theoretically, drive the agglomeration effect) forward over time at fairly high resolution. By correlating population change trends to population potential we negate the need to project these variables individually. This decision reflects a desire to (1) limit uncertainty where possible and (2) ground results in observed historical relationships paying particular attention to broad trends that can be characterized over space.

The SSPs include no climate change impacts on aggregate total population, urbanization, or the subnational spatial distribution of the population. The NCAR-CIDR approach was modified by incorporating additional spatial data in the form of the ISIMIP sectoral impacts likely to affect population outcomes. The index is a weight on population potential that is calibrated to represent the influence of the crop and water sectoral impact indicators on spatial patterns of population change. The ISIMIP data, which represent decadal deviation from long-term baseline conditions, are incorporated into the model as gridded spatial layers. The value is calculated as a function of these indicators; it represents an adjustment to the relative attractiveness of (or aversion to) specific locations (grid cells), reflecting current water availability and crop yields relative to "normal" conditions. The model is calibrated over two decadal periods (1990–2000 and 2000–2010) of observed population change relative to deviations of water availability and crop productivity from the 1970–2010 average for a subset of representative countries in each region.[190] Table B.4 provides the countries that were used to calibrate each subregion for the *Groundswell* model. Where more than one country was used to calibrate a subregion, the resulting coefficients were averaged.

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[189] 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.

[190] Accurate spatial data from censuses on the location of populations or the change in population over time are not available for most developing countries before 1990.

Table B.4: Countries used to calibrate each subregion modeled (from east to west)

Subregion	Countries
China and Mongolia	China
Southeast Asia (including Lower Mekong)	Thailand and Vietnam
South Asia	India and Bangladesh
Central Asia	Kyrgyz Republic
Caucuses	Georgia
Eastern Europe	Bulgaria
Turkey	Turkey
North Africa	Morocco
East Africa	Ethiopia, Mozambique and Tanzania
Southern Africa	Botswana
Central Africa	Democratic Republic of Congo
West Africa	Guinea and Mauritania
South America	Argentina and Brazil
Central America and Mexico	Mexico

Details on the modeling methodology, including the methods used for calibration, are in Appendix C.2. The model was validated using Mexico and Ethiopia, the process and results for which can be found in Appendix C.3.[191] Methods for data visualization can be found in Appendix C.4, and directions for future modeling work are provided in Appendix C.5.

B.3.3 Characterizing the Model

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

Gravity models can be used to model 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 to incorporate additional details, such as environmental parameters that affect the relative attractiveness of locations.

Gravity models do not directly model internal migration. Instead, deviations between the population distributions in model runs that include the crop and water impacts and the development-only (also referred to as the SSP or “no climate”) model runs are assumed to be driven primarily by differences in climate change–induced internal migration. 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-migrant 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.

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 change impacts on population change. For each of the three 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

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[191] The results of these validation exercises were quite similar despite very dissimilar geographies and economic contexts. Because validation is a time-consuming process it was determined that further validation would not be undertaken.

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 is preferable. It would be desirable to have even more scenarios, to better assess the uncertainty (or conversely confidence) in the results (Box B.2). However, for the reasons noted above, time and resource constraints prevented more than four realizations for the model per climate-development combination.

Box B.2: Sources of uncertainty in modeling climate migration

The climate migration modeling results incorporate sources of uncertainty that can affect the estimated number of climate migrants or the differences between the three scenarios and the development-only scenario.

1. ISIMIP impacts vary across models. In Central America, for example, the combined LPJmL water and crop models have generally lower impacts than the WaterGAP-GEPIC combination of water and crop models, though these differences vary across the region. The differences result in different effects in the gravity model; models with the highest impacts repel more people from affected areas in the former set of outputs than in the latter set.

2. Variations between the two global climate models—HadGEM2-ES and IPSL-CM5A-LR—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, for the focus regions (see Appendix C). This variance in precipitation has an impact on both the water and crop models.

3. The modeling 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 change 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.

4. If the SSP-only model finds that a place is relatively attractive and the sectoral climate change 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 change impacts, “push” factors will be reinforced. This phenomenon creates spatial momentum.

5. The climate in-migration results can be interpreted as population levels above what would otherwise occur in the absence of climate change impacts on livelihoods due to the increased viability of livelihoods, and climate out-migration results can be interpreted as population declines that would not otherwise occur in the absence of climate change impacts. There may be situations in which the development-only (SSP or “no climate”) model runs project higher rates of population decline in rural areas than the model runs that include climate impacts – i.e., that more benign or favorable climate conditions in the future put a brake on rural out-migration. In those relatively rare cases, it is not so much “climate migration” that is being measured as reductions in out-migration that otherwise would have occurred.

continued

Box B.2: Sources of uncertainty in modeling climate migration (cont.)

6. Model parameterization affects the results. The model was 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 LPJmL water and crop models and the WaterGAP water and GEPIC crop 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.

7. Because the historical population data for a country have to meet certain stringent criteria to be used for calibration, one or more representative countries from each subregion that meet those criteria are selected for calibration (Table B.4), and the coefficients derived from that calibration are applied to all countries in the region. If those countries are not representative from a climatological or geographical standpoint, or in terms of level of development, that will affect the degree to which those coefficients are applicable in the other countries, thus increasing uncertainty.

8. Countries within regions are at different stages of economic development, which can have a significant impact on the population totals by 2050 for the two groups.

