ASSESSING THE EVIDENCE:

CLIMATE CHANGE AND MIGRATION IN PERU

POTSDAM INSTITUTE FOR CLIMATE IMPACT RESEARCH

PIK

IOM
UN MIGRATION

Supported by:

Federal Ministry
for the Environment, Nature Conservation
and Nuclear Safety

based on a decision of the German Bundestag

The opinions expressed in the report are those of the authors and do not necessarily reflect the views of the International Organization for Migration (IOM) or the Potsdam Institute for Climate Impact Research (PIK). The designations employed and the presentation of material throughout the report do not imply expression of any opinion whatsoever on the part of IOM or PIK concerning the legal status of any country, territory, city or area, or of its authorities, or concerning its frontiers or boundaries.

IOM is committed to the principle that humane and orderly migration benefits migrants and society. As an intergovernmental organization, IOM acts with its partners in the international community to: assist in meeting the operational challenges of migration; advance understanding of migration issues; encourage social and economic development through migration; and uphold the human dignity and well-being of migrants.

Publisher: International Organization for Migration
17 route des Morillons
P.O. Box 17
1211 Geneva 19
Switzerland
Tel.: +41 22 717 9111
Fax: +41 22 798 6150
E-mail: hq@iom.int
Website: www.iom.int

Cover photo: Three people watching snowfields, glaciers and dry areas in Peru's Andean highlands. © Shutterstock/Alberto SEMINARIO

Around 70 per cent of the world's tropical glaciers are located in Peru. Glaciers have spiritual significance in many mountain cultures and their meltwater is essential for human consumption, agriculture, hydropower generation and mining. The extensive retreat of the Peruvian glaciers, triggered by global warming, already plays a role in people's migration decisions. Peak river runoff is projected in the coming decades, alongside a rise in the demand for water. Even in low-emissions scenarios, volume losses could be drastic by the end of this century, resulting in severe economic damage, risks of glacial lake outburst floods and water quality issues, as well as losses of aesthetic and spiritual ecosystem services. Local adaptation may help to reduce some of these losses, but displacement can result when impacts overwhelm adaptive capacities.

ISBN 978-92-9068-882-2 (PDF)

Suggested citation: Bergmann, J., K. Vinke, C.A. Fernández Palomino, C. Gornott, S. Gleixner, R. Laudien, A. Lobanova, J. Ludescher and H.J. Schellnhuber (2021). *Assessing the Evidence: Climate Change and Migration in Peru*. Potsdam Institute for Climate Impact Research (PIK), Potsdam, and International Organization for Migration (IOM), Geneva.

PUB2019/035/EL

ASSESSING THE EVIDENCE:

CLIMATE CHANGE AND MIGRATION IN PERU

Potsdam Institute for Climate Impact Research

PIK

IOM UN MIGRATION

EPICC East Africa Peru India Climate Capacities

cooperación alemana DEUTSCHE ZUSAMMENARBEIT

Supported by:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

based on a decision of the German Bundestag

INTERNATIONAL CLIMATE INITIATIVE (IKI)

FOREWORD
BY THE POTSDAM INSTITUTE FOR CLIMATE IMPACT RESEARCH

Over the past several thousand years, Peru's remarkable history has been strongly intertwined with climate extremes and fluctuating water availability. Today, anthropogenic climate change is creating challenges of a new character and unprecedented magnitude for people in Peru and human civilization at large.

The years 2015–2019 were the warmest five-year period ever recorded on Earth, with a global mean surface temperature (GMST) 1.1°C higher than before the Industrial Revolution. The impacts of this warming threaten the health and development prospects of ever more people – and much earlier and more severely than expected. Examples abound: glacier mass loss is greater than ever before; heatwaves are becoming deadlier; bush fires are reaching catastrophic dimensions; and increasingly frequent droughts are causing hunger in many vulnerable areas of the world. Homes and livelihoods are destroyed, sometimes forcing entire communities to settle elsewhere.

At the same time, global greenhouse gas emissions from fossil fuel use keep breaking records while we destroy carbon sinks, such as rainforests, at an alarming rate. As a consequence, current atmospheric carbon dioxide (CO_2) levels are higher than at any time during the last 4 million years. Even if all countries fulfil their mitigation pledges made within the Paris Climate Agreement of 2015, GMST would still rise between 2.9°C and 3.4°C by the year 2100. To meet the Paris target of keeping GMST well below 2°C, national ambitions will have to be quadrupled.

We have already entered a state of planetary emergency. If we fail to drastically reduce CO_2 emissions within this decade, the risk of abrupt and irreversible climate impacts will rise to unacceptable levels. Such risks include the threat of a global tipping process, eventually resulting in a "hothouse Earth", with catastrophic warming of 5–8°C in the longer run. For Peru, the impacts in such a scenario would be practically unmanageable.

Indeed, the country provides a tale of how severe climate impacts could become. Given Peru's long and rich history, and a geography that embraces most of the Earth's climate zones and features incredible biodiversity and astounding topography, policymakers must handle environmental changes that threaten land use, water availability, food production, public health and livelihoods for millions of people. Even with large reductions in global greenhouse gas emissions, climate change will nevertheless lead to severe impacts in Peru. Without drastic reductions, however, novel challenges could arise, including a near-complete loss of Peru's glaciers, as well as a possible Amazon rainforest dieback.

This report – the outcome of fruitful collaboration between the Potsdam Institute for Climate Impact Research (PIK) and the International Organization for Migration (IOM) – is a timely assessment of climate risks, environment–migration linkages and pertinent policies in Peru. It emphasizes that, today, people are already fleeing, migrating or being relocated due to climate risks. While moving is only one of many strategies that Peruvians use, worsening climate impacts will make it harder to adapt locally. Of course, once impacts transgress critical levels, migration may very well be the only chance to save lives as local adaptation becomes impossible. In a high-emissions scenario, however, fewer and fewer migrants will be able to migrate in peace and dignity, while forced and precarious migration will surge and possibly lead to violent conflicts.

This report is therefore an urgent call to action for States and cities worldwide to reduce their CO_2 emissions so that countries like Peru will have a reasonable chance to manage residual climate impacts. In addition, the information presented here can contribute to the scaling up of national efforts to build local climate resilience. Peru's diversity and remarkable history are invaluable assets in this fight. The country offers a rich suite of possibilities to explore and adaptation options to test, some inspired by the many traditional strategies that its people have developed over centuries of living in extreme environments.

Prof. Hans Joachim Schellnhuber
Director Emeritus
Potsdam Institute for Climate Impact Research

FOREWORD
BY THE INTERNATIONAL ORGANIZATION FOR MIGRATION

The impacts of climate change and environmental factors have increasing influence on global migration. People decide or are forced to move to avoid the impacts of natural hazards or because their living conditions are affected by climate processes that affect their socioeconomic well-being.

Peru is among countries in South America that are most vulnerable to the various impacts of climate change. Due to environmental and climate processes related to global warming, many urban and rural communities in the country are experiencing or could experience forced migration in the near future, putting at risk the fulfilment of their rights, such as the right to self-determination. Water scarcity appears to be a particularly crucial challenge in the attainment of development goals in vulnerable communities in Peru.

Within the framework of its mandate, IOM addresses the environment, climate change and migration nexus in Peru, in order to support its Government in the development and implementation of disaster risk reduction and climate change adaptation measures from a human mobility perspective. The Government has demonstrated great ambition in its climate commitments and has made environmental migration among its priority actions. This approach represents an excellent opportunity to support the country's most vulnerable populations, who live in areas exposed to impacts of climate change and are migrating in search of better opportunities.

IOM has partnered with the Potsdam Institute for Climate Impact Research to produce this report, which seeks to shed light on the available evidence on the environment, climate change and migration nexus in Peru. The study puts into perspective various climate risks and hazards that affect communities in the country's main topographical zones: the coast, the highlands, and the rainforest or jungle. Exposed to multiple hazards and with limited coping mechanisms at their disposal, these communities often resort to migration. The report looks at the available evidence on these movements and the complex interaction between climate and other factors driving migration in the country.

The ongoing development of a national plan of action to prevent and address environmental migration in Peru, which resulted from the 2018 Climate Change Law and its 2019 regulations, presents an ideal opportunity to build systems and mechanisms to protect vulnerable communities and respond to the needs of migrants. We hope that the findings of this report will help inform this initiative and offer useful recommendations to decision makers involved in the process.

Jorge Baca Vaughan
Chief of Mission in Peru
International Organization for Migration

ACKNOWLEDGEMENTS

This report was written by a team of experts from the Potsdam Institute for Climate Impact Research (PIK), which included Jonas Bergmann, Kira Vinke, Carlos Antonio Fernández Palomino, Stephanie Gleixner, Christoph Gornott, Rahel Laudien, Anastasia Lobanova, Josef Ludescher and Hans Joachim Schellnhuber. Jonas Bergmann acted as the overall editor of the report.

The writing of this report would not have been possible without the contributions of numerous individuals. We are especially grateful to the following PIK colleagues for their review of the different parts of the report and at various stages of its writing: Torsten Albrecht, Markus Drüke, Maria Martin, Matthias Mengel and Helga Weisz.

IOM partnered with PIK in the preparation of the report and the editing of its content. IOM contributors included Pablo Escribano, Sieun Lee, Rogelio Quintero, Sergio Zapata and Quynh Anh Thuy Chu.

We are also thankful for the invaluable technical support of Claudia Meintzinger, Ole Weber, Anastasiia Polianskaia and Frederic Grobler (PIK), as well as Miguel De Lim (IOM Publications Unit) for language editing, Harvy Gadia (IOM Publications Unit) for layout, and Roland Kutz (webreform GmbH) for cover design and selected figures, as attributed.

This publication was made possible through the support provided by the East Africa–Peru–India Climate Capacities (EPICC) Project. The Potsdam Institute for Climate Impact Research leads the execution of the project with its partners, The Energy and Resources Institute and the Deutscher Wetterdienst (the German Meteorological Service). EPICC is part of the International Climate Initiative. The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety supports this initiative on the basis of a decision adopted by the German Bundestag.

We sincerely thank the German Embassy in Peru for financing the translation of this report into Spanish, skilfully executed by María del Carmen Pizarro.

Aerial view of the Amazon rainforest, which comprises 59 per cent of Peru's land area. © Shutterstock/Gustavo FRAZAO

TABLE OF CONTENTS

FIGURES, TABLES AND TEXT BOXES

A dry lake bed in a valley in the highland region of Áncash, Peru. © Shutterstock/Arne THIELENHAUS

ACRONYMS

ABM	agent-based model
ANA	National Water Authority (Spanish: Autoridad Nacional del Agua)
CAN	Andean Community of Nations (Spanish: Comunidad Andina)
CENEPRED	National Centre for Disaster Risk Estimation, Prevention and Reduction (Spanish: Centro Nacional de Estimación, Prevención y Reducción del Riesgo de Desastres)
CEPES	Peruvian Centre for Social Studies (Spanish: Centro Peruano de Estudios Sociales)
CEPLAN	National Centre for Strategic Planning (Spanish: Centro Nacional de Planeamiento Estratégico)
CMIP5	Coupled Model Intercomparison Project Phase 5
CSM	South American Conference on Migration (Spanish: Conferencia Suramericana sobre Migraciones)
DRM	disaster risk management
DRR	disaster risk reduction
ENAHO	National Household Survey on Living Conditions and Poverty (Spanish: Encuesta Nacional de Hogares sobre Condiciones de Vida y Pobreza
ENSO	El Niño–Southern Oscillation
FAO	Food and Agriculture Organization of the United Nations
GDP	gross domestic product
GFDRR	Global Facility for Disaster Reduction and Recovery
GLOF	glacial lake outburst flood
GMST	global mean surface temperature
GTM-NDC	Multisectoral Working Group for the Implementation of the NDCs (Spanish: Grupo de Trabajo Multisectorial para la implementación de las NDC)
HDI	Human Development Index
IDMC	Internal Displacement Monitoring Centre
IDP(s)	internally displaced person(s)

INDECI	National Institute of Civil Defence (Spanish: Instituto Nacional de Defensa Civil)
INAIGEM	National Institute for Research on Glaciers and Mountain Ecosystems (Spanish: Instituto Nacional de Investigación en Glaciares y Ecosistemas de Montaña)
INEI	National Institute of Statistics and Informatics (Spanish: Instituto Nacional de Estadística e Informática)
INRENA	National Institute of Natural Resources (Spanish: Instituto Nacional de Recursos Nacionales)
IOM	International Organization for Migration
IPCC	Intergovernmental Panel on Climate Change
ISIMIP	Inter-Sectoral Impact Model Intercomparison Project
masl	metres above sea level
MERCOSUR	Southern Common Market (Spanish: Mercado Común del Sur)
MIMDES	Ministry of Development and Social Inclusion (Spanish: Ministerio de la Mujer y Desarrollo Social)
MIMP	Ministry of Women and Vulnerable Populations (Spanish: Ministerio de la Mujer y Poblaciones Vulnerables)
MINAGRI	Ministry of Agriculture and Irrigation (Spanish: Ministerio de Agricultura y Riego)
MINAM	Ministry of Environment (Spanish: Ministerio del Ambiente)
MINJUSDH	Ministry of Justice and Human Rights (Spanish: Ministerio de Justicia y Derechos Humanos)
NAP	National Adaptation Plan
NDCs	Nationally Determined Contributions (Paris Climate Agreement)
ONERN	National Office for Natural Resource Evaluation (Spanish: Oficina Nacional de Evaluación de Recursos Naturales)
PAHO	Pan-American Health Organization
PCM	Presidency of the Council of Ministers
RCP	representative concentration pathway
RREE	Ministry of Foreign Affairs (Spanish: Ministerio de Relaciones Exteriores)
SENAMHI	National Meteorological and Hydrological Service of Peru (Spanish: Servicio Nacional de Meteorología e Hidrología del Perú)
SINAGERD	National System for Disaster Risk Management (Spanish: Sistema Nacional de Gestión del Riesgo de Desastres)
SLR	sea-level rise
SNM	National Superintendency for Migration (Spanish: Superintendencia Nacional de Migraciones)
SSP	socioeconomic pathway
UN DESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNDRR	United Nations Office for Disaster Risk Reduction (formerly known as the United Nations International Strategy for Disaster Reduction (UNISDR))
UNFCCC	United Nations Framework Convention on Climate Change
UNHCR	United Nations High Commissioner for Refugees
UNODC	United Nations Office on Drugs and Crime
USAID	United States Agency for International Development
WFP	World Food Programme

Colourful slum buildings in Lima, Peru.
© Shutterstock/In Green

EXECUTIVE SUMMARY

Living in a country exposed to various natural hazards, people in Peru have had to develop mechanisms to sustain their livelihoods and build resilience. Accelerating climate impacts, such as glacier retreat and hydrological and temperature extremes, are exacerbating challenges for farmers, fishers and those living in slums or improvised housing. Already today, people whose livelihoods are affected by climate impacts are moving from rural areas to the cities, especially from the highlands (sierra) to the coast (costa), and, to a lesser degree, the Amazon rainforest (selva). Studies have observed that the internal migration of Peruvians out of exposed areas is an emergency response or an attempt at a strategic adaptation to climate stressors. While non-climatic reasons for moving still dominate in most areas of Peru (a country with historically high migration rates), climatic drivers for migration are becoming more prominent and are forming increasingly complex interrelationships with other factors underlying mobility. This trend will likely continue, as many climate impacts can no longer be avoided due to delayed action globally to curb greenhouse gas emissions.

The COVID-19 pandemic has shown how external shocks can undo development gains and threaten the fabric of society. Lack of access to freshwater, absence of savings to buffer income losses and other inequalities are magnified by the pandemic, with devastating consequences for many. Looking into the future, the climate challenge will inevitably grow as impacts become more severe[1] and unabated climate change will lead to unmanageable disasters. Even if countries are able to implement their Nationally Determined Contributions (NDCs), global mean surface temperatures will be 2.9–3.4°C higher in 2100 than during pre-industrial times. In a worst-case scenario, high-emissions pathways resulting in a 4°C or even warmer world by 2100 could trigger extremely severe climate impacts in Peru, some of which could render parts of the country uninhabitable. Three such potential "no-analog threats" are: (a) extreme heat stress in the Amazon region, which would overwhelm the body's ability to thermoregulate, combined with a possible Amazon rainforest dieback; (b) almost complete loss of Andean highlands glaciers, which provide key freshwater resources; and (c) more intense El Niño events, which will threaten coastal settlements on top of rising

1 Recent climate models have used four scenarios to cover possible future emissions – the so-called "representative concentration pathways" (RCPs). RCP 8.5, the "business as usual" or worst-case scenario – that is, without climate policy interventions – assumes the highest greenhouse gas concentrations, leading to a likely global mean surface temperature increase by the end of the twenty-first century of 3.2–5.4°C from pre-industrial times. For RCPs 6.0 and 4.5, the likely ranges are 1.7–3.2°C and 2.0–3.7°C, respectively. Only RCP 2.6, which requires strong mitigation measures, projects global warming that would stay well below the 2°C limit set in the Paris Climate Agreement (0.9–2.3°C) (Collins et al., 2013). These are global average changes. Projected local changes show a much larger spread and can exceed these numbers in some regions of Peru. This report refers to RCP 8.5 as high-, RCP6.0 and 4.5 as medium-, and RCP2.6 as low-emissions pathways or scenarios.

sea levels. Such threats could arise within the same space of time and initially trigger gradual, pre-emptive forms of migration that will eventually turn into large-scale displacement. These types of extreme impacts could still be avoided through global greenhouse gas emissions reductions. The COVID-19 revealed that timely intervention is key to avoiding uncontrollable damages from cascading risks.

Even if global warming is limited to 2°C by 2100, climate impacts in Peru would still be severe; however, keeping global warming to a minimum may allow for more time and options for adaptation. In this best-case scenario of a climate crisis "with brakes applied," impacts may be manageable with substantial governance and investment efforts. For example, adaptation efforts that boost rural farmers' resilience could reduce the number of people forced to leave their homes. Simultaneously, for those who need to leave, the chances of benefiting from migration could be higher, as investments in their resources and skills, as well as in destination areas, could be made in time and proportionate to the magnitude of flows. For example, migration could serve to sustain rural livelihoods through seasonal income diversification.

There is still a window of opportunity to reduce climate impacts and thus enable people to adapt where they live or obtain skills that would allow them to migrate in dignity. However, whether this space is, indeed, kept open will depend on global emissions reduction – so that global warming stays well below 2°C in the best-case scenario – and well-planned national adaptation strategies and implementation. Even in this optimistic, best-case scenario, however, challenges to policy that would safeguard people's well-being, either in their home communities or in destination areas, will be large. For example, existing migration networks, perceived opportunities (albeit short-term), and centralistic policies in Peru could incentivize migrants to concentrate in a few areas that may become more exposed to climate hazards in the long term. Informal and unplanned urbanization in a few major destinations with their own capacity problems and climate impacts, such as Lima, may cluster new vulnerabilities for migrants and host communities. In parallel, more people may move towards the resource-rich Amazon basin, implying a great need to manage these flows adequately to ensure sustainable livelihoods and avoid further deforestation and biodiversity losses. A polycentric adaptation strategy could use incentives to spread migration flows among various destinations, for example, to the Andean highlands, which were home to many of the ancient Peruvian centres of civilization and will be subject to less extreme temperatures in the future. Traditional knowledge in agriculture and water management should be researched further and successful measures should be included and mainstreamed in adaptation planning.

The report is based on a systematic literature review of close to 60 studies, document analyses of laws and policies, and expert interviews. The following sections outline the most significant findings of this report, which aims to provide the first comprehensive evidence base for policymakers, practitioners, researchers and donors who aim to address the topic of climate change and migration in Peru. The insights presented herein are also relevant to neighbouring countries with similar ecosystems and climate zones.

General demographic trends

Migration is one important factor in the ongoing changes in the size, structure and distribution of Peru's population. Population growth has translated into a large, young population, but this growth is now flattening, and the median age has risen to 31 years. In 2017, about one fifth of Peru's population of 31 million people were internal migrants. Migration has been a factor in the great shifts in the population shares of Peru's three main topographical zones between 1940 and 2017: the share of people living in coastal regions grew from 28 per cent to 58 per cent and that in rainforest regions, from 7 to 14 per cent; on the other hand, the regions in the rural highlands had a large decrease in their population share, that is, from 65 per cent to 28 per cent. Between 2012 and 2017, 15 administrative regions in Peru – many in the highlands – had negative net internal migration rates (i.e. there were more people migrating to another region than moving in). Migrants have often moved to Lima, secondary cities and other economic poles. For example, between 1981 and 2007, the share of Peru's population living in cities sized 0.5 to 1 million people grew from 0 per cent to 11 per cent. In 2017, Lima, with its population of more than 9 million people, was home to close to 3.5 million internal migrants. These historical flows have resulted in strong migration networks across the country that pull new migration towards cities and the coast and boost remittances to rural areas. While urbanization rates have started to flatten, urban–urban and intra-metropolitan migration has increased. Since 1990, more migrants (at least 3 million) have left the country than entered it, although recent crisis-driven immigration from the Bolivarian Republic of Venezuela has been significant. Many migrants from Peru are non-agricultural workers who send remittances back to urban areas in their country of origin.