9. Cross-border migration is included in the socioeconomic scenarios underlying this work, insofar as population totals by country include a cross-border migration component. However, the modeling was carried out separately for each country and the modeling work does not include cross-border movements as a consequence of climate change impacts. Climate change can be an inhibitor or a driver of cross-border migration, depending on a range of factors that propel individuals to decide to move and would need to be considered on a case by case basis. If in the future climate change impacts do result in higher or lower levels of bilateral flows between countries, then this will also lead to different results than those modeled here.

In the model, cross-border mobility is not affected by the climate drivers. Rather, the SSP assumptions are applied to cross-border movements. The model thus builds on the SSPs, which include cross-border migration, following a limited set of assumptions about the potential for international movements across scenarios.

The “top-down” model shows the results of household-level decisions that influence migration (de Sherbinin et al. 2008), but it does not build directly on the evidence (or data) from micro-level studies. It considers such factors only at an aggregate level. In an effort to connect this work to household-level migration research, subsequent chapters provide case study narratives for Morocco, Vietnam, and the Kyrgyz Republic. Those case studies situate, and to some degree validate, this work in the context of the household dimension.

The model is run at spatial and temporal scales that capture migration well. With grid cells of about 14 square kilometers at the equator, populations shift can be considered a form of short-distance migration. The temporal scale of decadal increments from 2010 to 2050 is adequate to capture the longer-term shifts in population caused by slow-onset changes in water availability, crop conditions, and sea level rise. The model does not capture movements over shorter time periods.

The focus is on the 40 years between 2010 and 2050. This period represents a meaningful planning horizon, especially when considering social dimension of migration. Appendix A provides ISIMIP water and agriculture sector impact maps for 2050–2100. 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 behavior. Armed conflict itself may have links to climate variability and change, but models have generally failed to forecast 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 war or market collapse. The models can also not anticipate new technologies that may dramatically affect adaptation efforts to the degree that climate change impacts become negligible. They also do not include long-term national strategic planning efforts across key sectors, such as water or agriculture, that may influence future sector resilience and that of associated livelihoods to projected climate change impacts. The SSPs, as well as outputs 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.

Relatedly, the impacts of the COVID-19 pandemic on poverty alleviation, mobility dynamics and overall development are discussed in Chapter 1. It is still too early to predict the long-term effects of COVID-19 on migration (Migration Data Portal 2021). For now, we assume that any impacts on population potential for a given location resulting from the pandemic, which forms the basis of the gravity model, may be shorter term and therefore would not affect future population distributions to 2050. Any longer-term impacts would need to be examined and considered in subsequent work.

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Appendix C

Technical Details on the Modeling Data and Methods

This section provides details on model inputs (Section C.1), methodology (Section C.2), validation work (Section C.3), geospatial processing and data visualization methods (Section C.4), and future directions (Section C.5).

C.1 DATA INPUTS

Section C.1.1 provides justifications on climate and impact model input choices, and Section C.1.2 provides information on uncertainties inherent in the population data.

C.1.1 Choice of ISIMIP Models

As mentioned in Appendix B, the modeling team needed to choose among a number of global climate models (GCMs) and crop and water models. Here the rationale is provided for the models used in this effort.

Climate models

Of the more than 30 GCMs that participated in the Coupled Model Intercomparison Project phase 5 (CMIP5; see Taylor, Stouffer, and Meehl 2012), five models were used in the ISIMIP Fast Track to drive the crop and hydrological models. These were already selected to cover a large fraction of the range of temperature and precipitation projections across the whole CMIP5 ensemble, although the entire range cannot be represented with only five models (Warszawski et al. others 2014; McSweeney and Jones 2016). For the present study, the climate model ensemble had to be further reduced to make its application in the population modeling framework feasible. From the five ISIMIP GCMs, the HadGEM2-ES and IPSL-CM5A-LR models were chosen. One reason for choosing these models is that the future precipitation trends differ substantially in magnitude, and partly even in sign, between these models for the focus regions of this report (Schewe et al. 2014), so that at least for these regions a large range of possible future climate change impacts can be covered with only these two models. Further, both models are also being used currently for producing new impact simulations within the ISIMIP2b project (Frieler et al. 2016), so that the analysis presented in this report could easily be updated when those new impact simulations become available. Moreover, the HadGEM2-ES model has a particularly fine native resolution, potentially rendering it more realistic than other models at the regional scale.

It is noted that the crop yield and water indicators exist for all five ISIMIP GCMs, so that the methodology of this report could easily be extended to include more GCMs. Further, while it would be desirable to use climate change impacts data at a higher spatial resolution, so far no consistent set of impact model simulations is available that have been forced by regional climate models (RCMs). It is worth recalling that the use of global impact simulations in this study presents an advance over using purely climate model-based indicators because they represent the actual resources (crops, water) relevant for livelihoods.

Crop models

Muller et al. (2017) provide an evaluation of global crop models by comparing simulations driven with observations-based climate inputs (within the ISIMIP2a project) to reported crop yields. Six of these models contributed future simulations within the ISIMIP FastTrack, which could have been used in the work underlying this report. Among these, at the global level, one of the best-performing models (in terms of time-series correlation and mean bias in global yield) for both maize and wheat is LPJmL (Bondeau et al. 2007). For maize, GEPIC (Liu et al. 2007) also performs very well; both models also have a reasonable performance for rice. Another advantage of this choice is that LPJmL is an ecosystem model, while GEPIC is a site-based model; thus, two of the major structural model types are covered.