Exposure to hazards

Hazard exposure in Peru is vast and rising. Today, half of Peru's national territory is exposed to recurring hazards, and one third of the population uses exposed space. More than 9 million people are exposed to heavy rains, floods, flash floods and landslides, 7 million to low and very low temperatures, and almost 3.5 million to droughts. Population growth, unplanned urbanization and the growth of informal settlements will likely mean more exposed people in the future. In addition, many internal migrants have no choice but to settle in areas exposed to multiple hazards, such as riverbeds, floodplains and water-stressed hills in the outskirts of cities.

Vulnerability and resilience

Some of the suggested indicators demonstrate that Peru's resilience has improved, whereas others show stagnation or even reversal of progress. For example, while the population share of vulnerable age groups, as well as Peru's dependency on imported energy and external health services, has sunk over the past two decades, rising dependency on food imports points to a challenge. Similarly, while some indicators of Peru's adaptive capacity have improved, including in terms of better agricultural capacity, more medical staff, as well as better access to water, sanitation and electricity, others indicate continuous challenges. For example, high child malnutrition rates suggest a lack of capacity to meet basic nutritional needs; insufficient water storage capacity reveals challenges to buffering water scarcity; and ineffective mobility and resource distribution point to inadequate transport infrastructure. While Peru has made some progress compared to other countries, aggregate vulnerability remains significant and subnational discrepancies are large. For example, one in five Peruvians lives in districts, especially in highland and rainforest provinces, that are highly or very highly vulnerable to food insecurity, given the recurring hazards and socioeconomic challenges.

A closer look reveals that although there have been improvements in many human development indicators in Peru, some population subgroups remain excluded from this progress – as such, climate impacts may leave these people more vulnerable than before. Over the past three decades, life expectancy at birth has been augmented by almost 10 years while education indicators likewise improved strongly. Poverty reduction has been significant, with almost 10 million people moving out of income poverty (based on the national poverty line) in the past decade. Higher incomes may mean improved access to goods and services that shield from climate impacts, but this is not a given. For example, even urban migrants with higher nominal incomes may face new vulnerabilities, given the higher cost of living in cities, prevalence of informal employment, and poorer social networks. Moreover, while poverty reduction has been remarkable, 2 out of 10 Peruvians still live below the national poverty line, and 7.5 million out of 31 million cannot afford basic commodities. Peru has also made significant advancements towards reducing developmental inequalities, although the gaps remain wide. For example, the poorest 40 per cent of the population earns only 14 per cent of total national income – almost the same situation as two decades ago. Gender and ethnic inequalities persist across all human development dimensions. The poverty rate is three times higher in rural than in urban areas, which means that close to half of the rural population is poor. Rural dwellers are also more severely poor than urban populations. Simultaneously, the number of people living in urban slums has increased. People deprived of assets, skills, political representation and access to services are particularly vulnerable to climate impacts. Those most at risk are heavily reliant on ecosystems, such as smallholders, and especially the poor, including land-poor families and households without diversifiable or transferable skills. About a quarter of Peru's total employment is in agriculture and many are subsistence farmers vulnerable to food insecurity. A major concern is that climate change threatens to reverse much of Peru's recent progress and push numerous people towards new vulnerabilities: 4 out of 10 Peruvians remain at risk of falling into poverty if hit by a negative shock.

Climate impacts

Climate change has had visible impacts across the country. Past climate trends in Peru were subject to uncertainties, given the country's complex mountain geography, as well as a limited density of weather observation stations and limited observation periods. Evidence shows that both temperatures and temperature-related extremes have increased over the last three decades – with the lowest increase observed in the Amazon region and the highest in the Southern Andes mountains, where the average temperature has been rising up to 0.3°C per decade since 1981. Rising temperatures at higher elevations have contributed to a countrywide glacier surface area loss of 30 per cent between 2000 and 2016. In highlands and coastal regions, observed annual rainfall shows no significant trends, although precipitation intensity increased in the southern highlands and coastal regions specifically. Discharges have increased in most coastal basins during the dry season, partially due to the first stages of glacial melt associated with higher temperatures. In the Amazon region, the reported rainfall trends are positive in the south and slightly drying in the centre. In the northern rainforest regions, precipitation and runoff trends are non-significant or contradict each other.

El Niño and La Niña events can have severe impacts in Peru, including large-scale displacement. The El Niño Southern Oscillation (ENSO)[2] phenomenon is Peru's most consequential driver of natural climate variability. Strong Eastern Pacific El Niño events raise precipitation levels in the (especially northern) coastal zone and lower them in the southern Andes and in the Titicaca and Amazon regions. Central Pacific El Niño events reduce rainfall over upstream regions along the Pacific slope. In contrast, strong La Niña episodes lead to increased precipitation in the Andes and in the Titicaca and Amazon regions. ENSO also affects the upwelling and nutrient availability off Peru's coast, with large impacts on fisheries. Extreme coastal El Niño events strongly increase rainfall off Peru's coastal zone; the latest occurrence in 2017 led to almost 300,000 displacements. Observed ENSO variance over the last few decades was significantly higher than in previous centuries.

Climate impacts on agriculture could be severe and lead to food insecurity, as well as increasing migration pressures. Agriculture provides permanent jobs and income to 2.5 million people in Peru, especially in rural areas – a number that rises temporarily to almost 14 million during the harvest season. Some 80 per cent of farmers in Peru depend on the food they produce. Already today, more than one out of three people in Peru do not have the recommended minimum daily calorie intake. Non-climate stressors include overuse of water resources, overfishing and insufficient soil management practices. Climate change raises food insecurity, as increasing temperatures and an increased risk of drought, flooding and other extreme weather events can have wide-ranging consequences for crop, livestock and fishery production. These risks could induce more anticipatory migration when livelihoods erode gradually or displace people when sudden-onset events destroy harvests or kill animals.

Future climate impacts will be severe in Peru, but the global emissions pathway taken will make the difference between a climate crisis "with brakes applied" (best-case scenario) and a "full-speed" climate disaster (worst-case scenario). Impacts will be challenging even in low-emissions pathways that would lead to a climate crisis "with brakes applied" (i.e. <2°C global warming by 2100, from pre-industrial times). Average temperatures could increase 0.75–1.5°C by mid-century and 1–1.75°C by the end of the twenty-first century (compared to the 1985–2005 average, not pre-industrial times). In low- and medium-high-emissions scenarios, less dry-season runoff and more wet-season runoff are expected by the 2050s and 2080s. Even in a low-emissions scenario, glacier volume losses for the Central Andes by 2100 are projected at 78–94 per cent, with drastic repercussions for water security. As another example, researchers have medium confidence that in low-, as in high-emissions scenarios, extreme Eastern Pacific El Niño events would occur about twice as often in this century. This increase could mean more extreme rainfall and displacement in Peru. Related needs for planned relocation are uncertain but may also rise.

In a high-global-emissions pathway resulting in 4°C global warming, the impacts of a "full-speed" climate disaster could become unmanageable in Peru. Average local temperature increase could range from an additional 1–2°C by mid-century and 3.5–6°C by the end of the twenty-first century (compared to the 1985–2005 period, not pre-industrial times). In particular, the number of extremely warm summer days (i.e. those with average temperatures beyond the 95th percentile of the summer season) in tropical areas of South America would increase by mid-century. What is considered an extremely hot summer day in Lima today would become 11 times more frequent compared to the years 1961–1990. Heatwaves would be normal in most summer months by 2100. The projected decreases in dry-season and increases in wet-season runoff would become more pronounced than in lower-emissions scenarios. Wet-season flood pulses in the rainforest regions will become far more critical. In a 4°C-hotter world, three severe threats without analogs (i.e. "no-analog threats") in Peru's long history could arise in parallel. First, the rainforest's habitability would be at risk due to practically year-round extreme heat stress that overwhelms the human body's thermoregulatory capacity, and which might contribute to massive rainforest degradation or dieback. This would inevitably induce large-scale displacement. Second, future deglaciation would be near-complete, with 91–100 per cent of glaciers disappearing. While this would temporarily lead to more meltwater and greater water availability, once turning points are reached, water stress will rise drastically, particularly during the dry season (while wet season runoff is expected to increase under a high-emissions scenario in the Andean basins). Water stress and outburst floods from glacier lakes could damage ecosystems and pose dire challenges to human consumption, as well as hydropower, agricultural and mining production, and displace many people. Third, without further adaptation, permanent sea-level rise of up to 0.7 m by 2100 could lead to losses of land, built capital and livelihoods along Peru's coast. Besides the threat of permanent losses, more frequent extreme El Niño events, storm surges and floods, on top of sea-level rise, could periodically drive more displacement. Taken together, these three "no-analog" threats, accompanied by other climate impacts, could result in parallel disasters for Peru and displacement on a scale that is almost impossible to govern.

2 ENSO is characterized by the "warming of the tropical Pacific Ocean east of the dateline. This oceanic event is associated with a fluctuation of a global-scale tropical and subtropical surface pressure pattern called the Southern Oscillation. This coupled atmosphere[ic]–ocean[ic] phenomenon … is known as the El Niño-Southern Oscillation (ENSO) … The cold phase of ENSO is called La Niña." (IPCC, 2018a, p. 548)

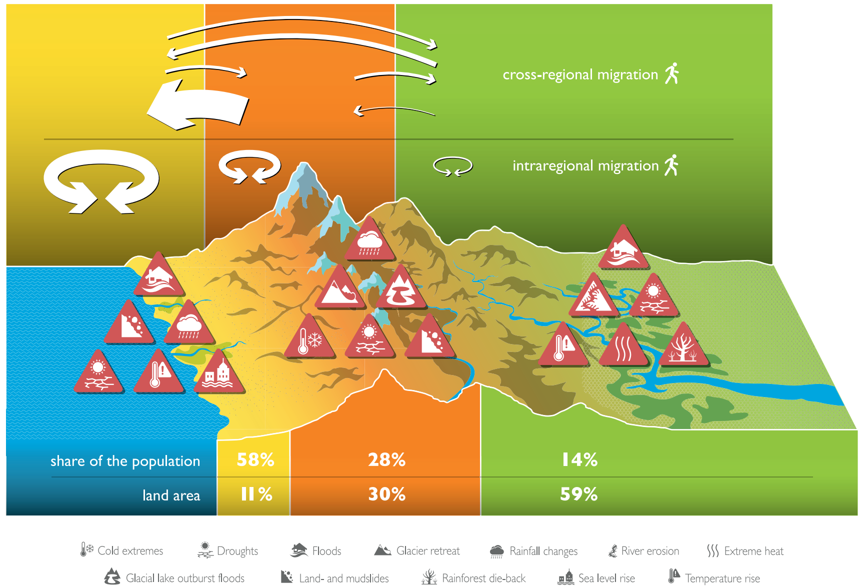
Harvesting using traditional techniques in the highlands of Peru. © Shutterstock/Mauricio GIL

Coping and adaptation

Peru is a land of extreme landscapes and climates, and its people have developed coping and adaptation strategies to deal with hazards where they live. However, the limits for dealing with future hazards may have already been reached in some areas. Despite local efforts, many people in Peru cannot recover fully from shocks. With accumulating and cascading hazards, they face risks of downward spirals of poverty and deprivation. For example, one year after the most recent El Niño event, half of the scallop farmers surveyed in one study had still not recovered. In another study, surveyed coastal households could not recover between one quarter to one third of their losses to floods and droughts. Already, many people cannot cope with or adapt to hazards because they lack resources or options. In one study, more than half of the households in highland communities surveyed in Piura rated their ability to cope with water scarcity as "bad". One quarter of surveyed people living by the coast did not have any options for coping with floods; in a study of rainforest communities, this number escalated to three quarters. Close to one fifth of farmers surveyed in the coastal zone lacked options to react to drought – the figure rose to more than half of farmers in the rainforest study. In addition, local adaptation has inherent limits, given the magnitude of anticipated future changes. In a survey of farmers living on Peru's northern coast, one third felt that they could do nothing to adapt to climate change in the long run. These people will be particularly at risk of becoming "trapped" in increasingly unsafe areas when more climate impacts erode the ecosystems on which they depend. Internal migrants in Peru have typically sent remittances to economically inactive and at-risk groups in rural areas; such remittances may support coping of populations staying in unsafe areas, but research on this remains limited. Where adaptation limits are crossed, facilitated migration or planned relocation may become necessary.

Climate migration

Figure A. Net lifetime migration across Peru's main topographical regions



Source: Conceptualized by Jonas Bergmann and produced by webreform GmbH.

Peruvians use migration as one of many strategies to cope with hazards, and more people are expected to migrate in response to increasing climate impacts in the future. Historically, many people in Peru are permanent or temporary migrants. They migrate for different reasons, including economic, social and educational opportunities, and environmental pressures. When they face climate hazards, both temporary and permanent migration is observed as a response. Examples of such migration include fishermen moving along the coastline as a function of ENSO-driven marine resource availability, and farmers in the coastal Piura Region migrating for income diversification during periods of drought. In the highlands, studies find that people migrate for work due to cold spells, freezing and frost in Cusco, Huancavelica and Puno. Migration in search for alternative income sources and to be able to remit money is also observed due to water scarcity driven by glacial recession in Áncash, Cusco and Junín, especially in later stages of retreat. Farmers also migrate due to livelihood and food insecurity triggered by rainfall changes and droughts in Áncash, Junín and Piura. In the rainforest regions of Ucayali and Loreto, farmers preemptively and temporarily migrate during the rainy season to mitigate food insecurity. While consecutive hazards drive permanent migration in these regions, studies have similarly observed migration as a way of coping with single, intense flooding events or riverbank erosion.

The exact nature of the climate–migration nexus in Peru is still not completely understood. Most studies in the literature review focus on climate impacts on environmental (such as food security and habitability) and *economic drivers* of migration as the most important in decision-making. Few studies provide insights on climate impacts on other macro drivers, such as political drivers (e.g. conflict or insecurity). Studies in Peru suggest that migration does not only occur when climate impacts erode livelihoods. Impacts can also affect other factors that are key to place satisfaction, such as recreational or spiritual ecosystem services, and thereby induce migration. Overall, climate impacts on ecosystem-based rural livelihoods are likely to enlarge existing internal migration flows from rural to urban areas, from the highlands towards the coast, and, to some extent, towards the rainforest. When and where people move depends partly also on governance efforts and the severity of climate impacts. The effects of these factors on cross-border migration, however, remain unclear. It is also difficult to predict longer-term migration and displacement in a high-emissions future scenario due to the three potential no-analog threats to the habitability of large areas by 2100, as already mentioned.

The consequences of migration in the context of hazards are varied and depend strongly on household profiles, as well as the characteristics of receiving areas. On the positive side, studies show that migration allows people to move away from harm. It can help them to diversify incomes, learn new skills and send remittances to at-risk people in rural areas. For example, surveyed households in Junín use migration mostly successfully to diversify livelihoods and manage risks related to worsening rainfall patterns. Families of fishers migrating along the coast due to El Niño-driven cyclical resource availability have benefitted from social remittances and technology, and some members of rainforest communities have gained educational opportunities through migration. On the other hand, studies have noted that hazard-driven migration has eroded local traditional knowledge and adaptive capacities in some coastal, highland and rainforest communities of Peru. It can also deprive sending communities, especially those in the highlands, of the labour resources required for labour-intensive agriculture. Studies have observed school desertion and interrupted schooling due to hazard-driven migration across Peru's rural areas, especially when children are sent to earn money elsewhere. Some studies indicate that migration can also have strong social impacts on those staying. For example, migration after floods in the rainforest can result in the separation of household members, abandonment of older family members and, ultimately, strained family relationships. Migrants also often face demanding new surroundings and psychosocial challenges. The skills of farmers are not always easily transferable to jobs in cities and thus imply risks of informal employment. For example, flood-driven migrants from rainforest regions often lack skills required by dignified jobs. Many either work precariously or are unemployed, leading to serious food insecurity. In receiving areas, pollution, stress on basic service provision and infrastructure, as well as job competition between migrants and the local population may be problematic. Simultaneously, migrants often end up in hazard-exposed areas, such as informal settlements on riverbanks, unstable slopes and water-scarce lands. Climate hazards are also increasing in destination areas. Water stress may pose significant challenges for migrants with limited access to basic services in coastal cities like Lima and in regional capitals like Huancayo and Huaraz, with their high dependency on greatly decreasing glacial meltwater.

Displacement and planned relocation

Without concerted disaster risk management efforts, the potential of sudden-onset hazards to displace people in Peru will increase. Past disaster displacement in Peru was due mostly to floods, El Niño events and intense rainfall. The most recent coastal El Niño event, in 2017, led to almost 300,000 displacements. Past experiences have shown that such disaster displacement can take a high psychosocial toll on people who have lost their livelihoods and assets, including homes and other infrastructure. For example, half a year after the coastal El Niño event of 2017, a representative survey across all campsites in Piura showed that one fifth of displaced people remained without access to water. In two of the most affected areas, around one quarter of displaced people could not leave because their livelihoods were destroyed. Among them, the number of people left without jobs increased by 215 per cent. Another study found that almost half of affected people suffered from post-traumatic stress disorder. Flood displacement in the rainforest regions has also deprived people of adequate basic services and access to livelihoods. Mental health challenges include post-traumatic stress disorder, depression and somatization, alongside many physical health challenges. Displacement pressure will likely increase, considering projections of more intense rainfall events and related flooding, landslides and riverbank erosion, and more heatwaves in many parts of the country. Researchers also foresee, with medium confidence, twice as many extreme Eastern Pacific El Niño events affecting the coast in this century, on top of sea-level rise. In a high-emissions future, a 100-year flooding event, on top of projected higher sea levels, could affect more than 100,000 people in Lima if further adaptation measures are not taken. Displacement risks also rise as more people migrate to exposed areas.

Because increasing climatic risks could reduce the habitability of affected areas, planned relocation of communities may become more necessary. However, Peru's experience shows how problematic they can be. Past relocation occurred primarily along the coast, the lower slopes of the highlands, and by rainforest rivers. Studies show that implementing authorities often disregarded land and social issues, livelihood necessities, and people's place attachments. They also note a lack of oversight, financial limitations and institutional frictions. Due to these shortcomings, planned relocation has often resulted in human rights violations and livelihood challenges. Many of those affected either decline to move, return or maintain dual residency. Many people in Peru live on risky lots because of their relative affordability and temporary livelihood benefits, such as proximity to rivers for irrigation purposes; however, increasing climate hazards could turn many of these areas uninhabitable or make the cost of lot upkeep prohibitively high, especially in a high-emissions scenario. Despite the current push by the Government of Peru for increased use of planned relocation, as enshrined in the Law on Population Relocation for Areas with Very High, Unmitigable Risk, this option can only be taken for a small share of the growing number of people affected by climate impacts. Given past cautionary tales, it should be a last resort in many areas and requires strong government oversight, as well as the participation of affected people in decision-making.

Recommendations

Against this background, this report provides the following recommendations for governing the nexus between climate change and human mobility in Peru and for addressing key research and data gaps in this area.

Key recommendations for governance

Peru's current polices provide a valid starting point for addressing the climate change–mobility nexus. Legislation on internal disaster displacement, disaster risk management and planned relocation, as well as human rights applicable in Peru, could help to support local adaptation and protect people on the move. The recently enacted Climate Change Framework Law, NDCs and ongoing work on the National Adaptation Plan (NAP) are also valuable advancements. Peru is in the process of building a cohesive, intersectoral and long-term strategy across all levels of government to address climate change-related mobility. However, some policy gaps persist and implementation often lags. Norms are still not sufficiently interconnected across different instruments, and financing and implementation constitute persistent challenges, especially at subnational levels. Increasing climate stress can aggravate these challenges, making action required now to avoid shock-driven crisis responses later:

(a) **Enhancing current frameworks**. Policymakers should invest in the ongoing drafting of the Action Plan to Avert and Address Forced Migration and Displacement due to the Effects of Climate Change – envisaged in the Climate Change Framework Law regulations – as a landmark project for ramping up government efforts on climate-related human mobility. The action plan is currently being developed by the Ministry of Environment and the Ministry of Women and Vulnerable Populations and could break new ground in the governance of this phenomenon. In addition, policymakers could integrate the issue better in the upcoming update to the National Strategy on Climate Change and in other relevant frameworks, such as the National Forest and Climate Change Strategy, the National Strategy for the Fight against Desertification and Drought, the National Plan for Food Security and Nutrition, and the Climate Change Adaptation and Risk Management Plan for the Agrarian Sector.