It should be noted that, for some crop-country combinations (e.g. wheat in Mexico), very few models show a good performance at the national scale in terms of time-series correlation and mean bias (Müller et al. 2017), which is, however, not to say that they cannot capture longer-term trends. To reflect overall agricultural productivity, the four major crops maize, wheat, rice, and soybean were combined into a total production index. Depending on the country, other crops are also important, but are not simulated by most of the global crop models.

Water models

The ISIMIP hydrological models have so far been evaluated (Gosling et al. 2017; Hattermann et al. 2017) mainly for 11 large river basins, of which only the Ganges (Bangladesh) and Blue Nile (Ethiopia) are relevant for the present set of case study countries. Moreover, in these studies the models have been anonymized, i.e. individual models cannot be identified. One criterion that narrows down the choice is that only a few models can provide simulations, including human water abstraction, dams, and reservoirs, which are major non-climatic human influences on the water cycle. These simulations are normally closer to observed discharge, and of the models that participated in both ISIMIP2a and the ISIMIP FastTrack, these are available from H08, WaterGAP, PCR-GLOBWB, MPI-HM, or LPJmL. From these, LPJmL and WaterGAP (Flörke et al. 2013; Döll, Kaspar, and Lehner 2003) were selected. LPJmL integrates crop yields, water resources, and ecosystems in a single model. WaterGAP, on the other hand, can be calibrated separately for each basin and therefore matches observed river discharge better than other global models in many river basins. It is noted that none of the ISIMIP global models include glacier dynamics. Work is ongoing to include glacier dynamics both in the Potsdam Institute for Climate Impact Research's regional hydrological model SWIM and in WaterGAP.

C.1.2 Uncertainties in the Population Data Inputs

Uncertainties in GPWv4 2010 population count grid generally relate to the timeliness and accuracy of the underlying census data and to the input resolution of the census units. In terms of timeliness and accuracy, a number of developing countries have censuses that are either out of date or that are known to contain inaccuracies. Hillson et al. (2014) discuss the accuracy and uncertainties in census data, especially in countries with rapidly growing and urbanizing populations. Cohen (2004) and CIESIN (2011) address issues of timeliness in the context of GPWv3. All of these factors affect the degree to which the baseline population distribution for 2010 is accurately mapped.

In terms of the spatial resolution of inputs, while GPWv4 incorporates significantly higher resolution census inputs than prior versions (12.5 million input units in GPWv4 versus about 400,000 in GPWv3), there are still significant portions of the developing world in which the spatial resolution of input units is suboptimal. The average input unit resolution for very high development regions is 944 km^2, whereas the low and medium human development countries have an average input resolution of 3,518 km^2 and 4,700 km^2, respectively. Further uncertainties in the year 2000 estimates relate to the lowest common denominator spatial units that match between the years in GPWv3 and GPWv4, or for which growth rates are available. These units are used to apply consistent rates of change across all sub-units. So, for example, if only admin1 units (state or province) match between censuses, population is backcast from 2010 to 2000 by using consistent rates of change across those units, even if GPWv3 and GPWv4 included population count data for 2010 at a significantly higher resolution. This affects the confidence in the decadal population change grids used for model calibration.

In general, the aggregation of the higher resolution population count and change grids to coarser 7.5 arc-minute grids (equivalent to about 193 km^2 at the equator) reduces the uncertainty in the data, since all things being equal, uncertainty tends to increase with resolution for census-based population grids.

C.2 TECHNICAL DETAILS ON THE POPULATION MODEL

As described in Appendix B, the value (from equation B.2) is calculated as a function of these indicators, and represents an adjustment to the relative attractiveness of (or aversion to) specific locations (grid-cells) reflecting current water availability and crop productivity relative to “normal” conditions.

$$v_i = A_i l_i \sum_{j=1}^{m} P_j^{\alpha} e^{-\beta d_{ij}} \qquad \text{(Equation B.2)}$$

In order to carry out the procedure, model estimates of the α and β parameters for the urban and rural populations are necessary, and (Equation B.2) must be calibrated. Two separate procedures are employed and carried out both for the urban and rural population distributions separately. As mentioned in Appendix B, 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 α and β parameters are 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 B.2. The negative exponential function described by Equation B.2 is very similar to Clark’s (1951) negative exponential function which has been shown to accurately capture observed density gradients throughout the world (Bertaud and Malpezzi 2003). To estimate α and β, the model in Equation B.2 is fitted to the 1990-2000 urban and rural population change from GPWv3 and to the 2000-2010 urban and rural population change data from GPWv4, and we compute the values of α and β that minimize the sum of absolute deviations:

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

where $P_{i,t}^{obs}$ and $P_{i,t}^{mod}$ are the modeled 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 α and β 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 modeling approach requires that the relationship between A_i and the different sectoral impact indicators is estimated, which are hypothesized to impact population change. When α and β are estimated from historic data (e.g. observed change between 2000 and 2010), a predicted population surface is produced that reflects optimized values of α and β, such that absolute error is minimized. Figure C.1 includes a cross-section (one-dimension) of grid cells illustrating observed and predicted population for 10 cells (e.g. in 2010). Each cell contains an error term that reflects the error in the population change projected for each cell over a 10-year time step—that is the difference between the projected and the actual population distribution at the end of the decade. It is hypothesized that this error can at least partially be explained by a set of omitted variables, including environmental and sectoral impacts. To incorporate these effects we first calculate the value of such as to eliminate (from Figure C.1) for each individual cell (which is labeled observed):