(b) **Integrating human mobility into adaptation planning for a climate crisis "with brakes applied" scenario (pathway to 2°C global warming by 2100)**. Policymakers and planners should integrate measures to prevent forced climate migration and support migrants under the five existing adaptation priority areas (agriculture, fishery, forestry, health and water) in Peru's NDCs, the related drafting of the NAP, as well as in upcoming updates to agricultural policies. Planning should be based on a scenario with global warming of around 2°C by 2100, in accordance with the Paris Climate Agreement. This may still result in severe climate impacts in Peru but would, at least, help buy more time and allow for more options for adaptation. Dynamic adaptation planning should set the course for 2050, but with a longer-term view to 2100. Research is needed to understand characteristics that make households more predisposed to displacement and how they could be supported in either adapting locally or in migrating in dignified ways. Appropriate planning includes: (a) investing in improving subsistence farmers' ability to adapt to impacts locally, for example, through improved agricultural techniques and climate-resilient crops; (b) developing capacities of local government units to deal with impacts at the source, for example, by funding personnel and training in agricultural resilience and water management; (c) identifying areas that may degrade so much that they would not be suitable for agriculture in the future, as well as supporting residents in acquiring skills to move early enough and attain adequate standards of living afterwards; (d) providing incentives for migrants to settle in municipalities more suitable to their needs, beyond the major hubs; (e) enhancing protection of and service provision to those moving, alongside investments in host communities; and (f) preparing, especially, major urban areas and their outskirts for more inhabitants and addressing the effects of this influx on local infrastructure, services, markets and social cohesion.

Key recommendations for research

Research attention on the nexus between hazards and mobility has been strongest for the Peruvian highlands and weaker for the rainforest and the coastal zones, even as the latter concentrates most of the country's population and economy. Methodologically sound studies have been conducted in all three topographical zones, but overall robustness varies. Below are recommendations on how to fill persistent knowledge gaps.

(a) **Solutions**. Scholars, practitioners and donors could jointly try to better understand possible solutions for people wanting to stay, including in situ adaptation through, for example, diversification and disaster risk reduction. Investigating, mapping and integrating traditional and indigenous knowledge in livelihood adaptation to extreme climatic conditions should become a key research area. Concurrently, researchers could investigate ways of supporting people leaving unsafe areas, such as pre-migration training and programmes that support making cities inclusionary. Scholars could examine polycentric incentives for migrants to settle across various destinations, such as educational and income opportunities and microcredit programmes. For example, studies could explore the possibility of reviving some of Peru's ancient highland centres. Options for host communities and people staying should also be examined, including careful ways of amplifying the positive effects of remittances.

(b) **Livelihoods**. Beyond smallholders mixing crop and animal farming, researchers could investigate how climate change affects livelihoods by the sea, in the agroindustry, agricultural processing and distribution industries, off-farm and urban livelihoods, and the secondary and tertiary sectors, and how these impacts relate to migration.

(c) **Drivers of migration**. Researchers could explore the interactions of migration drivers, including under-researched economic, political and demographic drivers such as consumer prices or conflict and disease prevalence. Indirect impacts of climate change on migration drivers, as well as the roles of migrants' skills, resources, knowledge and networks in moving could be further analysed.

(d) **Climate change**. Researchers should improve the analysis of the climate change dimension in studies on migration, displacement and planned relocation by considering multiple hazards and their long-term interplay. In addition, they could pay more attention to the likelihood of future no-analog threats. This would require strengthened interdisciplinary research and collaboration throughout all stages of research between natural and social scientists.

(e) **Consequences of moving**. More studies that provide comprehensive perspectives of the consequences of moving over the long term – including for those staying behind, those moving and host communities – could provide a better evidence base required for policymaking and programming. Researchers could examine how skills, resources, knowledge and networks shape these consequences.

(f) **Population and household characteristics, and larger structures**. Researchers could examine how individual demographic characteristics, such as age, education, ethnicity, gender and physical ability, alongside household dynamics and larger structural factors, such as power inequalities, affect how people strategize and deal with hazards, including through migration, and what their consequences are.

(g) **Non-mobility**. Factors that affect the decision to either move or not – including, but not limited to resource constraints – should be explored. Researchers could study how populations staying behind fare and how they could be supported in improving living standards where they are, if they choose to stay, or in leaving, if they desire to move but lack resources.

Key recommendations for data collection

Studies have used a variety of data, but existing instruments could be improved, and new data is needed to shed light on persistent research gaps and future adaptation options.

(a) **Better data on human mobility**. Authorities could include more items on migration in existing national data collection instruments such as censuses and national household surveys – specifically on migration motivations and consequences, and short-term and circular movements. They could also expand baseline and follow-up data on internal displacement and planned relocation, especially those pertaining to protracted situations. Data should be disaggregated whenever possible.

(b) **Longitudinal studies.** Researchers or authorities could steer longitudinal analyses with available current data to understand the temporal evolution of peoples' exposure and vulnerability to hazards, their varied response strategies and the consequences of these strategies over time.

(c) **More resources for weather, climate and agricultural data.** The State or the international community could provide more financial and human resources for short-term and seasonal weather forecasting, as well as long-term climate projections. Improving model performance and analytical methods to increase the robustness of projections would be desirable. Resources may also be used to expand the country's network of weather stations for a better understanding of spatial–temporal climate variability and to improve data for monitoring, including through better quality control of station data.

1. INTRODUCTION

1.1. SETTING THE SCENE

Across Peru's diverse geography, which consists of an arid coast, glaciated highlands and tropical rainforest, people are faced with a multiplicity of climate change impacts that are increasingly undermining traditional livelihoods and thereby influencing human mobility dynamics. Most Peruvians perceive climate change as a major threat (Ministry of Environment (MINAM), 2015b; Stokes et al., 2015) that requires strong political action (Takahashi and Martinez, 2018).

Already, global heating has shifted baseline risks in Peru. People have been simultaneously confronted with climate impacts and the devastating effects of the COVID-19 pandemic. While the interactions between climate change and health are an emerging research field, the pandemic laid bare that containing certain infectious diseases can be made more difficult by climate impacts like heatwaves and water scarcity.

The country has experienced substantial human development progress but remains unequal in its wealth distribution. Groups or segments of the population whose livelihoods depend on healthy ecosystems, such as farmers and fishers, are particularly affected by adverse climate impacts and are therefore often faced with the decision to either stay or move. More than a quarter of Peru's population works in agriculture. Many are subsistence farmers with limited financial and educational resources to adapt to climate change, as reflected in the small contribution (about 8%) of the agricultural sector to GDP (World Bank, 2019).

Climate impacts in Peru will be severe in any future emissions scenario and will include changes in the frequency and magnitude of existing hazards, such as extreme rainfall and drought. In a high-emissions future, however, drastic threats without modern precedents could emerge. These so-called "no-analog threats" are: (a) near-complete glacier retreat, (b) more frequent extreme El Niño events, on top of higher sea levels, and (c) extreme heat stress combined with a possible rainforest dieback in the Amazon basin. Glaciers in Peru are of special concern, as the water that they supply is crucial to agriculture and water security. Most glaciers have already been retreating significantly. In the short term, glacial melt leads to increased runoff until a point is reached at which dry-season runoff decreases and, in the worst case, may stop entirely. While research shows that Peruvian glacier retreat will be severe under most future climate scenarios, it remains unclear what the impacts will be on farmers, the freshwater supply of some cities, and sectors such as mining and hydropower generation.

In the past decades, Peru has seen migration for socioeconomic and human security reasons, mainly from rural to urban areas and from the highlands to the coast, as well as to the rainforest to some extent. Climate impacts in high-elevation zones will likely intensify this pattern, as they strongly affect poor farmers who are reliant on deteriorating ecosystems and who typcially use migration in an attempt at income diversification. Successful labour migration can serve to diversify a rural household's income base and any additional income can be channelled to support climate adaptation in the communities of origin. However, this potential can only materialize if there is labour demand in cities and migrants are able to integrate economically.

A large share of internal migration is to Peru's capital, Lima, the second largest desert city in the world. Lima's freshwater supply depends on water from the Andes mountains, which is experiencing changing rainfall patterns and glacier retreat. Hosting around 9 out of 31 million Peruvians, the city must address impending water scarcity. Water insecurity is particularly problematic for the urban poor. Part of this group are rural migrants, who often settle in slums and informal housing because they lack other options. The example of Lima shows how in Peru, as in other countries, people may move to areas where they would also confront climate risks. The depletion of ecosystem-based livelihoods and the ensuing migration do not only come with economic challenges, but also with difficulties for the sustainment of local culture and the social fabric. In urban settings, rural migrants may suffer from poor access to basic services, no longer be able to practice their traditions and experience pressures on their overall well-being.

People in Peru are already employing various coping strategies, but the magnitude of future impacts could overwhelm their adaptive capacity. A precondition for people to adapt effectively where they live or through migration is the implementation of the Paris Climate Agreement. Only if global warming is kept well below 2°C (from pre-industrial levels) by 2100 can countries like Peru have a chance to manage impacts and related migration dynamics.

Policy and planning are grappling to address the linkage between climate change impacts and mobility, partially due to a lack of systematized knowledge, a gap that this report aims to fill. To date, there has been no effort to systematize existing knowledge of these linkages in Peru. The aim of this report is to cover the knowledge gap in the systematic linkages between environmental hazards (especially climate impacts) and mobility in Peru, identify pressing data and research needs, and contribute to more evidence-based policy and planning.

Chapter 1 discusses the research approach and the framework for analysis (1.2 and 1.3) and broadly explains the context of Peru (1.4). Chapter 2 discusses population size and structure (2.1.1), as well as general migration systems and displacement trends (2.1.2–2.1.4). The report then assesses existing scientific evidence on climate–mobility linkages in Peru's three main topographical zones – the coast ("costa") (2.2.1), the highlands ("sierra") (2.2.2) and the Amazon lowlands ("selva") (2.2.3). To put the findings in context and shed light on possible blind spots in the coverage of risks in the literature, Chapter 3 provides a more detailed analysis of climate risks in the country. It discusses climate change trends and projections and related hazards (3.1), as well as historical trends and future projections of the El Niño Southern Oscillation (ENSO) phenomenon (3.2). The next subchapters explore vulnerability to these climatic changes in more detail (3.3), as well as their impacts on agriculture and food security (3.3). Based on these analyses, Chapter 4 assesses how laws and policies in Peru address the nexus between climate change and human mobility. Finally, Chapter 5 gives recommendations for policies on the issue, points to research gaps and underlines data needs.

1.2. RESEARCH APPROACH

The analysis of climate–mobility linkages uses features of an evidence-focused systematic literature review. The report identifies 59 published and unpublished studies that used a multitude of research designs and dealt either directly or indirectly with climate-related hazards and mobility in the country in recent decades. Boolean searches in specialized databases and complementary search strategies yielded data for the analysis.[3]

3 The CliMig database (available at www.unine.ch/geographie/climig_database) was the primary source for searches of English-language terms such as "Peru", "Latin America", "South America", "Ande*" and "Amazon*". Both published and unpublished studies that used any type of research design qualified for the review if they dealt with the topic of environmental hazards and mobility in the country and were conducted between 1990 and 2018. To minimize publication bias, additional searches included Boolean search runs in ProQuest Central, EBSCOhost Research Platform and Google Scholar, as well as the United Nations University Collections database (https://collections.unu.edu). Specialized databases, such as the Environmental Migration Portal, were screened for unpublished work and Boolean searches for academic theses were conducted in Dart-Europe, Open Access Theses and Dissertations (OATD) and Peru's Registro Nacional de Trabajos de Investigación (RENATI). The last search was conducted in January 2019.

The policy analysis is based on document analysis and interviews. To shed light on policy processes and actions taken by the Government of Peru, more than 40 policy documents were analysed. The analysis is complemented by information from semi-structured interviews and workshops with policymakers and practitioners in relevant fields. The qualitative data was collected in 2018 and 2019 in the context of the East Africa–Peru–India Climate Capacities (EPICC) project led by the Potsdam Institute for Climate Impact Research.

1.3. ANALYTICAL FRAMEWORK

To structure the discussion around climate change impacts on patterns of migration, displacement, planned relocation and non-mobility, this report draws on the concept of "climate risks". "Risk" concerns the "potential for consequences where something of value is at stake and where the outcome is uncertain"; it is based on the "probability of the occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur" (Oppenheimer et al., 2014, p. 1048). High risks exist not only when adverse outcomes are highly probable, but also when they are less probable yet entail highly adverse consequences (Intergovernmental Panel on Climate Change (IPCC), 2014b). The IPCC represents risk from climate impacts as a function of climate-related hazards, exposure and vulnerability.

(a) *Hazardous* events and trends are adverse events and trends that damage human or natural systems. This report focuses mostly on climate-related hazards. It also examines analogies of environmental hazards that are not related to climate change or, where attribution is still unclear, if they help to cover gaps or understand potential future pathways.

(b) Hazards matter when they threaten targets of value (*exposure*).

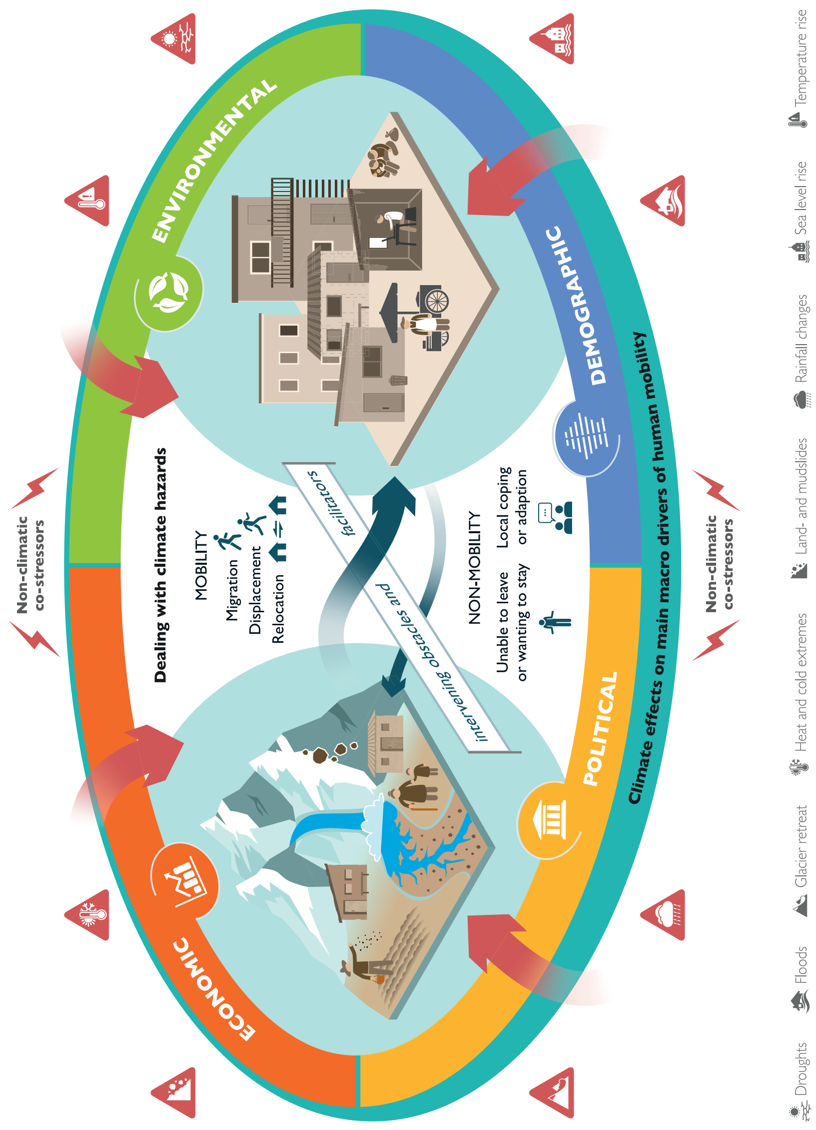
(c) The extent of the impacts of hazards on exposed systems depends on these systems' *vulnerability*, defined as the "propensity or predisposition to be adversely affected" (IPCC, 2014, p. 128), as well as their capacity to cope and adapt.

Natural climate variability and anthropogenic climate change influence all these three variables – hazards, exposure and vulnerability – and, ultimately, risks and impacts. Socioeconomic processes are also major influences on exposure and vulnerability, through variables such as development, demography, inequality and governance, as well as adaptive and mitigative actions taken.

People face risks with different probabilities and intensities of impacts – and their livelihood strategies to deal with them can include mobility (IPCC, 2018b). Affected communities, households and their individual members have specific characteristics, including where they are located (*exposure*); how they make a living (*livelihoods*); how they rely on nature (*ecosystem services*); and how rich or poor they are in various dimensions of life (*vulnerability*) and along several lines of differentiation (e.g. age, education, ethnicity, gender or physical ability). They use different strategies to anticipate or prepare for hazards and deal with the concrete consequences once these hazards occur. For example, people who choose to stay can change their livelihood activities or asset base. On the other hand, people may opt for a change of residence through migration when hazards impact any of the various drivers of mobility (Foresight, 2011). This is especially the case when climate impacts affect the most important drivers of mobility, namely, economic (e.g. producer prices and availability of jobs), environmental (e.g. food security and habitability), political (e.g. conflict insecurity) and, to some extent, demographic drivers (mostly disease prevalence). Figure 1 (p. 22) illustrates these conceptual links. Simultaneously, hazards can displace people or lead to planned relocation by the Government.

The next subchapter discusses the general country context of Peru as a baseline for the subsequent analysis of climate–mobility patterns identified in the scientific literature.

Figure 1. Schematic overview of how people deal with hazards and the role of mobility in their strategies



Source: Conceptualized by Jonas Bergmann and produced by webreform GmbH.

Note: The four main categories of drivers of climate-related mobility shown in this figure (economic, environmental, political and demographic) are selected based on evidence from Foresight (2011). Hazards are illustrative for Peru.

1.4. COUNTRY CONTEXT

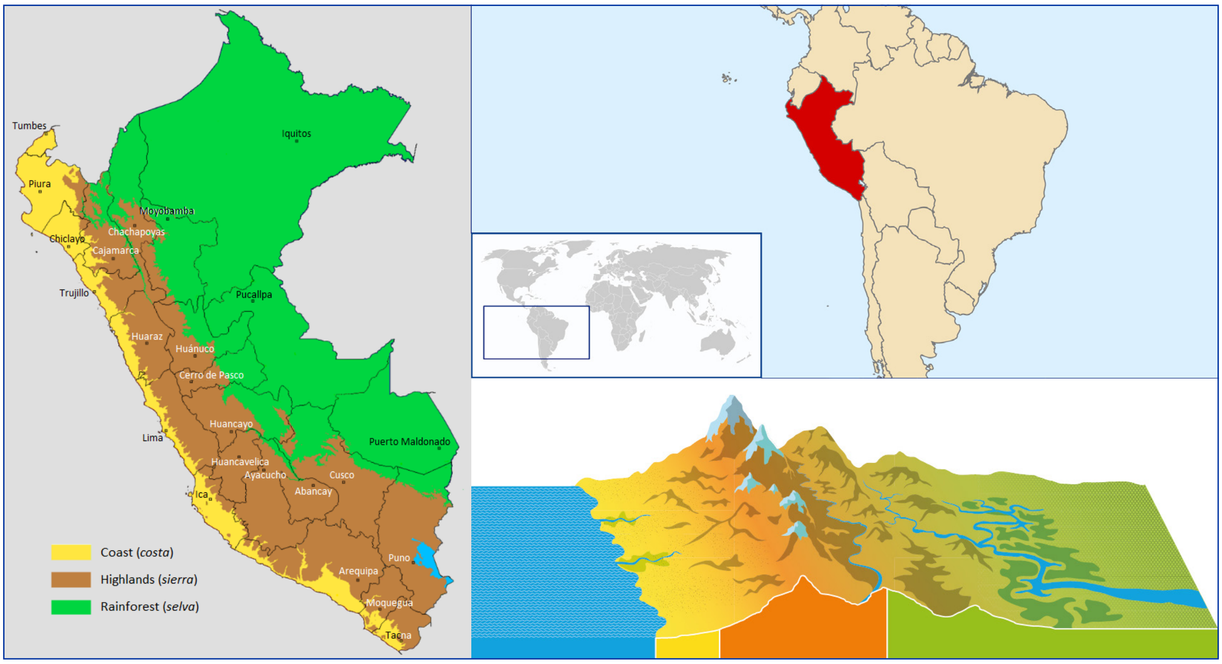
1.4.1. Geography

Peru is located on the Pacific coast of South America. Its northern extreme is close to the equator, while its southern extreme converges with the subtropics (Mächtle, 2016). The country shares land borders with Chile to the south, the Plurinational State of Bolivia to the southeast, Brazil to the east, and Ecuador and Colombia to the north (Figure 2, upper right). Peru's total coastline measures about 2,400 km. With a land area of about 1.280 million km^2, Peru is the twenty-first largest country in the world, the third largest in South America, roughly the size of the Niger and twice the size of France (United States Central Intelligence Agency (CIA), n.d.).