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

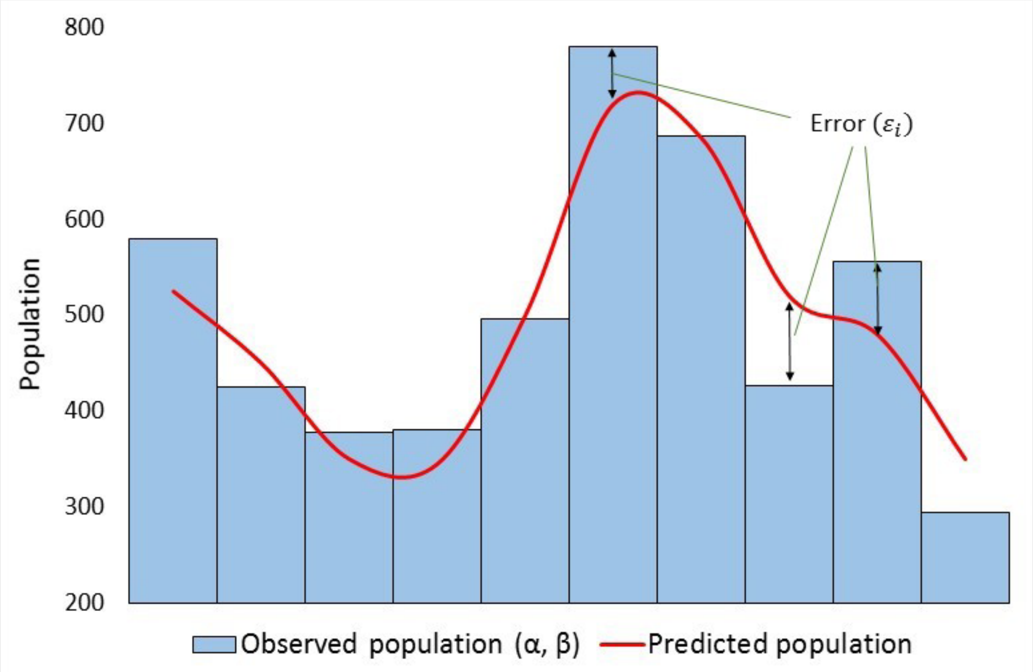
The second step is to estimate the relationship between observed index and cell-specific water availability and crop productivity metrics by fitting a spatial lag model:

$$A_{i,t} = \rho W A_{i,t+} \beta_1 C_{i,t} + \beta_2 H_{i,t} + \varepsilon_{i,t} \qquad \text{(Equation C.3)}$$

where C and H are the set of explanatory variables that go into producing index A_i (crop productivity and water availability, respectively), is the spatial autocorrelation coefficient and W is a spatial weight matrix. From this procedure, a set of cell specific α values is estimated for both urban and rural population change.

For future projections (for urban and rural populations), projected values are used of and and coefficient estimates from Equation C.3 to estimate spatially and temporally explicit values of A_i. Finally, to produce a spatially explicit population projection, estimates of α and β are adjusted to reflect the SSPs (e.g. the SSP4 storyline implies a more concentrated pattern of development than SSP5, see Jones and O'Neill 2016), incorporate spatio-temporally variant estimates of for the RCPs, and exogenous projections of national urban and rural population change, and the model applied as specified in Equation B.2.

Figure C.1: Cross-section of grid cells illustrating observed and projected population distributions



Note: The error term is used to calibrate the index A(i).

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 B.2) are excluded, as the value of in these cells (0), renders the observed value of inconsequential. Second, the distribution of observed was found, in most cases, to include significant outliers that skewed coefficient estimates in Equation C.3. In most cases, these values were found to correspond with very lightly populated cells where a small over or under-prediction of the population in absolute terms (e.g. 100 persons) is actually quite large relative to total population within in the cell (e.g. large percent error). The value of (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 C.3 would have a substantial impact on coefficient estimates. To combat this problem, the most extreme 2.5 percent of observations is 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 5-10 percent of grid cells.

C.3 VALIDATION WORK

To test the population model, out-of-sample validation was applied to the development-only ("no-climate") model as well as to the modified model in which climate change impacts are introduced through ISIMIP sectoral impact indices. The intent was to both assess the performance of the model itself and any improvements related to the modifications introduced for this work. For each country we randomly selected half of the subnational grid cells to serve as training data, the remaining set of cells was withheld ("out-of-sample"). We fit the models to the training data set for the observed population change over the period 2000-2010, and projected values for out-of-sample cells. To assess goodness-of-fit, we calculate the mean absolute percentage error (MAPE) for the set of out-of-sample cells as:

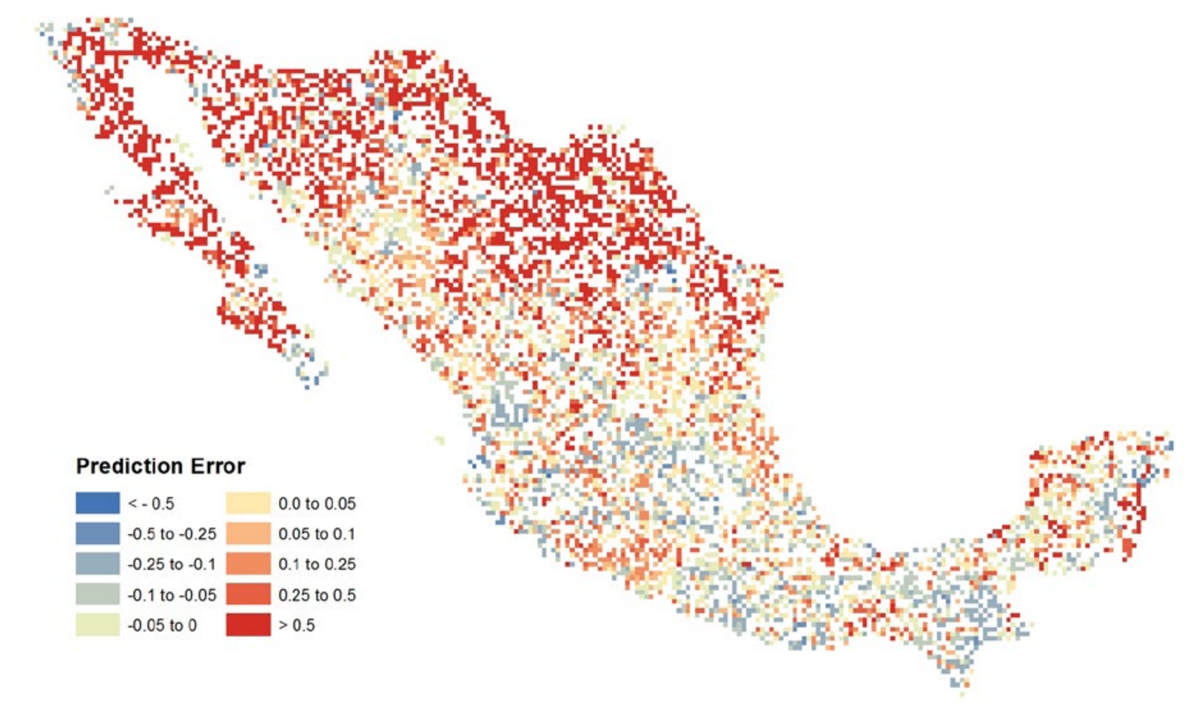
$$\text{MAPE} = \frac{\sum_i \| P_{i,obs} - P_{i,pred} \|}{\sum_i P_i} \qquad \text{(Equation C.4)}$$

Prediction error from the no-climate model was just under 13 percent for Mexico, and just over 17 percent for Ethiopia (see Table C.1). The modified version of the model was tested, in which ISIMIP indices were introduced on two combinations of water availability and crop productivity indices under RCP8.5: the GEPIC crop/WaterGAP2 water model combination in Mexico and the LPJmL crop/LPJmL water model combination in Ethiopia. In both cases results improve marginally over the no-climate model. The MAPE declined roughly 1.5 percent in Mexico and almost 2 percent in Ethiopia when the modified models are applied.

Table C.1: Mean Absolute Percentage Error (MAPE) by model and country

Model	Mexico	Ethiopia
No Climate	12.84%	17.28%
GEPIC/WaterGAP2: RCP8.5	11.32%	
LPJmL crop/LPJmL water: RCP8.5		15.37%

Figure C.2: Percentage error by grid-cell for the Mexico out-of-sample subset; GEPIC/WaterGAP2 model, RCP8.5 (2000-2010)



The spatial distribution of error (percent) by magnitude for the Mexico GEPIC/WaterGAP2 model is illustrated in Figure C.2. Warmer colors indicate over-prediction, and cooler colors under-prediction. There is a strong correlation between observed population size and the magnitude of prediction error, with the largest errors occurring in the most lightly populated grid cells. Thus, the most obvious trends are over-prediction of rural populations in northern regions, and smaller under-prediction in many more lightly populated cells in central and southern areas. In general prediction errors were smallest in large urban areas, reflected by the lighter colors in Figure C.2.

One interpretation of the relatively small, yet consistent improvement in MAPE is that it confirms the hypothesis that climate-driven indicators such as water stress and crop yields explain a small portion of the unexplained local error in the development-only ("no-climate") model.

C.4 GEOSPATIAL PROCESSING AND DATA VISUALIZATION METHODS

In addition to the modeling methods, it is important to describe the methods used for generation of internal climate migrant (climate migrant) estimates and data visualization. This section describes those methods.

Beyond the population distribution modeling that includes the sectoral climate impacts for crops and water, as well as sea level rise, results presentation depended on two additional sets of spatial population projections (Table C.2). In one set of projections, only the SSPs are used to produce a no climate change impacts (development only) set of population distributions. Also, a counterfactual population projection based on 2010 population distributions, but scaled according to the SSP2 and SSP4 population totals by country and decade, was produced. It is "counterfactual" because it is a scenario in which there is no migration, and all population growth is a function of natural increase within each grid cell. These additional spatial population projections were produced to develop estimates of climate migrants and other internal "development" migrants in ways described under section C.4.1.