Peru is typically divided into three main topographical zones. These are: (a) the narrow plains of the coast (costa), (b) the central highlands and valleys (sierra), and (c) the forested expanse of eastern Amazonia (selva), (Figure 2, left). Bottom right of Figure 2 sketches the topographical gradient from west to east. This simplified representation shows that 11 per cent of Peru's landmass accrues to the coast and about one third to the highlands, whereas the Peruvian part of Amazonia comprises 59 per cent of the country's total land area. The coastal zone has declining availability of flat coastal land from north to south. Virtually the "spine" of Peru, the Andes are a dominant geological feature of the country, consisting of several high mountain chains (or *cordilleras*) separated by deep lateral valleys. In the south, the high plateau ("Altiplano"), where Lake Titicaca is found, is embedded between the residual Western and Eastern Cordilleras. Peru has 37 peaks higher than 6,000 masl and large parts of the Andes are higher than 3,000 masl. The country has the second largest share of the Amazon rainforest, after Brazil. The Amazon River and its tributaries, along with other rivers, form a vast hydrological drainage system in the rainforest zone.

Peru's available water resources are large but distributed very unevenly (Figure 3). The Pacific basin, home to 66 per cent of the Peruvian population, has the country's lowest water availability per inhabitant. The available water supply in some of the densely populated coastal cities is below the minimum requirement. For example, Lima, with a population of more than 9 million people, is the world's second largest desert city after Cairo and has repeatedly experienced water stress.

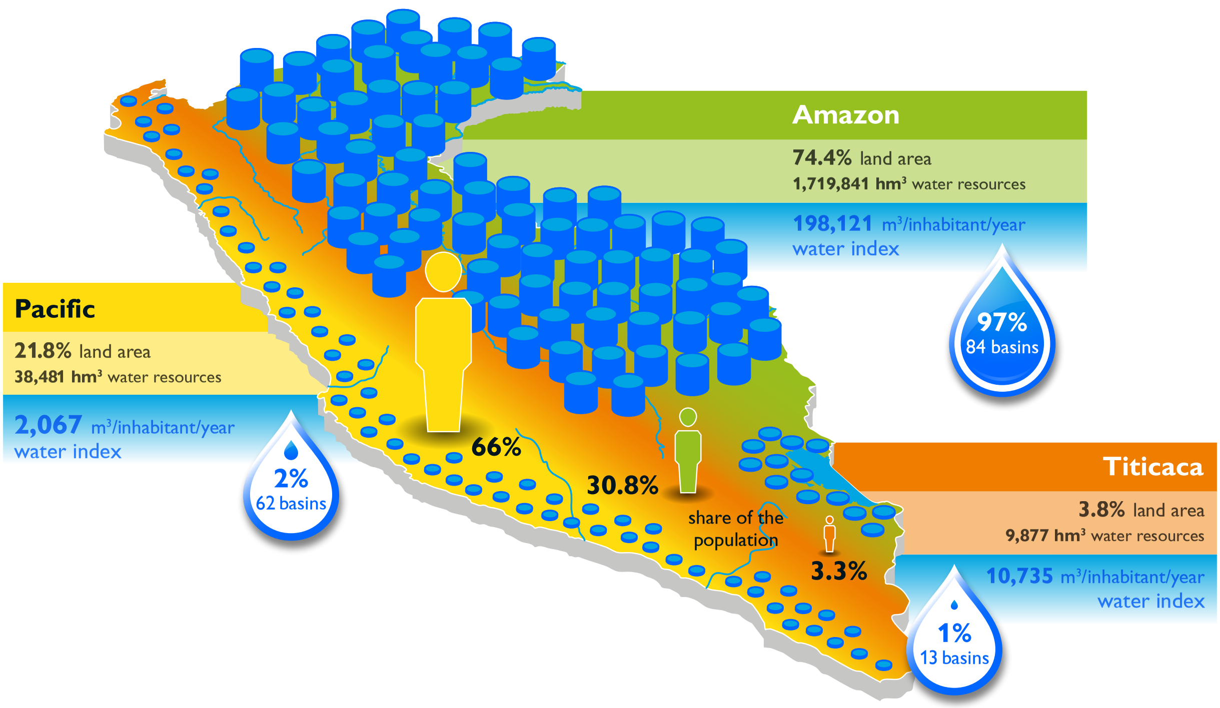
Figure 2. Peru's three main topographical zones (left), global and regional location (upper right), and topographical gradient (bottom right)



Sources: Left: Wikimedia Commons. *Regiones geográficas del Perú* (Geographical regions of Peru). Copyright-free material (Original user: Maulucioni, 2019) (translated into English). This artwork is licensed under the Creative Commons Attribution-Share Alike 4.0 International licence.
Top right: Wikimedia Commons. Peru location. Copyright-free material (Original user: Rei-artur, 2006). This artwork is licensed under the Creative Commons Attribution-Share Alike 4.0 International licence.
Bottom right: Conceptualized by Jonas Bergmann and produced by webreform GmbH.

Note: These maps are for illustration purposes only. The boundaries and names shown and the designations used on these maps do not imply official endorsement or acceptance by the authors, the International Organization for Migration or the Potsdam Institute for Climate Impact Research.

Figure 3. Uneven water availability per capita across Peru's three large drainage systems



Source: Conceptualized by Jonas Bergmann and produced by webreform GmbH based on data from the National Water Authority (ANA, 2018).

Note: In the three drainage systems (Pacific, Amazon and Titicaca), each barrel represents one basin. The combined volume of all barrels per drainage system is indicative of their total water volume.

Irrigation and hydroelectric power are the largest uses of water in Peru. In 2012, agriculture accounted for 89 per cent of national water consumption; domestic and industrial activities, 10 per cent; and mining and other activities, 1 per cent (National Water Authority (ANA), 2013). The agricultural sector creates the largest water demand across all three major drainage basins (i.e. the Pacific, Atlantic and Lake Titicaca basins). Around 96 per cent of non-consumptive water use accrued to hydroelectric energy generation.

Peru's soil offers agricultural and pastoral opportunities, yet also presents challenges (National Office for Natural Resource Evaluation (ONERN), 1982; National for Strategic Planning (CEPLAN), 2011; Food and Agriculture Organization (FAO), 1995). For example, 3.8 million hectares of the country's total land surface is desert, with 30 million hectares (24%) more in the process of desertification (National Institute of Natural Resources (INRENA), 1996 and 2006; Ministry of Environment (MINAM), 2016a; Peruvian Centre for Social Studies (CEPES), 2015). Peru has the third largest area of drylands in South America, with more than a third of the country being drylands (MINAM, 2016a). (Subchapter 3.4 discusses these opportunities and challenges in greater detail.)

Peru is the country with the ninth largest area of forests worldwide (CEPLAN, 2011). Forests provide essential ecosystem services for communities in the country and worldwide. In the Peruvian Amazonia, rainforest covers about two thirds of the land, even as deforestation has been a grave problem in the country (USAID, 2014; MINAM, 2016b). Causes of deforestation include migration for agricultural land and clearing of forests for agricultural production, as well as logging and illegal wood extraction. Increasing climate impacts also threaten the survival of the rainforest (discussed in more detail in Box 3 in Section 2.2.3).

The Andes contain important deposits of natural minerals and metals (Mächtle, 2016). These resources have turned industrial and small-scale mining into important sectors of Peru's economy (Triscritti, 2013). For example, Peru is among the world's top producers of gold, silver, copper and zinc (Bury, 2005). The country's southeast also features some natural gas resources, while the northern coast is home to some petroleum fields. The north-eastern part of the Peruvian Amazonia contains mineral oil deposits (Davies et al., 2018).

1.4.2. Economy and livelihoods

While the full economic effects of the COVID-19 pandemic on Peru cannot yet be estimated, large losses in 2020 may have long-term consequences for Peruvian businesses. During the lockdown, economic activity dropped more than 40 per cent in some months and as much as half of Lima's workers became unemployed.

Peru can be understood as a dual economy, split between export and subsistence production (Carranza, 2016). One part of the economy produces exportable goods, mostly in the mining industry and agroindustry. The other part carves out a living by producing food, household items, services and other outputs for personal use (consumer goods). This "dual economy" is marked by strong disparities. The much larger export sector clearly dominates the country's economy. Even in their stricter definitions, exported services and goods have accounted for 20–30 per cent of Peruvian GDP since 2004 (World Bank, 2019).

Agricultural employment has declined but the sector still employs more than a quarter of the population. The agroindustry covers activities such as crop and livestock farming, resource extraction and fisheries. Although the percentage of agricultural workers in the total national labour force has declined in the second half of the twentieth century, both subsistence and commercial agriculture (for either local markets or export) remain important. It is estimated that agriculture has employed just below 30 per cent of the country's workforce since 2007 (World Bank, 2019). Employment rates in agriculture are considerably higher in rural areas, which often translates into high susceptibility to climate impacts. The fishing industry, on the other hand, has grown strongly, despite occasional interruptions brought about by overfishing and disasters. Fishing is additionally important in the Amazon basin, where forestry and resource extraction play key roles. (Subchapter 3.3 discusses the agriculture sector and its climate change challenges in more detail.) In 2017, it was estimated that although 30 per cent of the population worked in agriculture, the sector accounted for only 8 per cent of Peru's GDP, whereas industry made up 38 per cent and services, 60 per cent (CIA, n.d.).

Industry is the smallest sector in terms of employment. Industry includes construction, mining, manufacturing and energy production. Since the 1990s, the sector's share of total national employment has been meandering between 14 and 17 per cent (World Bank, 2019). The industry tended to be protected or nationalized during the 1970s and reprivatized in the 1990s. Manufacturing is concentrated in Lima and other urban areas. Mining of mineral and fossil resources has grown substantially towards the end of the twentieth century but was strongly negatively impacted by the COVID-19 lockdowns ((United Nations Development Programme (UNDP), 2020b).

Services have become the most important sector in terms of employment in recent times. The sector includes communications, transportation, finance, government activities and private economic activities that produce non-material outputs. Services have accounted for the largest share of total employment ever since data for the sector existed, rising from close to 48 per cent in 1990 to 56 per cent in 2018.

A substantial share of Peruvians work in the informal economy outside of social protection, regulation and taxation (CEPLAN, 2016). In agriculture, the rate of informal employment was 97 per cent in 2014, while around three in four jobs in transportation, construction and commerce were informal. An estimated one fifth of Peru's GDP comes from the informal economy. Non-agricultural informal labour was especially hard-hit by the COVID-19 pandemic.

1.4.3. Political system, social conflicts and (in)security

The amended 1993 Constitution stipulates a presidential system that concentrates power in the executive branch of government. The country is still highly centralized, although the regions have regional governments and can create subnational policies (Thiery, 2016). Since 2003, Peru has had 26 administrative entities at the regional level: 24 regions and two provinces with special regimes (the Constitutional Province of Callao, with its own regional government, and the province of Lima, which is autonomous from the Lima Region). The next levels of government are local and consist of provinces, districts and municipalities. Given the subsidiarity principle, the subnational levels are key to dealing with both climate change and mobility issues. National-level legislative power rests on the Congress of the Republic, which has parliamentary oversight of the acts of the executive branch and determines the State budget.

Challenges in the political system persist (Thiery, 2016). Since its independence from Spain in 1821, Peru has witnessed several military coup d'états and other stark transitions that have taken a toll on institutional development. While democratic consolidation has started again in the twenty-first century, corruption and the lack of institutional capacity and resources are persistent barriers to more effective governance across all levels, posing possible challenges to climate change governance as well. While interference from military and guerrilla groups have decreased, organized criminal groups, including drug cartels, still pose challenges to State monopoly on the use of force in some areas of the country.

Social conflict is witnessed across the country (Brandt, 2016). In 2013, about 80 per cent of cases of social conflict were classified as "open conflict" and the remaining 20 per cent as "latent conflict". Almost three quarters of open conflicts were related to problems with the environment and natural resources, mostly mining in the Andes and fossil fuel extraction in Amazonia. Most of these conflicts evolved around the Andean regions, and the regions of Lima and Loreto in Amazonia. Contentious issues included environmental contamination, land use and resource rights. Half of all registered conflicts resulted in violence, with an estimated 200 deaths and more than 2,300 injured persons between 2006 and 2013 (Brandt, 2016).

Challenges of insecurity continue. Close to one third of Peruvian urban dwellers above 15 years old experienced being victims of crime between 2014 and 2015, and, as a result, perception of public insecurity rose (Pan-American Health Organization (PAHO), 2017). Homicides increased by 24 per cent between 2011 and 2014, to 6.7 cases per 100,000 inhabitants – a rate similar to Uruguay's but higher than, for example, Ecuador's and Argentina's (United Nations Office on Drugs and Crime (UNODC), 2019). Within the same period, violence against women declined only slightly and remained high, with 70.8 per cent of women reporting at least one occasion of psychological or verbal domestic violence in 2014 (67.4% in 2011); 38 per cent, of physical violence (32% in 2011); and 9.3 per cent, of sexual violence (from 7.9% in 2011) (PAHO, 2017).

1.4.4. Country context: A summary

In summary, Peru is a large and "megadiverse" country, with three broad topographical zones or regions – the costa, sierra and selva – featuring very different climates, natural environments and economies. The mainly-desert coastal zone concentrates most of Peru's economic activities but has the least water. The highlands are home to a shrinking rural subsistence farming system and provide essential natural minerals and metals. The Amazon lowlands constitute a vast basin and a wealth of ecosystem services and natural resources, including most of Peru's water. The economy is split between subsistence agriculture and the more industrialized, export-oriented sectors, in addition to growing urban livelihood systems. Agroindustry, including fisheries, in the coastal zone is also important for the country. Zones with high agricultural dependency are located especially in the rural highlands and rural Amazonia. These areas – and the ecosystem-dependent production activities that they host – are particularly susceptible to climate change impacts. Peru's natural environment suffers from soil erosion and deterioration, overexploitation of natural resources, and deforestation. The country's democratic institutions are in the process of consolidation, but still face substantial challenges of corruption and a lack of institutional capacity. These problems constitute a legacy for confronting the imminent challenges of climate change. Social conflicts and insecurity are persistent problems across society and affect many areas of origin and destination of migrants.

Upon this baseline Chapter 2 discusses general demographic and mobility trends in Peru. The report then assesses the existing scientific evidence on linkages between climate-related hazards and mobility in Peru's three main topographical zones (the costa, sierra and selva).

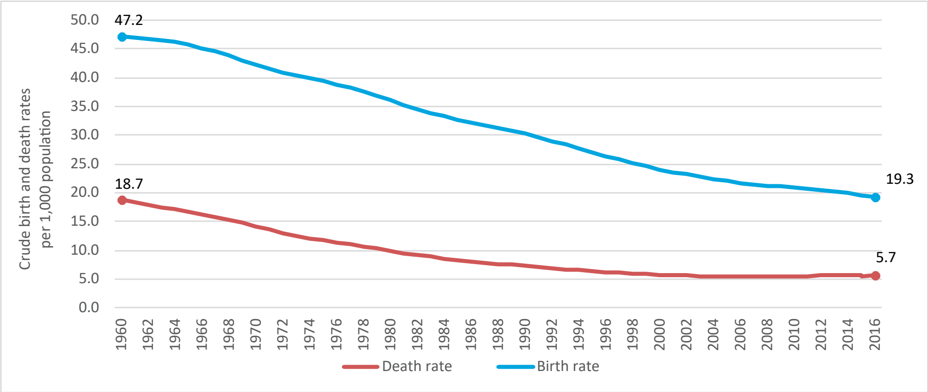
2. THE CLIMATE CHANGE, ENVIRONMENT AND HUMAN MOBILITY NEXUS

2.1. GENERAL DEMOGRAPHY

2.1.1. Population size and structure

Peru is experiencing a demographic transition. Figure 4 shows that mortality rates have declined steadily between 1960 and 2016. In the same period, birth rates have decreased strongly. Social change and economic development have been behind these declines. Former President Alberto Fujimori's forced sterilization campaigns in the 1990s have also contributed to declining birth rates (Ewig, 2006; Boesten, 2007; Serra, 2017). Peru is currently moving towards a low, stationary stage: the rate of natural increase has become low and may get closer to replacement level.

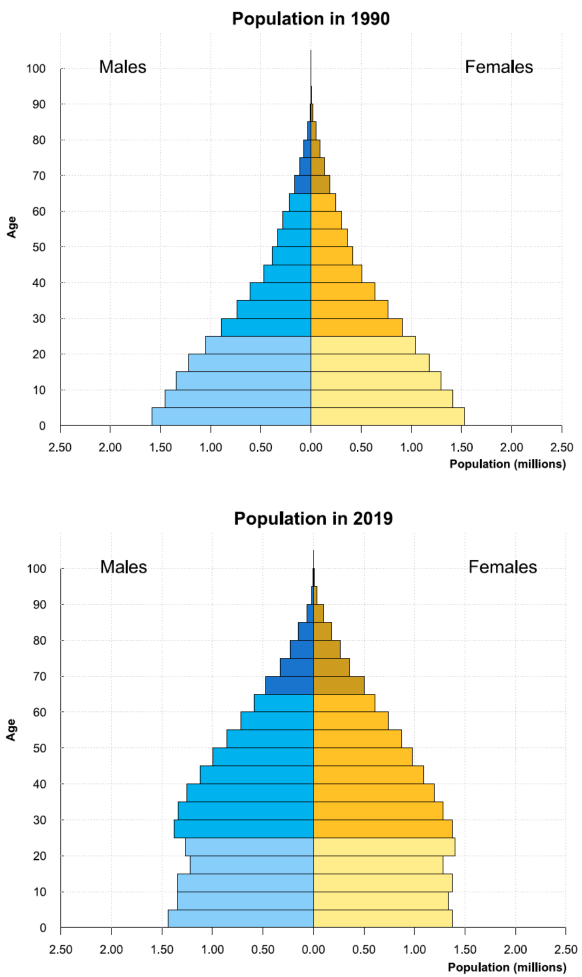
Figure 4. Peruvian crude birth and death rates, 1960–2016



Source: Produced by Jonas Bergmann based on data from the World Bank (2019).

The demographic transition in Peru over the past decades has been accompanied by shifts in the relative sizes of the different age groups. Figure 5 shows an expansive population pyramid in 1990, with the population mostly under 30 years of age. By 2019, decreasing birth rates have shifted the base of the pyramid: the younger age groups' share of the population has become relatively stationary.

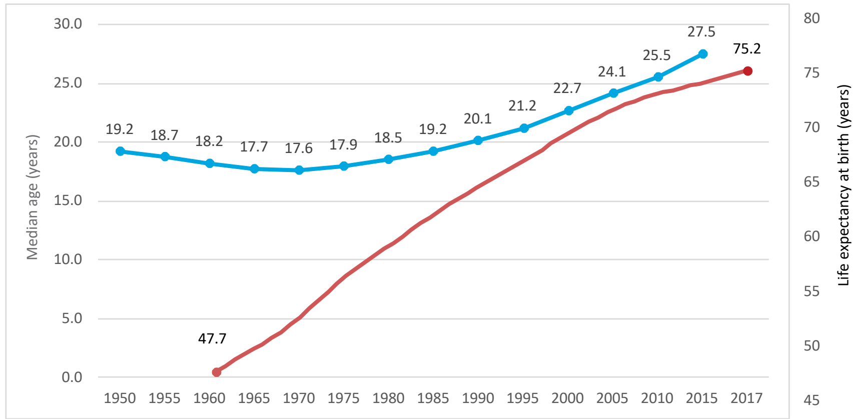
Figure 5. Peruvian population pyramid shift: 1990 and 2019



Source: Reproduced by Jonas Bergmann from United Nations Department of Social and Economic Affairs (UN DESA, 2019, pp. 1 and 2).

The overall population is still rather young, but the demographic transition has resulted in a smaller share of younger and a larger share of older people, with generally higher life expectancy. Figure 6 shows how the median age of the population reached a minimum of 17.7 years in 1970, and then increased steadily to 27.5 years in 2015. Over the same period, life expectancy has increased drastically from 53 years to 75 years.