Table C.2: Spatial population projection scenarios

Climate impacts scenarios (combining ISIMIP sectoral impacts by RCP with SSPs)	No climate impacts (SSP-only) population projections used for comparison	Counterfactual population projections
Pessimistic (Reference Scenario) (RCP8.5/SSP4): Population is projected based on ISIMIP sectoral impacts model outputs for RCP8.5 and on development trajectories found in SSP4	SSP4: Population is projected based on development trajectories found in SSP4	SSP4 Counterfactual: Population is projected using the spatial population distribution in 2010, but proportionally scaled to match the population totals for each decade under SSP4
More inclusive development (RCP8.5/SSP2): Population is projected based on ISIMIP sectoral impacts model outputs for RCP8.5 and on development trajectories found in SSP2	SSP2: Population is projected based on development trajectories found in SSP2	SSP2 Counterfactual: Population is projected using the spatial population distribution in 2010, but proportionally scaled to match the population totals for each decade under SSP2
More climate-friendly (RCP2.6/SSP4): Population is projected based on ISIMIP sectoral impacts model outputs for RCP2.6 and on development trajectories found in SSP4	SSP4: Population is projected based on development trajectories found in SSP4	SSP4 Counterfactual: Population is projected using the spatial population distribution in 2010, but proportionally scaled to match the population totals for each decade under SSP4

Note: Shared Socioeconomic Pathways—SSP2 (moderate development) and SSP4 (unequal development); Representative Concentration Pathways—RCP2.6 (low emissions) and RCP8.5 (high emissions); ISIMIP = Inter-Sectoral Impact Model Intercomparison Project

Three approaches were used to develop summaries for data visualization. These are described in the following three sections.

C.4.1 Climate Migration Estimates

In the first approach, total climate migrants are shown for the three scenarios, along with confidence intervals, to understand the scale and trend of migration. To produce these estimates, the total populations in each grid cell for the respective no climate change impacts (development only) population projections are subtracted from the three spatial population projection scenarios that include climate change impacts—i.e. the pessimistic reference, more inclusive development, and more climate-friendly scenarios. Then, all those grid cells that have positive totals in the region are summed to estimate the number of climate migrants.[192] To arrive at other internal migrants—shifting populations as a result of the development (SSP) scenarios—no climate impacts (SSP only) scenarios were subtracted from the counterfactual population projection. Again, positive grid cells were summed to estimate other internal migrants (those who move because of development trajectories).

Two types of graphs are used to present the data: linear trend and categorical bar charts. The linear trend charts are used to display the trend in number of climate migrants and climate migrants as a percentage of the total population from 2020 to 2050. The dark line represents the average, and the lighter shade of the same color represents the confidence interval across model runs. Bar charts were used to display climate migrants and other internal migrants by scenario and decade, with confidence intervals for bars representing the climate migrants. The other internal migrants bar has no confidence interval because the results are based on subtracting the counterfactual population distribution from the population distribution of a single SSP model run (SSP2 or SSP4). Confidence intervals for climate migration estimates are generally fairly wide owing to the small number of model runs per scenario, and for reasons further described in Appendix B (Box B.2). The statistical formula for calculating the confidence interval is found in Section C.4.3.

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[192] At the country and regional levels, all in-migration (positive grid cells) must necessarily be balanced by out-migration (negative grid cells), so total migrants can be assessed by summing differences in the positive cells.

C.4.2 Climate In-Migration and Out-Migration Hotspot Mapping

A second approach of hotspots mapping of climate in- and out- migration is used to indicate top areas of attraction and/or repellence across the landscape. These climate in-migration hotspots are identified for each scenario by taking the top 5 percent of the distribution in increased population densities compared to the respective no climate change impacts scenarios, and the climate out-migration hotspots reflect the bottom 5 percent of the distribution of decreased population densities compared to the respective no climate change impacts scenarios. We then overlay the areas for the top 5 percent in-migration hotspots and the bottom 5 percent out-migration hotspots across the three scenarios, and we identify those areas where at least 2 out of 3 scenarios coincide. An area qualifies as a climate in-migration or out-migration hotspot when results are consistent across at least two out of the three scenarios. These are termed climate in- and out-migration hotspots.

A combination of ArcGIS tools and Python scripting were used to identify which grids cells represented the top and bottom 5 percent referenced above. For each of the three scenarios, a grid cell was flagged with a "1" if it was greater than or equal the lowest possible population density value for climate migrants in the top or bottom 5 percent. These flags were then added together to determine the total number of scenarios identifying the grid cell as a climate in-migration or out-migration hotspot. Table C.3 displays the possible results in each grid cell after the flags were added together.

Table C.3: Flags for in-migration and out-migration hotspots

Number of scenarios in agreement	Description
0	This grid cell is not within the top or bottom 10 percent. This grid cell is not considered a climate in-migration or out-migration hotspot.
1	One scenario identifies this grid cell as being in the top or bottom 10 percent. This grid cell is not considered a climate in-migration or out-migration hotspot.
2	Two scenarios identify this grid cell as being in the top or bottom 10 percent. This grid cell is considered a climate in-migration or out-migration hotspot.
3	Three scenarios identify this grid cell as being in the top or bottom 10 percent. This grid cell is considered a climate in-migration or out-migration hotspot.