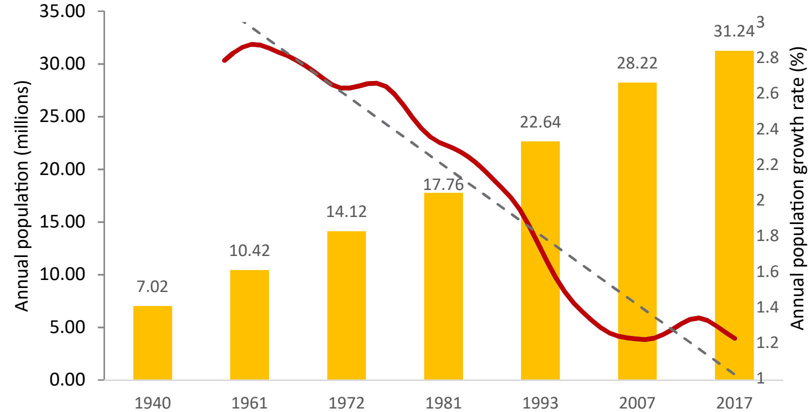
Figure 6. Peruvian median age, 1950–2015, and life expectancy at birth, 1960–2017



Source: Produced by Jonas Bergmann based on data from UN DESA (2017b) and the World Bank (2019).

Due to the demographic transition, Peru's annual population growth has gradually slowed. Figure 7 shows total population increase from 7 million in 1940 to about 31.2 million people during the latest census round in 2017. Annual population growth rates, however, declined from close to 3 per cent in the early 1960s to about 1.2 per cent in 2016 (these figures factor in population change through international migration). Subnational population growth rates in Peru have been differed strongly between regions. Most regions have been growing at decreasing rates until the last decade, when some regions also experienced negative growth for the first time.

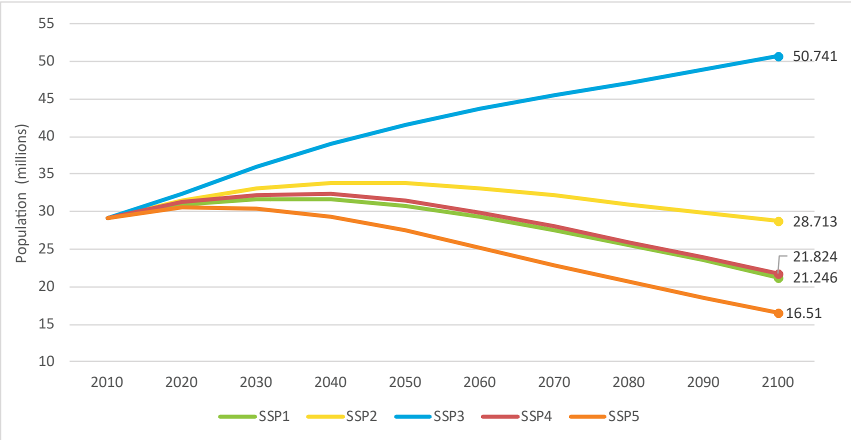
Figure 7. Peruvian total population, 1940–2017, and annual population growth rate, 1960–2017



Source: Produced by Jonas Bergmann based on data from the 1961–2017 censuses (National Institute of Statistics and Informatics (INEI), n.d.) and data from the World Bank (2019).

In the future, Peru will continue to grow, but at slower rates. The United Nations projects the population to peak at more than 41 million in 2050 in its medium-growth variant (UN DESA, 2017b); the National Institute of Statistics and Informatics (INEI) projects about 40 million people by then (INEI, 2009). Figure 8 shows population projections for 2050 ranging from 27.6 to 41.6 million depending on the shared socioeconomic pathway (SSP) taken (O'Neill et al., 2017; Riahi et al., 2017). Beyond 2050, different SSPs may result in even wider divergences in population size.

Figure 8. Peruvian population projections for five shared socioeconomic pathways



Source: Produced by Jonas Bergmann based on data from Riahi et al. (2017).

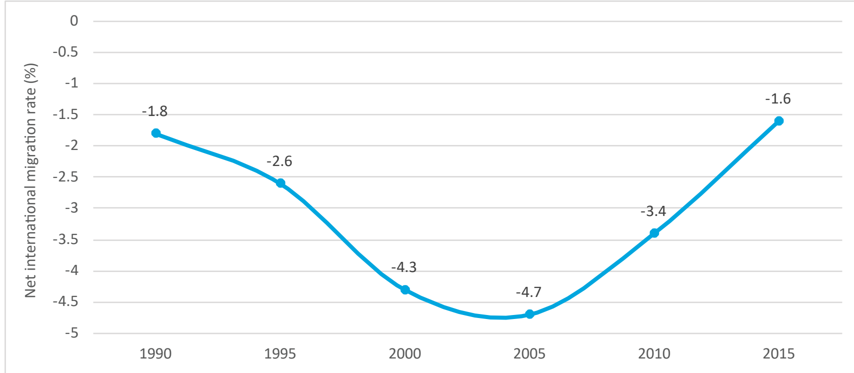
Section 2.1.2 describes the overall migration picture in Peru, which matters because climate-related mobility trends are and will continue to be embedded in larger migration systems. It first analyses cross-border movements, then proceeds to the topic of internal migration, before finally discussing the special case of internal displacement. As data on planned relocation is scarce, these movements are only discussed in the context of climate change in Subchapter 2.2.[4]

4 The migration data used in the next section is explained below.
Flow data illustrates how many migrants enter and leave a given area over a specific period, such as one year or five years. *Stock data*, conversely, refers to the number of all migrants residing in a given area at a particular point in time (definitions adapted from UN DESA (2017a, p. 9)). The central data instruments in Peru – the national census and the National Household Survey on Living Conditions and Poverty (ENAHO) – share a common definition of "migrants" and "migration": Migrants are "persons who transfer their habitual residence (origin) to another geographical area (destination), with the intention of permanence" (INEI, 2018, p. 85, translation by the author). Two types of migration are measured: *lifetime migrants* are persons registered in a place different from the place of their birth; recent migrants are persons who, at the time of the enumeration, lived in a place other than their place of residence five years prior. Consequently, some types of movements – including seasonal, circular, temporary, multiple and short-distance – may not be adequately represented in these statistics.

2.1.2. International migration

Historically, more people have emigrated out of Peru than entered it. Net cross-border (international) migration rates[5] have been continuously negative between 1990 and 2015, with a "peak" of -1.6 per cent in 2015 and a low of -4.7 per cent in 2005 (Figure 9).

Figure 9. Net Peruvian cross-border (international) migration rates, 1990–2015



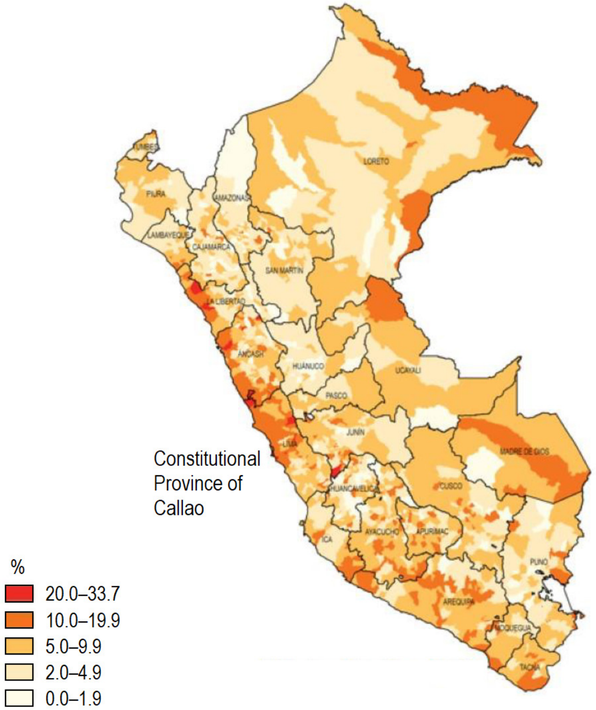
Source: Produced by Jonas Bergmann based on data from UN DESA (2016).

The stock of foreign immigrants living in Peru has been low in the past decades. Foreign-born populations accounted for about 0.3 per cent of the total population between 1990 and 2017 (UN DESA, 2018a). Historically, Peru has been home to few refugees, but since recently has been hosting more than 560,000 Venezuelans who either hold temporary stay permits or are registered asylum seekers (Office of the United Nations High Commissioner for Refugees (UNHCR), 2018).

At the same time, many more Peruvians have left the country. The stock of Peruvian emigrants who have left since 1990 amounts to at least 3 million (INEI et al., 2018). Emigrants moved mainly to the United States of America, Spain, Argentina, Italy and Chile. In 2017, roughly 5 per cent of Peruvian households had at least one member residing abroad. Of these households, 90 per cent were urban and only 10 per cent were rural. In certain rural provinces, more than 20 per cent of households have a family member abroad (Figure 10) (INEI, 2018).

5 Net migration rate is calculated as immigrants minus emigrants over the past five years, per 1,000 people.

Figure 10. Percentage of Peruvian households with a member abroad, by province

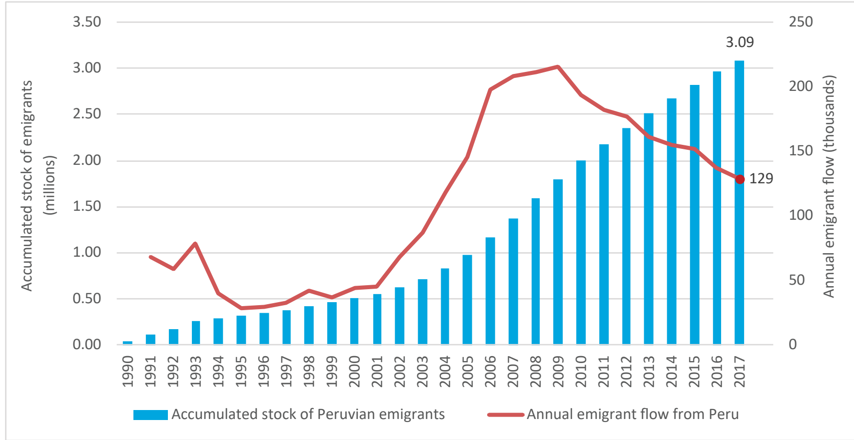


Source: INEI, 2016a, slide 24 (translated into English). Reproduced with permission of INEI – Oficina Técnica de la Difusion.

Note: This map is for illustration purposes only. The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the authors, the International Organization for Migration or the Potsdam Institute for Climate Impact Research.

Flows have changed strongly over time (INEI, 2017; INEI et al., 2018). Figure 11 depicts how Peru's emigrant stock has accumulated over time. Emigration from Peru was very low until the first half of the 1970s, growing only afterwards and into the 1980s due to the agrarian crisis, an increasingly worsening economic situation, social unrest and conflict. Emigrant flows declined in the 1990s, seemingly due to a stabilizing economy. Until the early 2000s, flows fluctuated but stayed below the 100,000 level. They then increased strongly until peaking in 2009, only to recede to mid-2000s levels in 2017 due to stricter immigration policies and the global financial crisis, which resulted in shrinking labour markets in destination countries.

Figure 11. Accumulated Peruvian emigrant stock and annual emigrant flow, 1990–2017



Source: Produced by Jonas Bergmann based on border-crossing statistics from INEI et al. (2018).

Peruvian emigration is socially stratified. Most emigrants are relatively young: 71 per cent are aged 15–49, 47 per cent aged 20–39 and 25 per cent aged 20–34 (INEI et al., 2018). Slightly more women than men emigrate. As regards occupation, 22 per cent of emigrants declared themselves to be students, 13 per cent to be office workers and 12 per cent to be service workers. Only 1 per cent named agriculture as their main livelihood activity. Thus, international migration among Peruvians working in agriculture has been very low, an indication of its potentially limited relevance in a future impacted by climate change.

Surveys suggest a high future emigration potential of Peruvians. In a study by Latinobarómetro (2018), 23 per cent of surveyed Peruvians considered the "concrete possibility" of emigrating, putting Peru in the midrange among surveyed Latin American countries. In another survey, conducted by Gallup (2017) between 2013 and 2016, 30 per cent of Peruvian respondents reported having a "desire" to emigrate permanently to another country if they had the opportunity (Esipova et al., 2017). This figure is about the same as that for sub-Saharan Africa as a whole (31%) and 7 percentage points higher than that for Latin America and the Caribbean. However, desires, plans and preparations are different from actual migration. Statistics on Peru are not publicly available, yet worldwide, between 2012 and 2015, only 9 per cent of respondents generally desiring to migrate were planning and 3 per cent were preparing to migrate (IOM, 2017b).

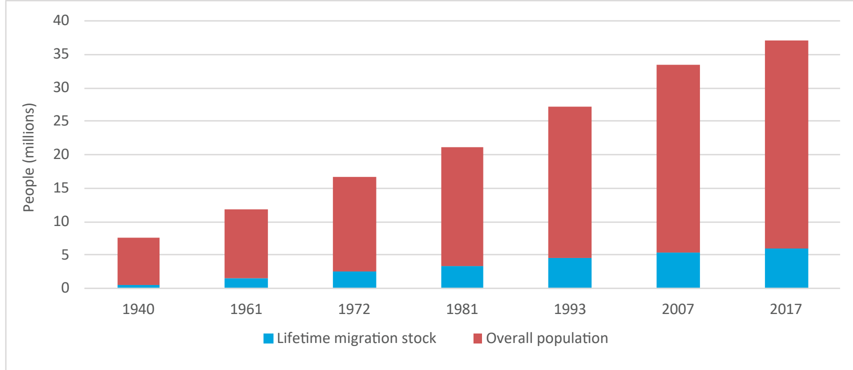
Emigrants often maintain social and economic networks in their home country of Peru. This is evidenced by the 42 per cent of Peruvian emigrants who sent financial remittances back home in 2015. Only 5 per cent of the recipients of these international remittances resided in rural areas and more than 80 per cent of all recipients were located in the coastal zone. Almost three quarters of received remittances went to household expenses, 14 per cent to education, 7 per cent to housing and 4 per cent to other expenses, while 4 per cent was set aside as savings (INEI, 2016a and 2017). Remittances to Peru have made a relatively modest and fluctuating contribution to the overall economy: they represented 1.4 per cent of Peru's GDP in 2017 (an increase from 0.3% in 1990) but still lower than the maximum of 2.1 per cent achieved in 2007 (World Bank, 2019). At any rate, remittances could hold potential for future use in the context of climate adaptation and development, especially among urban receivers.

The volume of Peruvian return migrants is also large. Between 2000 and 2017, the stock of Peruvian emigrants grew by 2.6 million; in the same period, a total of 0.3 million emigrants returned to the country (INEI et al., 2018). The annual flow of returns has been increasing, with the largest annual returns occurring in more recent years. The impact of these returns on potential adaptive capacities is difficult to measure, but acquired skills, networks and resources may contribute positively.

2.1.3. Internal migration

Much more people migrate within Peru than across its borders. Internal migration is the change in permanent residence across administrative divisions within Peru. It is most often analysed at the coarsest administrative level of the regions and seldom at the finer levels of the provinces and districts (INEI, 2018). The level of analysis matters: for example, in 2012, about 20 per cent of the population of Peru, or 6 million people, were residing in a different region of Peru than their region of birth; a much higher percentage of 35 per cent of the population, or 10 million people, were living in a different district than their district of birth (Sánchez Aguilar, 2015b). The numbers slightly increased at the latest census, in 2017 (INEI, 2018). Over time, the stock of internal migrants between regions has considerably grown, as Figure 12 shows.

Figure 12. Stocks of Peruvian lifetime internal migrants moving between regions and total population, 1940–2017



Source: Produced by Jonas Bergmann based on census data (INEI, n.d.).

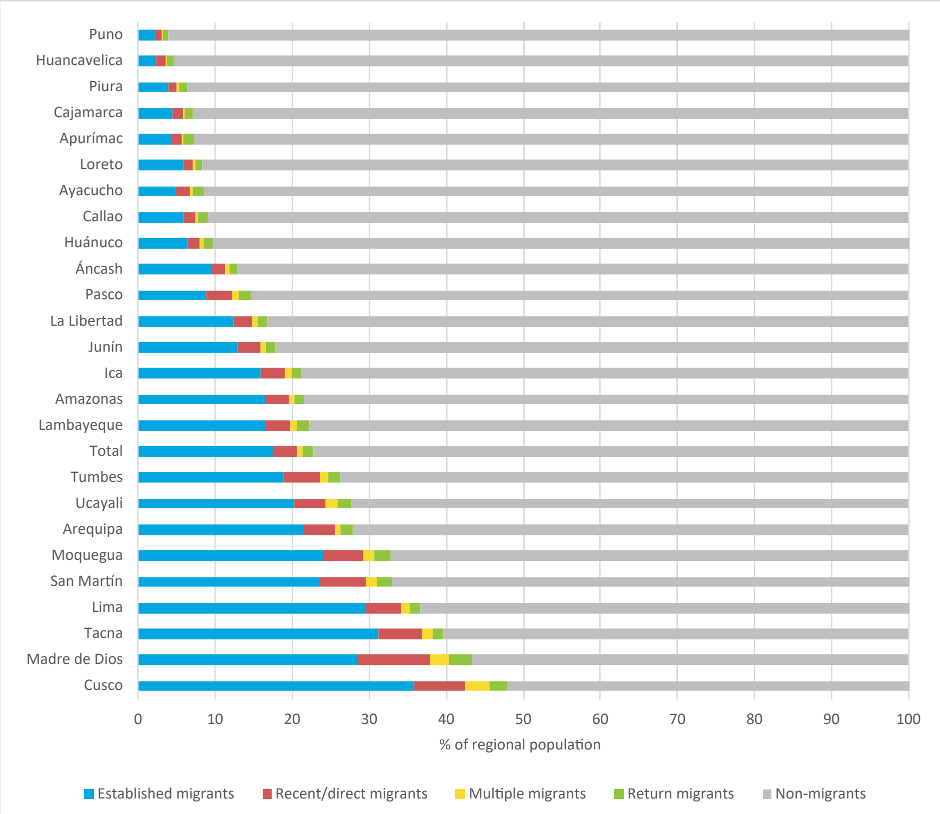
From the 1970s onwards, agrarian and economic crises, as well as internal conflicts, constituted major push factors for emigration from the highlands. Due to a stabilizing economy, more decentralized growth and, possibly, growing international emigration, the once relatively intense internal migration has plateaued (Sánchez Aguilar, 2015a). While overall population soared, internal migrants' share of the total population has remained stable since the 1980s. General tendencies in movement over the past several decades have been from rural areas to cities and from poorer to more prosperous regions (Sánchez Aguilar, 2012, 2015a and 2015b). On the one hand, people have moved towards the coastal strip, which has a large concentration of Peru's cities, industries, agrobusinesses and, thus, employment opportunities. On the other hand, the Amazon basin has attracted internal migrants with its wealth of natural resources, land and emerging jobs in the hydrocarbon and mineral extraction sectors, as well as tourism. These movements constitute the baseline upon which climate impacts will likely influence future migration.

Internal migration in Peru occurs along different temporal trajectories and is strongly regionalized. During the 2002–2007 period, most Peruvian internal migrants – about 18 per cent of Peru's population – had been established for more than 5 years (Sánchez Aguilar, 2015b). Recent internal migrants (who migrated during the previous 5 years)[6] represented 3.2 per cent, and multiple migrants (whose place of habitual residence, place of residence five years before and place of birth differed) represented 0.8 per cent of the total population of

6 Unless otherwise specified, a recent internal migrant is considered to be one who moved within five years prior to the relevant census or study (as in the case with Sánchez Aguilar (2015b)).

Peru. Besides this temporal distinction, shares of internal migrants in the population varied strongly by region, as Figure 13 shows that nine regions had more than 90 per cent of their populations consisting of non-migrants, while six regions had more than 30 per cent of their populations made up of migrants. Shares of migrants ranged from a low of 4 per cent in Puno to a high of 48 per cent in Cusco. While, historically, more people have left than moved to Cusco Region, close to half of its remaining population are migrants from other regions, many coming to the regional capital due to its large tourism industry (Sánchez Aguilar, 2015b). Figure 13 also shows that return migration plays some role in all regions.

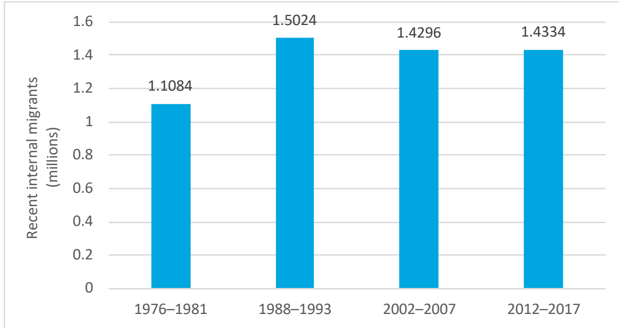
Figure 13. Peruvian internal migrants' share of the regional population, by region and migrant type, 2002–2007 period



Source: Produced by Jonas Bergmann based on census data (INEI, 2007) analysed by Sánchez Aguilar (2015b).