C.4.3 Climate Migration Estimates for Zones

A third approach addresses migration in select natural, rural, and urban zones. This provides a deeper narrative in relation to the coastal zone, urban areas, and rural livelihood zones—reflecting a combination of attractiveness and viability of ecosystems. Within the zones, trends in positive or negative population differences between the three scenarios (pessimistic reference, more inclusive development, and more climate-friendly) and the respective no climate change impacts scenarios are examined (Table C.2). Positive differences in zones reflect the likelihood that these zones will be more attractive to migrants owing to better water availability and crop productivity conditions, and negative differences reflect the likelihood that the zone will be less attractive to migrants owing to declining water availability and crop productivity. Again, confidence intervals are applied reflecting the range across the four model inputs (see Table B.3) for each of the three scenarios. The following are the zones used in this analysis:

i. The coastal zone is defined as those areas within 10 kilometers of the coastline.

ii. Urban areas are defined by identifying all those areas that have a population of >=300 persons km[193], except for South Asia where >=3,000 persons per km^2 is applied (owing to much higher population densities there).

iii. Livelihood zones are aggregations of "anthropogenic biomes", which reflect a combination of agricultural livelihood types and population densities.

The Zonal Statistics tool summarizes the values of a data set based on its spatial overlay with another data set. This tool was crucial for determining the counts of various projected populations described above in each of the zones, so that differences among the different climate change impact scenarios, SSP-only scenarios, and the counterfactuals could be assessed. To produce estimates by zone, we ran the results for each scenario (including the four members of each climate change impacts scenario) through zonal statistics in ArcGIS. The zones used for the item (i) was a 10 kilometer coastal buffer; the zone used for item (ii) was the urban areas mask dynamically generated for two time slices; and the zone used for (iii) were livelihood zones derived from an aggregation of anthropogenic biomes for the year 2015 (also referred to as "anthromes"; Ellis et al. 2010). Note that the anthropogenic biomes are static, in the sense that their boundaries do not change over the 40-year time horizon from 2010 to 2050 owing to either increases in population density (a key parameter in their definition) or climate change. This was a necessary simplifying assumption, since projected anthropogenic biomes do not exist.

ArcGIS's Zonal Statistics as Table tool was used to obtain the total population for each scenario within zones (i) and (iii). For zone (i), the PLACE III data set (CIESIN 2012)—used for the 10 kilometer coastal buffer—has a significantly smaller cell size, roughly 1 kilometer compared to the scenario's 14 kilometers. When their grid cells are spatially aligned, there are 225 PLACE grid cells within one scenario grid cell. Consequently, determining the population within the coastal zone was a multi-step process. First, the number of PLACE grid cells within each scenario grid cell was calculated by running the ArcGIS Zonal Statistics as Table tool and using the COUNT field function within the tools output table. The COUNT field function provides the total number of PLACE cells within a single scenario cell. Within the output table, values within the COUNT field ranged from zero to 225, with 225 identifying the scenario grid cell as completely covered by coastal grid cells. A proportion of the coverage was obtained by dividing the COUNT field by 225. Finally, each grid cell was labeled as "majority coastal" if the proportion was greater than .50 or "not majority coastal" if the proportion was equal to or less than .50. Scenario grid cells that did not intersect with PLACE grid cells were left as NULL. Using the calculated proportions and the majority labels, the total population within the coastal buffer zone could be calculated.

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[193] This is the Eurostat definition of urban densities at 1 kilometer resolution, and includes the proviso that contiguous pixels must add up to 5,000 persons to qualify a location as urban (http://ec.europa.eu/eurostat/statistics-explained/index.php/Urban-rural_typology). When applied to the grid cell size used in this modeling of approximately 200 km^2 at the equator (193 km^2 to be precise), the total population per grid cell would be 57,880 people if the average population density is 300 persons per km^2. This would qualify as a small city in most regions of the world.

For zone (iii), the livelihood zones, the anthropogenic biomes data set originally had 19 different anthropogenic classes. Using the ArcGIS Reclassify tool these classes were reclassified to create six different classification groups. Table C.4 shows how the values were reclassified.

Table C.4: Reclassification of anthropogenic biomes to create livelihood zones

Original Description	Reclassification
Urban	Dense settlements (populated >=100 persons per sq km)
Mixed settlements	
Rice villages	Rice growing areas
Irrigated villages	Irrigated croplands grouping
Residential irrigated croplands	
Rainfed villages	Rainfed croplands grouping
Residential rainfed croplands	
Populated croplands	
Remote croplands	
Pastoral villages	Pastoral and rangeland grouping
Residential rangelands	
Populated rangelands	
Remote rangelands	
Residential woodlands	Seminatural and wildlands grouping
Populated woodlands	
Remote woodlands	
Inhabited treeless and barren lands	
Wild woodlands	
Wild treeless and barren lands	

After the data set was reclassified, the ArcGIS Zonal Statistics as Table tool was used to determine which anthropogenic biomes intersected with each scenario grid cell. Since multiple anthropogenic biomes can intersect a grid cell, the “Majority” zonal statistics type was selected. The final output table produced by the tool contained a MAJORITY field. This field contained the value that corresponded to the anthropogenic biome that covered the greatest area of the scenario grid cell. The final output table also included the scenario population projections. Therefore, the total population within each anthropogenic biome could also be calculated to derive the climate migrants as a percent of population.

Creating the urban extents and obtaining the total population within those extents, as described in item (ii), was also a multi-step process. ArcGIS and Python were used together for automation. First, for each of the scenarios, the grid cells that were within the population density threshold were identified. A subset of the original data, comprised of the identified cells, was created. Each individual grid cell within the subset was part of the urban extent and contained the population count value for that area. The ArcGIS Summary Statistics tool was used to calculate the total population within the urban extent area by summing all the grid cell’s population count values. The data were saved in tabular format.