Total internal migration flows have been stationary relative to Peru's population size. Figure 14 shows the flows of recent internal migrants who moved within the five years prior to the respective censuses. Flows reached a peak in the 1980s, when the national population was still much smaller. Since then, the number of Peruvians who changed their place of residence to another region in Peru over a five-year-period prior to the relevant census decreased slightly to 1.43 million at the 2017 census. Between 2012 and 2017, about 5.3 per cent of the Peruvian population older than five years moved to a different region; this is about the same as the 5.4 per cent that moved between 2002 and 2007 (INEI, 2018). To reiterate: the level of analysis matters. For inter-district migration, the numbers are higher: 12 per cent of the population moved districts between 2002–2007 and 16 per cent between 1988–1993 (Sánchez Aguilar, 2015b).

Figure 14. Stocks of Peruvian recent internal migrants moving between regions, taken at four censuses

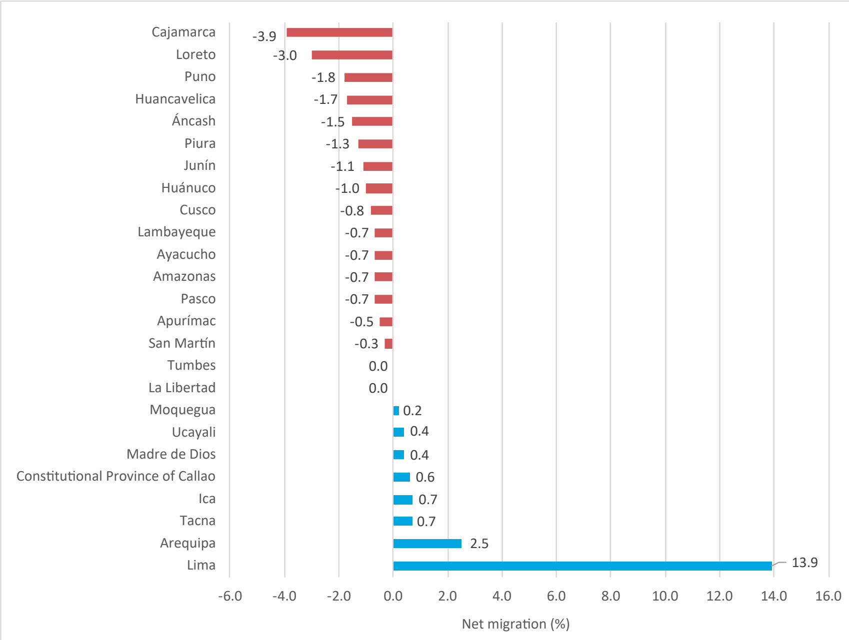


Source: Produced by Jonas Bergmann based on 1981, 1993, 2007 and 2017 census data (INEI, n.d.).

Note: A recent internal migrant is one who moved within the five years prior to the relevant census.

Flows between regions have been diverging: some regions have gained, while several others have lost large shares of their population through migration. Net migration rates consider recent immigration and emigration flows simultaneously across regions. Between 2012 and 2017, 15 regions had negative net and 8 had positive net rates of recent flows (negative net migration is when more people move out of a region, while positive migration is when more people move into a region) (Figure 15). Lima, for example, welcomed 511,000 immigrants from and lost 311,000 emigrants to other regions. Cajamarca, by contrast, saw about 37,000 people moving into the region, while 92,000 moved out.

Figure 15. Net recent migration rates for Peru's population aged five years and older, by region, 2012–2017 period



Source: Reproduced by Ole Weber based on data from INEI (2018).

Note: Recent migration pertains to movement during the 2012–2017 period. Red indicates negative net migration (more people moving out of the region to another); blue indicates positive net migration (more people moving into the region).

Internal migration has been a key but declining driver of urbanization in Peru. Latin America's fast urbanization between 1930 and 1970 was mainly due to rural–urban migration; these flows later fell in most countries and have been increasingly replaced by urban–urban migration (Cerrutti and Bertoncello, 2003). Migration across administrative subdivisions within the same megacity or metropolis, often from the centre towards the periphery, has also been rising. Natural increase, through changing mortality and fertility rates, has become a key factor in urban population growth. In Latin America, it has been estimated that the contribution of rural–urban transfer to urban growth fell from 46 per cent in the 1950s to 38 per cent before 2000 (Villa et al., 2017). For Peru, the authors estimate that rural–urban migration accounted for 57 per cent of urban population growth between 1950 and 1960 – a value that steadily fell to only 15 per cent before 2000. While considerably smaller, a 15 per cent contribution to urban population growth through migration still translates into substantial flows of migrants into the cities.

Peru has had exponential urbanization rates that are now flattening. The country's urban population share grew from 41 per cent in 1950 to 80 per cent in 2016 (World Bank, 2019; UN DESA, 2015). Between the last two censuses (in 2007 and 2017) the urban population grew by 1.6 per cent, while the rural population declined by 2.1 per cent (INEI, 2018). Urbanization is expected to continue but is expected to flatten in the future. A change of -15 per cent in the rural population between 2015 and 2050 is anticipated, resulting in an urbanization rate of 86 per cent by 2050 (UN DESA, 2015), although the actual rate depends on the socioeconomic pathway (Riahi et al., 2017).

Migration corridors in Peru show strong directionalities and centre on Lima, given the perceived abundance of educational and work opportunities in the capital. Nowadays, Lima is home to about one third of the country's total population – or almost 8.6 million, more than double the population in 1981 (INEI, 2018). Lima has continuously attracted by far the largest net number of migrants across all regions of Peru: by 2017, Lima had attracted a net number of close to 2.8 million lifetime migrants. It is the top destination for migrants from almost all other regions; for the few regions with a different top destination, Lima is the second most important destination (Sánchez Aguilar, 2015b).

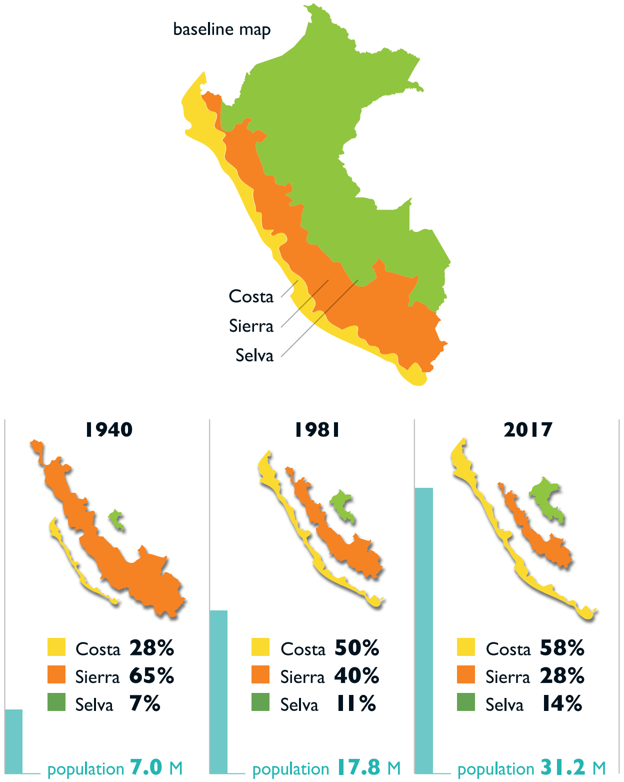
Beyond Lima, migrants have also moved towards other major cities. These cities include those in areas with export-oriented jobs, such as mining and cash crops. An analysis of the population distribution across all settlements with more than 2,000 inhabitants illustrates the growth of secondary cities as well, due to both migration and natural growth. The share of the total national population who lived in cities with a 0.5–1 million population grew from 0 per cent in 1981 to 11 per cent in 2007 (INEI, 2011), while upper- and lower-middle, small, and very small cities lost relative shares.[7] This is consistent with the overall trend in Latin America of medium-sized cities growing most dynamically (Cerrutti and Bertoncello, 2003). Consequently, urban–urban, intraurban (e.g. to peripheral suburbs) and intra-metropolitan migration are becoming increasingly relevant (Sánchez Aguilar, 2015a): between 2002 and 2007, about 60 per cent of internal migration flows to cities came from other cities (INEI, 2011).

Population distribution has also changed markedly across Peru's three topographical zones. Figure 16 shows that between 1940 and 2017, the population shifted away from the highlands towards the coast (INEI, 2018). These two regions almost switched shares of Peru's total population: in 1940, 28 per cent of the population resided in the coastal zone and 65 per cent in the

7 In 2007, the population living in cities with more than 2,000 people was distributed across cities of different sizes, as follows: 44 per cent in the Lima metropolitan area; 11 per cent in cities with a 0.5–1 million population; 20 per cent in cities with 0.1–0.5 million; 5 per cent in cities with 0.05–0.1 million; 7 per cent in cities with 0.02–0.05 million; and 13 per cent in cities with 0.002–0.02 million (INEI, 2011).

highlands; in 2017, 28 per cent lived in the highlands and 58 per cent in the coastal zone. During the same period, Amazonia doubled its share of the population from about 7 per cent to 14 per cent. Note that these changes in numbers were due not only to migration, but also to deaths and births (natural increase).

Figure 16. Percentage population distribution by topographical zone over time



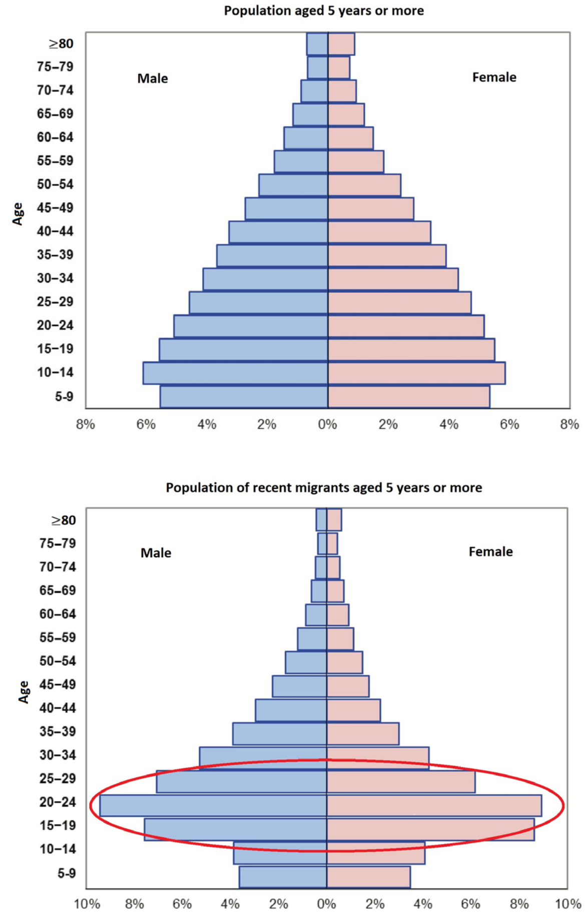
Source: Conceptualized by Jonas Bergmann and produced by webreform GmbH based on data from INEI (2018).

Notes: This map is for illustration purposes only. The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the authors, the International Organization for Migration or the Potsdam Institute for Climate Impact Research.

These population distributions consider the effects of natural increase (births and deaths) and migration. The baseline map shows the correct proportions of Peru, with approximate locations of its three topographical zones (the costa, sierra and selva). The sizes of these regions are scaled for each year shown according to percentage-wise population distribution.

Internal migrants are relatively younger than the overall population (Sánchez Aguilar, 2015b). Figure 17 shows the difference between the overall population pyramid and the recent migrant population pyramid, with the latter having a considerable bulge in the younger groups (i.e. the so-called "youth bulge").

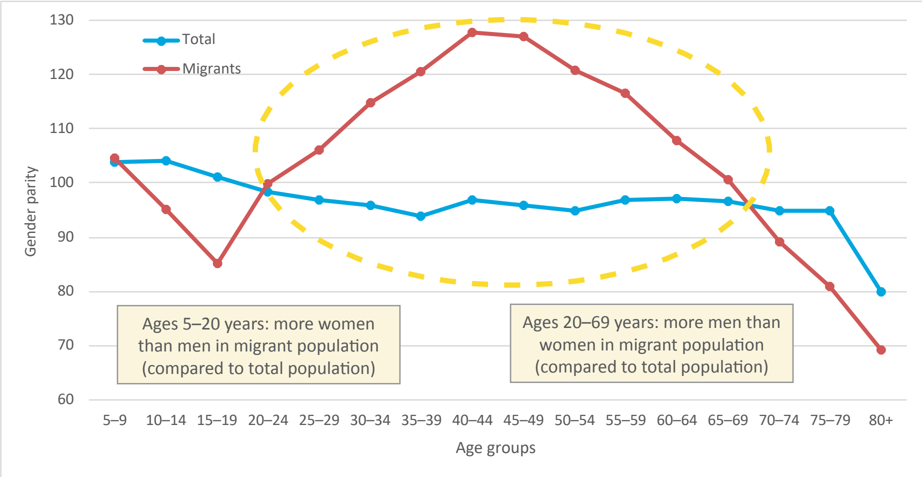
Figure 17. Age pyramids for Peru's total and recent internal migrant populations, 2007



Source: Sánchez Aguilar, 2015b, p. 79.

Between 2002 and 2007, males outnumber female migrants aged 20 to 69, with the reverse being true for the youngest and oldest age groups (Figure 18). These trends run contrary to those observed in the general population pyramid. Some regions of Peru had 1.4 times more male than female migrants, and only in a few did female outnumber male migrants (Sánchez Aguilar, 2015b).

Figure 18. Gender parity in Peru's total and migrant populations, by age group, 2002–2007



Source: This figure was adapted by Jonas Bergmann (text and elliptical figure overlay) from Sánchez Aguilar (2015b, p. 81).

Note: A gender parity of 100 denotes parity between genders. Values above 100 mean more men than women and values below 100 more women then men.

Recent internal migrants tend to be better educated than the overall population. In 2007, 43 per cent of the non-migrant population had only primary education or less, compared to 29 per cent of recent internal migrants. (Sánchez Aguilar, 2015b). On the other hand, only 12 per cent of non-migrants and 17 per cent of recent internal migrants had some higher education (Sánchez Aguilar, 2015b). Especially in poorer regions, the better-educated tended to leave. Only in a few exceptions (Lima, Arequipa and Tacna), did recent internal migrants have lower education than non-migrants.

Most recent internal migrants work in the secondary and tertiary sector and earn relatively well. A very high 98 per cent (virtually all) are working: two thirds in small commerce and service providers, compared with only 12 per cent in agriculture (Sánchez Aguilar, 2015b). Every year from 2001 and 2012, working migrants earned a higher average monthly income than non-migrants across all sectors. However, the data does not account for potentially higher costs of living in destination areas and how sending remittances may decrease personal disposable income.

Sending money home is one connection that internal migrants have with their areas or origin. Between 2009 and 2013, the absolute value of internal remittances increased alongside internal migration flows (Sánchez Aguilar, 2015b). Internal remittances have accounted for a relatively stable, albeit slightly decreasing, share of total income – from 1.4 per cent in 2009 to 1.2 per cent in 2013. Almost one third of recipients of internal remittances were women. Close to one third of recipients were 65 years and older, and 47 per cent were economically inactive. Given that the volume of internal remittances is substantial, and that recipients were often rural dwellers in vulnerable situations (Sánchez Aguilar, 2015b), internal remittances might be particularly important for climate adaptation and development. However, note that data may be fragmented, given the potential informality of transfers.

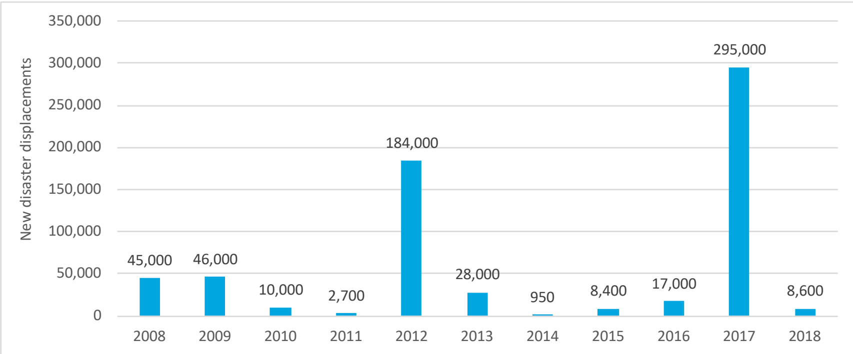
2.1.4. Internal displacement

The line between migration and displacement is often blurred, especially in the context of slow-onset hazards. In the context of sudden-onset hazards, this line is less blurred, and movement tends to be predominantly classified as "displacement". At any rate, there are also secondary, more "voluntary" movements, such as when reconstruction workers move into damaged towns.

Conflict displacement, a salient feature of Peru's past, has been overtaken by disaster displacement. Internal conflicts have displaced many people in the decades surrounding the turn of the millennium. In 2017, the stock of persons internally displaced by conflict was still about 59,000, which was already a drastic fall from 150,000 in 2014 and from even larger numbers in the 1990s and early 2000s (Internal Displacement Monitoring Centre (IDMC), 2018 and 2019b). By contrast, between 2008 (when data was first published) and 2018, the IDMC recorded approximately 645,000 instances of disaster displacement in Peru. Disaster displacement has strongly fluctuated between these two years, as Figure 19 shows: the mean annual figure for this period was about 58,700, while the median was 17,000. The single heaviest push factor for disaster displacement in the past decade was the El Niño Costero that hit Peru at the beginning of 2017 (IDMC, 2019b), bringing torrential rainfall, floods and mudslides (Section 2.2.1 discusses these in more detail). Data on stocks of displaced persons and on protracted disaster displacement is rare.

Recorded disaster displacement is primarily due to weather phenomena, mostly of hydrological origin. Floods have been the main driver of disaster displacement in these statistics, followed by wet mass movements, extreme temperatures, earthquakes and storms. According to models by the IDMC, the annual risk of future internal displacement from flooding in Peru concerns, on average, around 21,000 people (IDMC, 2019b). Without implementing further adaptation measures, global riverine flood displacement risk can double by the end of the century, even with the most optimistic combination of scenarios, whereas the current emissions trajectory, coupled with projected population growth, can result in a five-fold increase (Ginnetti et al., 2019).

Figure 19. Disaster displacement in Peru, 2008–2018



Source: Produced by Jonas Bergmann based on data from IDMC (2019b).

Data from the National Institute of Civil Defence (INDECI) complements these statistics. Between 2003 and 2017, the environmental hazards relevant to this discussion[8] have caused much damage in Peru. Table 1 details a total of 241 people who disappeared during this period, about 1,000 who died and 2,200 who suffered injuries (INDECI, 2018). Over 1.3 million people were *damaged* (defined as "strongly harmed and without the capacity to recover"), while over 14.7 million people were *affected* (defined as "suffering minor impacts"). The definition does not explicitly refer to displacement, but the number of destroyed houses – about 125,000 – give an indication. The disasters relevant to this report (as detailed in footnote 9) also affected about 1.4 million homes and 15,000 educational facilities.

8 These exclude emergencies linked to volcanoes, earthquakes, contamination and others, but include low temperatures, landslides, erosion, *huaicos* (flash floods), floods, heavy rains, drought, thunderstorms and strong winds.

Table 1. Impacts of disasters in Peru, 2003–2017 (total)

Impacts on persons				
Casualties	Disappeared	Injured	Damaged	Affected
989	241	2 220	1 316 612	14 704 799

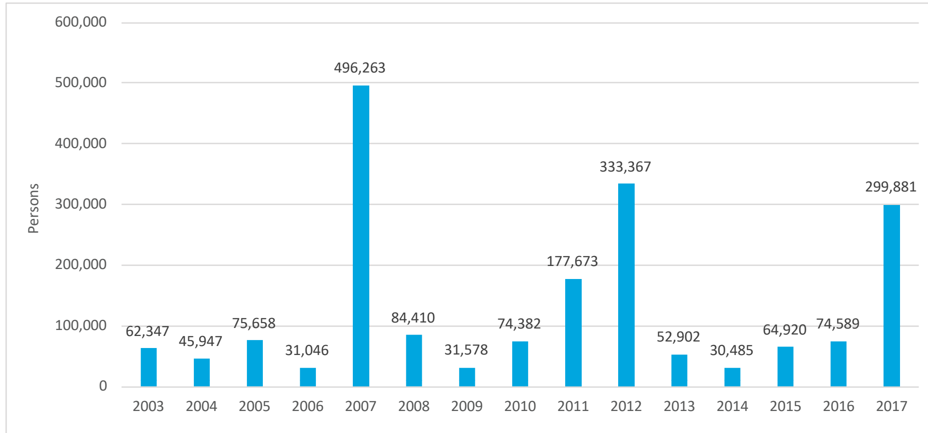
Impacts on assets							
Houses damaged	Houses affected	Educational facilities destroyed	Educational facilities affected	Health facilities destroyed	Health facilities affected	Hectares of crops lost	Hectares of crops affected
125 303	1 353 427	762	15 060	121	2 865	1 078 211	1 700 215

Source: INDECI Database of Emergencies and Damage (INDECI, n.d.).

Note: The INDECI definitions of "damaged" and "affected" apply.

The number of persons damaged by disasters fluctuated strongly by year (Figure 20). Disasters damaged at least 30,000 people each year, with a median annual figure of 74,000. However, during a particularly disastrous year like 2007, up to 500,000 people suffered some form of damage.

Figure 20. Persons who suffered from disaster-induced damage in Peru, 2003–2017

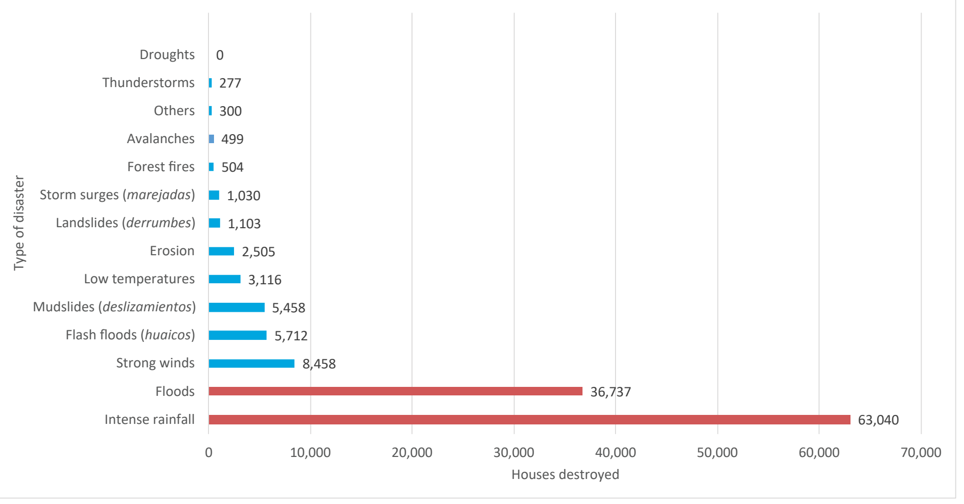


Source: Produced by Ole Weber based on data from INDECI (2018, p. 204).

Note: These statistics include all types of disasters, contrary to Table 1 and Figure 21, which include only disasters relevant to this report, as enumerated in footnote 9. (The INDECI definition of "damaged" applies.)

Figure 21 shows that among hazards possibly linked to climate change, those that have destroyed most homes were intense rainfall (approx. 63,000) and floods (approx. 37,000). Those that have resulted in most people who suffered disaster-induced damage (not shown in Figure 21) were floods (approx. 535,000), intense rainfall (approx. 442,000), low temperatures (approx. 106,000) and strong winds (approx. 63,000).[9]

Figure 21. Peruvian houses destroyed by type of hazard, 2003–2017



Source: Reproduced by Ole Weber based on data from INDECI (2018, p. 211).

Note: Flooding and intense rainfall, the two major sources of destruction, are highlighted in orange.

2.1.5. Demography: A summary

In summary, the Peruvian population has undergone substantial demographic changes that have a strong potential to influence migration patterns. Peru is moving towards demographic maturity: a low transitionary state with a still-young population, but a higher share of older people than before, against a backdrop of overall higher life expectancy. This change may have resulted in high mobility potential, since younger people tend to be more mobile (Plane, 1993; Rogers and Castro, 1981; Millington, 2000). Given the demographic trends, the potential cohort effect of the "youth bulge" in the internal migrant population is set to decline in the future. Overall, population size has been growing, but at a flattening rate. Disaggregated regional analysis shows that the population is still growing substantially in some regions and shrinking greatly in others. At this level of analysis, it is difficult to estimate the potential effects of these growth and depopulation patterns on livelihood options and the (over)use of ecosystem services. Finally, uncertain future socioeconomic developments translate into a range of uncertainties in projections of future population size. It is important to bear these socioeconomic uncertainties in mind, as they also influence mobility potential, in addition to exposure and vulnerability to climate change.

9 Conversely, low temperatures affected by far the most people, followed by intense rainfall, inundation and droughts. (The INDECI definitions of "damaged" and "affected" apply.)

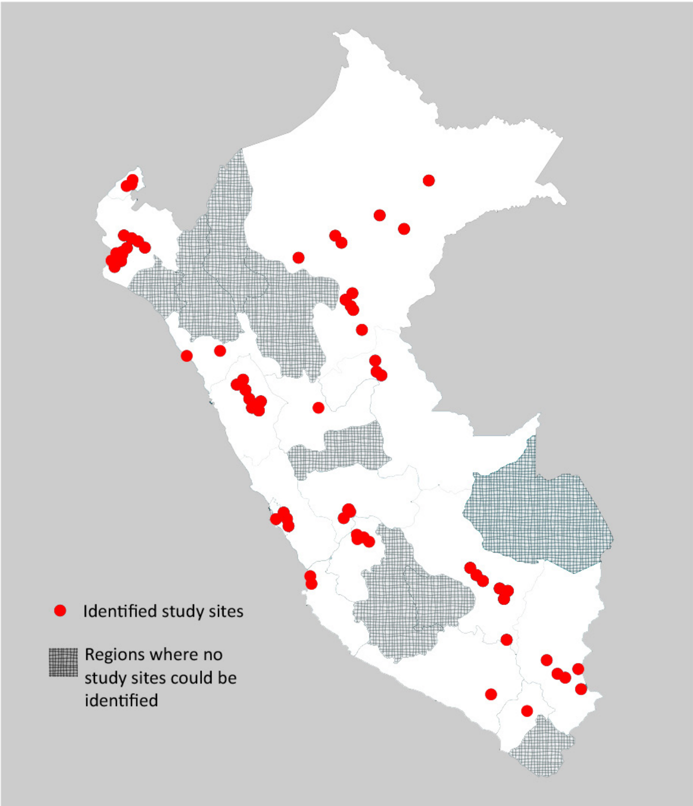
Existing migration systems in Peru have become deeply entrenched over time and provide the context for climate-related flows. International emigration has been relatively modest thus far and has mainly involved professions outside of agriculture, although surveys indicate large future desires to emigrate. The volume of remittances from international migrants is comparable to neighbouring and economic peer States, and most go to urban dwellers. Internal migration is much larger than cross-border migration and has involved relatively stable shares of the population over time. Strong disparities exist between receiving and sending areas – with Lima being the central "jigsaw piece" of destinations alongside other economic poles, such as secondary cities. Rural–urban migration continues to be strong, with urban–urban and intra-metropolitan movements becoming increasingly significant. Through migration and natural increase, the population has grown considerably in the coastal zone and somewhat in Amazonia, while declining strongly in the highlands. More internal migrants are male than female and tend to be relatively young and educated above the average, with a few exceptions. They usually work outside of agriculture and tend to earn higher incomes than non-migrants. Data on available net income is unclear, however. Internal migrants use some of their income to support family members – mostly women and economically inactive relatives – back in their home communities. Internal remittances could thus be important for local climate adaptation. Besides migration, Peru has also seen fluctuating numbers of displaced people. Nowadays, disasters displace more people than does conflict. Recorded disaster displacements are primarily due to floods, El Niño events and intense rainfall, followed by wet mass movements and extreme temperatures. All these drivers are likely to be affected by climate change, as explained in Chapter 3.

2.2. HUMAN MOBILITY IN THE CONTEXT OF CLIMATE RISKS

This subchapter analyses the existing evidence on the linkages between climate-related hazards and migration in Peru, and thus allows learning about possible future migration patterns when climate impacts will be rising. Figure 22 provides a map of the identified investigation sites of the reviewed studies. This subchapter is divided into sections according to the three main topographical zones of Peru: the coast (costa), highlands (sierra) and the rainforest (selva). Each section first gives an overview of existing studies, then synthesizes data on livelihoods, exposure and vulnerability to hazards, and impacts of hazards. The sections assess available information on coping and adaptation and, finally, evidence on human mobility and its consequences.

When discussing the different hazards mentioned in the reviewed studies, cross-references are made to sections of the climate risk chapter (Chapter 3) that contain information on hazards beyond what is presented in the studies. Similarly, Subchapter 3.3 gives an analysis of vulnerability to complement information provided by the reviewed studies.

Figure 22. Geographic coverage of the reviewed studies of Peru



Source: Produced by Pablo Escribano (IOM) based on data from Jonas Bergmann; figure editing by Jonas Bergmann.

Note: This map is for illustration purposes only. The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the authors, the International Organization for Migration or the Potsdam Institute for Climate Impact Research.

A fishing village resident in Cabo Blanco, Peru works to clean the town of mud after flooding brought about by coastal El Niño rains. © Shutterstock/CLJ Giordano

2.2.1. The coast

Research on climate change impacts on mobility patterns of people living close to the ocean is scarce. Only two of the studies were peer-reviewed and both employ robust methods (Badjeck, 2008; Badjeck et al., 2009; Kluger et al., 2018). There also exists grey literature on the subject. Slightly more studies are available on communities and populations living farther away from the coast but still on the desert plains of Peru. Of these, only one study was peer-reviewed (Bayer et al., 2014). There is also one methodologically strong doctoral thesis (Oft, 2009, the basis of Oft, 2010). Grey literature adds to the findings, albeit with lower methodological rigor.

Livelihoods

In the examined studies, livelihoods of communities directly by the sea strongly depend on marine resources. In Parachique, in northern Peru, for example, there are artisanal and industrial fishermen, shellfish divers, and boat owners (Sperling et al., 2008). Livelihoods are often gendered and socially stratified. For example, women tend to process shellfish and poorer people tend to rely on resource extraction from the dry forest and some dryland crop farming. Some families mix inland and marine livelihoods. Besides artisanal fisheries, mariculture of scallops plays an important role (Badjeck et al., 2009; Badjeck, 2008; Kluger et al., 2018). The processing and distribution industry that revolves around marine resources also employs many people (Kluger et al., 2018).

Few studies examine livelihoods on the coastal desert in adequate depth. The more detailed analyses centre on small-scale crop and livestock farmers (Aragón et al., 2018; Oft, 2009; Bayer et al., 2014). In the largest study sample (Aragón et al., 2018), farmers mostly irrigate land due to the arid conditions throughout the year. Fruits and cereals (mostly rice) contribute about one third each to the total economic value of agricultural output. Slightly more than half of farmers also own livestock. Around 10 per cent of households have a child working on their farms: on average, two household members work off farms. The farmers are smallholders and often use traditional farming methods. Similarly, 84 per cent of households surveyed by Oft (2009 and 2010) pursued crop farming as their main economic activity, sometimes complemented with livestock farming. Farmers sell or export cotton, rice and corn grown on fields irrigated by a reservoir or river. Herders are more dependent on seasonal river flows; they cultivate temporary crop fields when seasonal flows allow for cultivation by riverbeds. The activities of all farmers are undiversified, with less than 7 per cent relying on multiple economic activities. The three desert communities in Piura assessed by Sperling et al. (2008) are described as more diversified. They depend, to different degrees, on the cultivation of various crops, mixed with some livestock farming. Some of the crop farming is irrigated, some of it is done in moist riverbed areas and some of it is rain-fed. In middle Piura, the carob tree provides beans, fuelwood and charcoal and serves as a handicraft raw material. Some villagers engage in beekeeping for additional income. Besides agriculture, there are some non-specific and anecdotal mentions of urban livelihoods, such as single mothers employed as maids or working in the agroindustry, and a few men working as moto taxi drivers (Venkateswaran et al., 2017). These livelihoods, however, have not been researched in detail.

Exposure to hazards

People's (mostly ecosystem-based) livelihoods directly by the sea are exposed to a range of recurring climate-related hazards. All studies reviewed analyse the impacts of El Niño events (Subchapter 3.2 gives a contextual analysis of ENSO that explains trends, projections and the current exposure of over 7 million people to related hazards (National System for Disaster Risk Management (SINAGERD) et al., 2014)). El Niño events mean increasing sea surface temperatures, less intense upwelling, increased sea levels, torrential rainfall triggering pluvial and fluvial flooding (especially in the north of Peru), changing river discharges, mudslides, and so-called *huaicos* – flash floods formed in the highlands through extreme rainfall, carrying mud, rock and debris flows through ravines and valleys (Ferradas, 2015). Few studies examine multiple hazards, although farming activities adjacent to the coast are also subject to repeated droughts and dry spell periods (Sperling et al., 2008). (Section 3.1.5 offers a contextual analysis of drought in Peru, which highlights the exposure of 13,000 communities across the country (SINAGERD et al., 2014).)

Many people residing in the desert are highly exposed to hazards. In Piura, communities need to cope with "too wet, too dry" conditions (Sperling et al., 2008, p. 25) – that is, alternating extreme rainfall and drought. During recurrent El Niño events, sudden-onset events, such as storms, intense rainfall, pluvial and fluvial flooding, and *huaicos*, affect communities.[10] The geographical and hydrological characteristics of the desert – including the steep river gradients – elevate exposure (French and Mechler, 2017). Many people and communities – often poor – live in government-designated flood-risk zones that are highly exposed (Bayer et al., 2014; French and Mechler, 2017). Urbanization of these periodically flooded zones is increasing, often with the acquiescence of authorities. Corruption also plays a role. The poor in both rural and urban informal settlements tend to be the most exposed – among them are migrants, who often settle on affordable, but high-risk land (Venkateswaran et al., 2017). Bayer et al. (2014) also find that established residents who have previously experienced floods and isolation are

10 Despite their classification as sudden-onset, some rainfall events develop over weeks.

better prepared for disasters and could deal with damage more easily. Slow-onset changes, such as periodic dry spells and droughts, add to the problem, as well as temperature extremes characterized by increasing daytime maximum temperatures, decreasing nighttime temperatures, and abrupt temperature changes (Section 3.1.3 offers a contextual analysis of rising trends in temperature extremes and projected future increases). Some communities also describe fog, forest fires and strong winds as annual problems (Sperling et al., 2008).

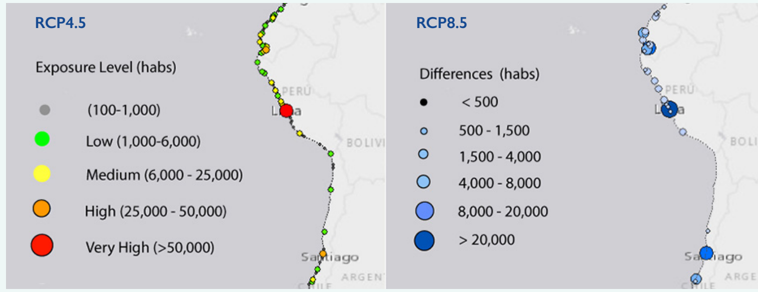
Text box 1. No-analog threat: Sea-level rise and El Niño pressure on the coastline

Beyond the hazards analysed in the reviewed studies, Peru is expected to face the no-analog threat of the losses of land, infrastructure and coastal livelihoods due to permanent sea-level rise (SLR) under a high-emissions scenario, combined with more periodic, strong El Niño hazards. We describe a phenomenon as a "no-analog threat" that which is without current equivalents or modern precedents and with large adverse effects. High emissions could drive accelerating sea-level rise of up to 1 m within the next 100 years, resulting in risks for Peru's coastline, especially as more, strong El Niño events compound the problem. These risks could affect the Peruvian economy and result in displacement, especially during El Niño events.

Limited research on impacts at both national and subnational scales shows that impacts on coastal areas of Peru could be large (Gosling et al., 2011). A rise of 0.3– 1 m could flood the beaches along the coast of Lima (Teves et al., 1996), which attracts 2 million tourists each year. The Peruvian Ministry of Environment expects sea-level rise to threaten key infrastructure, such as coastal roads and the seaport in Callao (MINAM, 2010b), which accounts for three quarters of Peru's imports and exports (USAID, 2011; Pearson, 2009). Saltwater encroachment will also affect freshwater supplies, and major beach cities, such as Máncora in Piura, will become uninhabitable. Inundation through sea-level rise can expose certain settlements in Peru (Reguero et al., 2015) if no adaptation measures are taken. Figure 23 illustrates projected exposure with a medium-emissions pathway (left). It shows how in a high-emissions scenario (right), the number of exposed inhabitants rises in many areas, with the areas affected most critically remaining largely the same. New, error-corrected elevation data shows that exposure to sea-level rise and coastal flooding in Peru may be several times higher than previously assumed (Kulp and Strauss, 2019). Exposure will also rise as populations are expected to grow in low-elevation coastal areas of Peru. Severe losses of land and built capital could also occur in northern Peru, particularly in the highest-emissions pathway (Reguero et al., 2015). Coastal flooding events will add to inundations. A 100-year flooding event alongside projected sea-level rise in a high-emissions scenario could affect more than 100,000 people in Lima if no adaptation measures are taken (Reguero et al., 2015; map not shown). The synergetic effects of rising sea levels and more, strong El Niño events could also worsen periodic coastal flooding and affect many people for several months.[a]

Note: [a] An older global study analysed the possible harm brought about by a 1-m sea-level rise with a 35 per cent increase in coastal storm surges (Dasgupta et al. (2009). It found that such a rise would have a small absolute magnitude of impacts on the coastal zone, but large relative to the totals for the zone. The study identified, for example, an exposure of about 47 per cent of the coastal population in Peru (61,000 people) and 46 per cent of coastal GDP (USD 177 million).

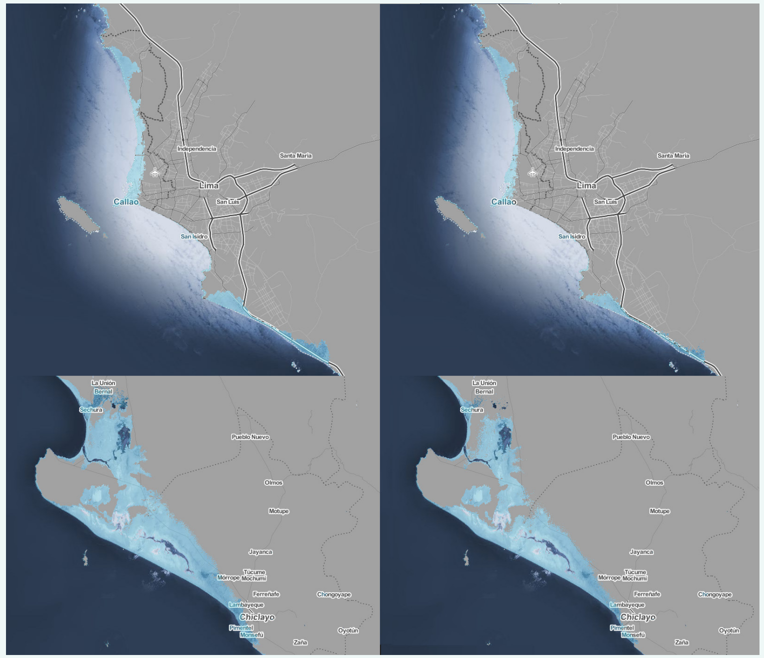
Figure 23. Exposure levels for projected 2090 populations at RCP4.5 and additional exposure at RCP8.5



Source: Reguero et al., 2015 (cropped from original). This artwork is licensed under the Creative Commons Attribution 4.0 International licence.

After 2100, sea levels will likely continue to rise for a long time, raising exposure even further. Both emission pathways leading to 2°C and 4°C warming, respectively, could result in severe SLR lock-ins beyond 2100, as illustrated by SLR models for Lima and Callao (Figure 24, top), as well as Sechura and Chiclayo (Figure 24, bottom).

Figure 24. Exemplary post-2100 sea-level rise lock-ins



Source: Generated using Surging Seas Mapping Choices, drawing on Strauss et al. (2015) (cropped from original). Reproduced with permission of Climate Central.

Note: The figures show possible sea-level rise lock-in for Lima and Callao (top), and Sechura and Chiclayo (bottom), in 2°C (left) and 4°C (right) warming scenarios.

The combined impacts of permanent sea-level rise and more frequent and temporary, yet severe, El Niño events could drive human mobility responses in Peru. There exists no historical analog for understanding the full extent of the future threat of sea-level rise for Peru. Decisions to move will be heterogenous, but governance and policies will be major determinants; bottom-up models, such as agent-based models, should be applied to understand possible pathways for Peru (Wrathall et al., 2019). Sea-level rise is a gradual process and global studies suggest that substantial investments in adaptation and protection may have the potential to lower the magnitude of the threat (Anthoff et al., 2006; Nicholls, 2011). However, such investments are costly and would require long-term planning and anticipation for many areas that are still experiencing growth of both their populations and economies. With rising impacts on livelihoods alongside losses of land and built capital, some people may need to find new ways of making a living elsewhere. Storm surges and floods could result in more displacement, especially given the synergetic effects of more frequent severe El Niño events, on top of rising sea levels. The need for planned relocation could increase in certain areas.