For each country and region of focus, the tabular data, saved in CSV (Coma Separated Values) format, was imported into R and manipulated using “reshape” and “plyr” packages (R Development Core Team 2008). The table was first reshaped from “wide” (i.e. information for each pixel ID was included in multiple columns) to “long” to facilitate the representation of the data by four categories: decades, scenarios, models and anthropogenic biomes. In the next step, the data were aggregated using “ddply” function by summing the climate migrant population (the climate change impacts minus no climate change impacts populations) in each of these four categories. We further aggregated the data by calculating the average and standard deviation of the four model runs per scenario described in Appendix B (Table B.3). These statistics helped us calculate the 95 percent confidence intervals using the following formula:

$$AVG \ \pm z * \boldsymbol{SE}$$

SE is the standard error and is calculated as $\frac{SD}{\sqrt{n}}$, where SD is the standard deviation and n is the number of model runs.

The z value for the 95 percent confidence interval is 1.96. The value of 1.96 is based on the fact that 95 percent of the area of a normal distribution is within 1.96 standard deviations of the mean.

Thus, the upper/lower limit of the CI is calculated as:

$$\text{AVG} \pm 1.96 * \frac{SD}{\sqrt{n}}$$

In the final step, we plotted data using ggplot function of “ggplot2” R package.

Bar charts were used to represent the climate migration by livelihood zone by scenario and decade, with whiskers used for confidence intervals. For the other zones (coastal and urban), linear trend charts were used to display the decadal change along with confidence intervals. The confidence intervals are generally fairly wide owing to the small number of model runs per scenario, and for reasons further described in Appendix B (Box B.2).

C.5 FUTURE DIRECTIONS

Key features of the gravity approach to modeling future population distributions include its flexibility in producing alternative outcomes that are consistent with qualitative global change narratives such as the SSPs, as well the ability to calibrate the model to historical data, thus grounding the results in observed outcomes. Additionally, the model can accommodate alternative national and sub-national projections of urban/rural change, additional parameters and/or alternative mathematical forms of distance decay, varying assumptions regarding the habitability of land parcels, and is applicable at varying spatial scales and/or levels of aggregation. The gravity framework is also advantageous in that it is easily expanded or altered to consider additional spatially explicit climate, sectoral impact, socio-economic, or geopolitical data that may aid tailoring the model to specific countries, regions, or localities. For example, in separate work for East and West Africa additional layers were added for conflict deaths and age structure of the population. The novel approach to estimating climate migration introduced here considered a specific set of scenarios and sectoral impacts corresponding to two plausible socio-economic and climate futures. However, as a tool for generating scenarios and exploratory research the gravity structure appears to hold significant promise.

C.5.1 Country and Regional Downscaling

For purposes of comparability across countries and regions, as well as scenarios, the approach adopted for this work required that all model inputs were spatially and temporally consistent across all countries. This constraint restricts data inputs largely to those that are globally available. However, in many cases a richer, more detailed set of climate, biophysical, socio-economic, and political indicators are available at the regional, national, sub-national, and local level. Downscaling can easily be achieved. Significant model refinements resulting in higher resolution and therefore more detailed projections (free from the constraint of global data consistency) are one of many possible future applications of the gravity approach.[194] Additionally, in regions for which detailed historic migration data exist, the model can be expanded to project bi-lateral migration flows potentially incorporating machine learning techniques to

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[194] Impact simulations driven by regional climate models (RCMs) are not yet available via ISIMIP. RCM-driven impact simulations are a desirable next step and would particularly be beneficial for mountainous countries in which orography plays a strong role in local rainfall.

improve scenario-based predictive capacity. At the national or subnational/city level there is significant opportunity for the enhanced application of the approach presented here.

C.5.2 Adding Additional Climate Impacts, Geophysical Detail, and Climate Feedbacks

In this report we considered climate change impacts on two sectors, agriculture and water, in addition to sea level rise (coastal populations and infrastructure). The ISIMIP fast-track projections include projections related to two additional sectors (ecosystems and health). In the aforementioned work in East and West Africa, changes in net primary productivity were used to gap-fill areas of countries without crop production. In semi-arid areas, this can represent an important factor determining levels of pasturage for nomadic pastoralists. In addition, flood risk was projected out to 2050 and included in the model. The ISIMIP 2 was launched in May of 2013 and lasted four years, broken into two, two-year segments (ISIMIP 2a and ISIMIP 2b). The fisheries, permafrost, biodiversity, and energy sectors were added to the original fast-track sectors for this phase of the project. Data from ISIMIP 2b are now available but were not available for the release of the first Groundswell report, and for consistency we continued to use the Fast Track model runs for this report.

These data are easily incorporated into the gravity framework, either through the existing A(i) index or through additional indices that exert influence over the attractiveness or repulsiveness of specific locations. Future work should, where appropriate, include an expanded catalog of sectoral impact data relating to a wider range of livelihoods. In addition to sectoral impacts, the existing geospatial mask can be expanded to include additional geophysical characteristics deemed important, including those that are not temporally static such as projected changes in coastlines, and the gravity field can easily accommodate additional detail including, but not limited to, the projected availability of certain resources, anticipated response to climate feedbacks, resource availability, and policy designed to influence settlement patterns.

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