Vulnerabilities

The vulnerabilities[11] of those situated directly by the sea are partially stratified by livelihood (Sperling et al., 2008). People relying on crops and resource extraction from dry forests are most vulnerable, as they are susceptible to damage by droughts and floods and have little diversification options. Among fishers, small-scale producers – who are often youth or immigrants – are the most vulnerable due to their limited assets, profit margins and job experience. While mariculture offers higher profits, reliance on a single species that is vulnerable to climate-related hazards also makes it riskier than artisanal fishing (Kluger et al., 2018). The least vulnerable are households with diversified incomes who can rely on marine resources during normal and La Niña years and complement their livelihoods with farming during el Niño years (Sperling et al., 2008).

Some desert populations also have high vulnerabilities. About 27 per cent of desert farmers surveyed by Aragón et al. (2018) are poor. Most households could hardly cover their living expenses with their incomes (Oft, 2009 and 2010). They have almost no savings and only some basic liquid assets. Livelihoods are also vulnerable because they are heavily centred on one activity (Oft, 2009 and 2010): as much as 85 per cent of the surveyed households are completely dependent on ecosystem-service based farming. Morever, diversification of the labour force is low, with many households having only one or two income earners. As noted by Aragón et al. (2018), the lack of non-farming income sources and high poverty makes farmers highly vulnerable to production shocks. Many of the farmers are not only poor but also have low levels of education – and while a lack of education does not necessarily inhibit good agricultural production, it is a barrier to switching livelihoods. Only 58 per cent of surveyed heads of desert households have completed primary education (Aragón et al., 2018), and women are especially vulnerable in terms of education (Oft, 2009 and 2010).

According to Sperling et al. (2008, p. 38), inland desert communities "define vulnerability largely according to land access, size, and quality and the possession of livestock." Households that rely solely on agriculture are at greater risk; possession of more livestock and more land allows for spreading of risk. In the village of Chato Grande, for example, the groups most vulnerable were young, land-poor families and large, land-poor families with many children. They depend on day labour jobs and small patches of land, both of which are often lost during El Niño. Poor families with small and valueless livestock are also vulnerable to losing large shares, if not all, of their asset base. In some areas – often, those exposed to hazards – people also lacked land titles and faced related insecurities (Bayer et al., 2014). Housing, especially of poor people, is often precarious due to a lack of government oversight and the use of fragile building materials such as cane and adobe (French and Mechler, 2017). Internal migrants can have higher vulnerabilities than natives if they lack awareness of local hazard realities or coping and adaptation strategies (Venkateswaran et al., 2017). Unplanned development, a dearth of technical capacity, lack of coordination, weak disaster preparedness and communication, and ignorance have contributed to flooding vulnerabilities in desert communities. Given these factors, disasters in the Peruvian desert tend to be "mostly human-caused" (Venkateswaran et al., 2017, p. 75).

Impacts

The impacts of climate-related hazards on communities living directly by the sea can be devastating. Generally, El Niño results in damage to infrastructure, disruption of social services, infectious diseases, and losses in crops, fisheries and livestock (Sperling et al., 2008). Some impacts of El Niño on Peru's coastal communities are geographically differentiated (Badjeck, 2008; Badjeck et al., 2009): communities in the north, for example, tend to experience losses of fish catch and collapses of scallop populations; in the south, however, changing sea temperatures tend to boost scallop availability. Climate-related hazards are aggravated by pre-existing stressors, such as ocean pollution (Sperling et al., 2008). For one community by the sea, the authors noted that if short-term, El Niño flood-induced damage is not too devastating, the additional rainfall can bring positive, longer-term effects, such as larger pasture and planting areas and refreshed ecosystems for people engaging in crop and livestock farming or resource extraction. In addition, cold and nutrient-rich waters during La Niña can also improve fishing conditions.

11 Vulnerability is most commonly defined as "the propensity or predisposition to be adversely affected." It "encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt." (IPCC, 2014, p. 128).

The impacts of hazards on the desert plains have been frequently destructive. El Niño impacts on water, sanitation, transportation, health and education infrastructure have often been devastating (French and Mechler, 2017). Many people remember El Niño events as major life experiences with strong immediate and long-term impacts (Bayer et al., 2014): rural communities often lose houses, water sources and agricultural assets. Some of these communities become isolated during flooding events. Ferradas (2015) discusses the devastating impacts of floods related to several El Niño events. To give a few examples: two thirds of Piura was flooded in 1925. In the 1982–1983 event, more than 2.5 million Peruvians suffered direct or indirect damage. In 1987, *huaicos* destroyed more than 500 homes in Chosica. In 1997 and 1998, rains, mudslides and floods affected about 0.6 million people, damaged 108,000 houses and destroyed an additional 42,000. In 2015, mudslides, landslides and rains either destroyed or affected 500 houses in Chosica yet again. The unexpected 2017 event left over 1.5 million people affected, caused around 150 deaths, and destroyed or damaged hundreds of thousands of houses (Venkateswaran et al., 2017). Table 2 gives an overview of the estimated losses and damage during the most recent El Niño events in Peru.

Table 2. Damage and losses during recent El Niño events

Sector	1982–1983	1997–1998	2017 (preliminary figures)
Population	• 512 deaths • 1,304 injuries • 1.27 million affected	• 366 deaths • 1,040 injuries • 531,104 affected	• 138 deaths • 4159 injuries • 1.74 million affected
Transport network	• 2,600 km of highway damaged • 47 bridges destroyed	• 3,136 km of highway damaged • 370 bridges destroyed	• 6,614 km of highway damaged • 326 bridges destroyed
Housing	• 98,000 homes destroyed • 111,000 homes damaged	• 42,342 homes destroyed • 108,000 homes damaged	• 63,802 homes destroyed • 350,181 homes damaged
Education	• 875 schools damaged	• 956 schools damaged	• 2,870 schools damaged
Health	• 260 health posts damaged	• 580 health posts damaged	• 934 health posts damaged
Total value of losses	**USD 3.28 billion** (in 1998 dollars)	**USD 3.5 billion** (in 1998 dollars	**USD 3.1 billion** (in 2017 dollars)

Source: French and Mechler (2020, p. 5), citing INDECI (2016 and 2017).

Impacts often go well beyond infrastructure damage. Frequently, the damage to school buildings and withdrawal of children from school due to economic hardships also means losses of educational opportunities (Sperling et al., 2008). According to Oft (2009 and 2010), El Niño events reduce agricultural exports and household incomes. Shocks to agricultural and livestock activities raise poverty: Sperling et al. (2008) note the loss of crops and harvests from both long and short planting seasons, as well as of pasture, livestock, land and irrigation infrastructure. Poor families with small livestock bases especially tend to lose their entire asset base. In addition, pests and animal diseases tend to spread. During and after El Niño events, people's health also suffers from injuries, vector-borne and other infectious diseases, respiratory problems, and reduced diet and nutrition (Bayer et al., 2014; Sperling et al., 2008). Venkateswaran et al. (2017, p.49) underline social capital and cohesion as key assets crucial for "daily survival" in the aftermath of the 2017 flooding. They note that, often, women and children were disproportionately in vulnerable situations, including through unequal post-disaster burden-sharing. While not necessarily outweighing the losses experienced, El Niño can have some longer-term positive effects in the desert as well (Sperling et al., 2008): rains can activate occasional fields, raise pastures and livestock, and revitalize dry forests.

Beyond El Niño events, temperature and dry spells play an important role. Communities describe drought as damaging livelihoods significantly, as it reduces crop, pasture, carob and bee output, as well as milk production (Sperling et al., 2008). Dry conditions also raise animal morbidity and mortality, while livestock prices tend to sink as buyers take advantage of the situation. Due to the temperature changes, crop diseases are also more pronounced (Oft, 2009 and 2010). The lack of a sufficient supply of potable water raises gastrointestinal and respiratory diseases (Sperling et al., 2008); children may also lose educational opportunities due to malnutrition. According to Aragón et al. (2018), high and extreme temperatures reduce agricultural output and damage farming livelihoods. According to the authors' projections, the number of days with temperatures harmful to crops will rise substantially in the desert. Since the desert is already warm to hot, even slight increases in temperature will have a strong impact on cultivation potentials.

Coping and adaptation

Living directly by the sea, fishers and scallop farmers employ a range of coping and adaptation strategies, such as prey-switching, exit fisheries and adopting a different livelihood, to deal with the impacts of hazards (Badjeck, 2008; Badjeck et al., 2009; Kluger et al., 2018). When the 2017 El Niño Costero (in 2017) heavily impacted coastal livelihoods in northern Peru (Kluger et al., 2018), fishers rated the impact mostly between "intense" and "very intense", as it resulted in a loss of equipment and time to fish during the event. Most fishers could not switch livelihoods; rather, they employed strategies, such as prey- or gear type switching, or harvested further out. A high 19 per cent migrated, on their boats, to other harvesting zones. After the El Niño event, fisheries gradually recovered. About a year after the disaster, although most fishermen described their incomes as still "strongly" or "very strongly reduced" (despite rising prices for scarce fish), most felt that recovery had started, with production perceived as approaching pre-disaster levels.

The impacts of such El Niño events are often long-lasting and are addressed through different livelihood strategies (Kluger et al., 2018). Whereas artisanal fisheries recovered gradually after the 2017 El Niño Costero, mariculture continued to struggle after the event. With scallop populations dying by the coast, 93 per cent of affected scallop farmers rated the impacts as "intense" to "very intense", and 100 per cent reported earning "less" or "much less". In contrast to fishers, many scallop farmers switched sectors: they either went into fishing (thereby raising stress on this resource and competition with artisanal fishers) or worked in agriculture or construction. Because re-cultivating scallops requires time, the lack of harvest one year after the event meant that scallop farmers continued to suffer financially, with only slightly more than half of them perceiving that recovery had started. The disaster affected not only scallop farmers, but also many workers in processing plants who lost their livelihoods and had to find other jobs.

On the desert coast, reacting to climate hazards is often challenging. Sperling et al. (2008, p. 40) distinguish between "coping measures… focused at mediating the specific impact of a hazard that has occurred" and "adaptation strategies… focused on systematically reducing underlying vulnerabilities to hazards, with the goal of avoiding disastrous impacts." To cope with water scarcity and drought, they highlight the importance of selling livestock and other assets. Oversupply and exploitation by buyers, however often, push down prices. Therefore, this strategy "reduces the immediate impact of the climatic shock but also depletes the asset base of the household", likely raising longer-term vulnerabilities to future shocks (Sperling et al., 2008, p. 35). Migration is judged to be a similarly unsustainable coping strategy, as discussed in the next section.

A more specific finding about floods in the coastal zone is the distinction between "coping" and "adaptation"[12] (Oft, 2009 and 2010). In surveys across Piura, the largest share of respondent households – around one third – ask for help from family and friends to cope with floods. A significant share of affected people do nothing. The next most often used strategies are reducing expenses and doing extra work. These coping strategies often only covered about three quarters of the losses incurred. Migration is relatively seldom employed as a coping strategy (discussed in the next subsection: Human mobility and its consequences). Preparatory strategies to floods show a different breakdown: when asked what respondents would do better next time, 23 per cent would not change their farming strategies, 20 per cent would diversify crops and 15 per cent would not grow anything at all. A much smaller fraction of the population would employ migration as an adaptation strategy (discussed in the next section: Human mobility and its consequences). Sperling at al. (2008) find that adaptive capacity is a function of wealth, which qualifies access to assets such as seeds, fertilizer, land and livestock. For example, households that succeed in preserving a threshold amount of livestock throughout an El Niño event are better able to adapt and reap profits from some of the positive side effects of the disaster. Another study shows that residents in Tumbes find ways to circumvent water shortages and loss of assets and homes, but nevertheless require considerable time to recover from El Niño-induced damage and achieve "stable housing, viable agriculture and livestock and income stability" (Bayer et al., 2014, p. 370).

When affected by water scarcity on the coastal desert, the largest share of households in Piura (around one third) ask for help from family and friends to cope with losses, while one fifth reduces expenses (Oft, 2009 and 2010). As much as 16 per cent of respondents do nothing, 12 per cent do extra work, 9 per cent seek credit and 3 per cent sell livestock, while 8 per cent migrate temporarily (as discussed in the next section: Human mobility and its consequences). To adapt to future water-scarcity, almost half of households surveyed would not grow crops, while one fifth would diversify their crops. Much fewer people would not change anything and only 1 per cent would employ migration for adaptation. In times of drought, some households search for fuelwood to produce charcoal to smooth income, which has resulted in deforestation (Sperling et al., 2008). Sometimes, children, whose health is particularly at risk from climate impacts, are withdrawn from school so they can help support the family's livelihoods. Another large-scale survey reports that farmers make different production decisions to respond to extreme heat (Aragón et al., 2018, p. 35): they change crop mixes to include more resilient and flexible plants and use more land. Due to extreme heat events, they also sell livestock, are forced to resort to child labour and

12 "Coping" is defined as short-term reactions to a given shock, while "adaptation" refers to long-term behavioural adjustments to recurrent shocks (Oft, 2010).

work additional time off their farms to smooth consumption or income. The authors point, however, to the limitations of these strategies in the long term, given that more extreme temperatures are expected in the future and that there are limits to increasing land use. Their data does not allow for a detailed analysis of migration, taken up in the next subsection.

Human mobility and its consequences

Migration

In coastal areas, environmental changes have historically influenced the availability of local resources, which, in turn, has driven fishermen's relative reliance on either seasonal or long-term migration as a livelihood strategy. For example, the El Niño events of 1983–1984 and 1997–1998 increased scallop availability along the southern coast and attracted migration. When subsequent La Niñas triggered larger scallop stocks in the north, migration flows reversed (Kluger et al., 2018). When men migrated, their families tended to stay behind. With the establishment of scallop aquaculture in the south, many migrant fishers became permanent residents in the 2000s; however, about 3,000 fishermen still relied on seasonal movements for harvest. Because migration has been institutionally encouraged by a de facto open-access regime, analysts expect such seasonal flows to grow. Reasons for not moving included family obligations, habitat restrictions and satisfaction with the fish species in place, as well as lack of opportunities due to cost barriers, access conflicts and lack of specialized skills, which limited options for mobility. After the 2017 El Niño Costero event, around 28 per cent of scallop farmers had left Sechura, particularly those originally from outside the area.

The outcomes of migration as a livelihood strategy for communities by the sea can be diverse (Badjeck, 2008; Badjeck et al., 2009). On the one hand, migration allows people to diversify livelihoods and move away from hazards, with gains from social remittances and technology transfers mentioned by the author. On the other hand, migration involves logistical costs and can threaten educational opportunities and community cohesion. In some cases, migration has resulted in the expansion of informal housing in areas exposed to hazards. Further anecdotal evidence points to problems related to in-migration, such as discrimination, higher rates of drug use and even social unrest. Sperling et al. (2008) emphasize the negative effects of migration on family structures, social networks, educational opportunities and local knowledge. In their assessment, "migration is unwanted and does not really represent a choice, but rather a lack of alternative income opportunities" (ibid., p. 40). While this is a one-sided perspective that considers neither the full range of impacts nor the costs and benefits of alternatives, the literature shows that the challenges brought about by migration can be considerable.

The literature describes the policy and institutional responses for communities living by the sea as insufficient. As early as Badjeck (2008) pointed out that migration, as a response to changing environmental conditions, must be urgently integrated in policies to deal with disasters and prevent their adverse consequences. Ten years later, Kluger et al. (2018) described the continued absence of such policies. They suggested spreading risk by decentralizing mariculture to other areas of Peru.

Farther away from the sea, on the desert plains where displacement after El Niño events are recurrent, migration also plays a role in coping and adaptation. Bayer et al. (2014) found that following the 1997–1998 El Niño event, 5–10 per cent of the population on their research study sites left for good and a significantly higher percentage looked for temporary work in other parts of the region or in close-by, neighbouring Ecuador. Only "a few were able to wait out the rain[s] without looking for work" (Bayer et al., 2014, p. 364). Some villagers shifted their houses to safer ground while retaining agricultural land in exposed areas. Oft's (2009 and 2010) relatively large survey shows that 8.4 per cent of households in the lowlands affected by water scarcity turned to migration as a coping strategy. On the other hand, 6.8 per cent migrated as a coping strategy during floods. Most often, such migration was temporary and involved day labour in areas or regions spared by environmental hazards (Oft, 2009 and 2010). Geographic opportunities play an important role; in the author's words: "Some farmers do not consider flooding a problem, while others are affected by flooding [and] cannot do anything [about] it; they sometimes leave the place and migrate somewhere else" (Oft, 2009, p. 93). By contrast, when asked how they would adapt to water changes over the longer term, only 2 per cent and 1 per cent, respectively, pointed to temporary migration during droughts and floods. Sperling et al. (2008) describe the migration of household members as an "option of last resort" to smooth income. Migrants tended to go to urban centres in the coastal zone or the Amazonian lowlands to search for jobs. In some cases, as in the village of Chato Grande, migrants' destinations were a function of the type of hazard exposure, since floods and droughts "have different impact durations and, hence, pose different requirements for alternative income sources" (Sperling et al., 2008, p. 40). With floods, migration was more temporary, while droughts led to more permanent movement towards other destinations. The authors also highlight the gender dimension of flows: for example, in the village of Locuto, men would migrate to other rural areas to work on farms, while women migrated to cities to engage in domestic work. As mentioned previously, Aragón et al. (2018) did not examine migration and remittances in detail; their limited analysis of migration proxies in their large-scale survey did not yield significant results.

Few studies examine the outcomes of migration from the coastal zone. In the assessment of several desert communities by Sperling et al. (2008), migration is found to have adverse impacts on social and family structures, local knowledge and educational opportunities for children. Since migrants often lack "education and marketable skills", they tend to end up in precarious jobs; still, despite the harsh conditions and the noted involuntariness, migration helps "to compensate for losses and ensure food security" (Sperling et al., 2008, p. 40). Oft (2009, p. 37) does not analyse migration outcomes in detail but links them to "unorganized urban expansion".

Displacement

El Niño events frequently destroy or damage houses and assets in the coastal zone, forcing people into displacement. Ferradas (2015) mentions several such events. For example, the 1925 flooding destroyed numerous houses in Chiclayo, Monsefú and Eten; in Trujillo, citizens had to take shelter in a cathedral after dams broke. The *huaicos* of 1987 destroyed more than 500 homes in Chosica in the Lima Region. The 1997–1998 torrential rains destroyed approximately 42,000 homes and damaged 108,000, displacing many. Affected areas included villages in Alto Piura that were partially or completely destroyed, and Ica, where the destruction of 420 homes affected more than 2,000 residents. After the 2017 flooding, more than 31 shelters consisting mostly of tents were put up to house more than 11,600 displaced persons, within the vicinity of their residences or a short distance away, along roads connecting to the city of Piura (Venkateswaran et al., 2017).

Some data exists on the outcomes of El Niño-induced displacement. The best data exists for the El Niño Costero that hit Peru at the beginning of 2017. It brought torrential rainfall, floods and mudslides and was the single heaviest push for disaster displacement in the country in the past decade (IDMC, 2019b). A representative survey in September 2017 of 25 campsites in Piura showed that even months after the disaster, 20 per cent of the displaced remained without access to water and 22 per cent had less than 6 litres per day (IOM, 2017a). In two of the most affected regions, Cura Mori and Catacaos, 28 per cent and 21 per cent, respectively, of displaced people in camps could not leave because their livelihoods had been destroyed. Simultaneously, 70 per cent and 37 per cent, respectively, did not want to leave the camps out of fear of future disasters. Before the disaster struck, livelihood activities had been mainly agriculture (44%) and day labour (25%). After the disaster, 20 per cent of those previously in agriculture, 24 per cent of those previously in domestic work, 29 per cent of those previously in formal commerce and 39 per cent of those previously working in handicrafts moved out of these livelihoods. Among those displaced, the number of people without jobs increased by 215 per cent and those in informal jobs by 12 per cent. In April 2018, another non-representative survey found that 56 per cent of the displaced had previous displacement experiences (IOM, 2018a). About one year after the event, when the survey was completed, 63 per cent of males with livelihoods in agriculture remained affected. The same was true of 19 per cent and 38 per cent, respectively, of females with livelihoods in animal husbandry and handicrafts. Around 38 per cent of surveyed people reported that they were frequently without water. Another study found a 50 per cent prevalence of post-traumatic stress disorder among people affected by the 2017 El Niño Costero, especially those with low incomes and those whose houses were destroyed or had become uninhabitable (Espinoza-Neyra et al., 2017 and 2018). Another study highlights the despair and suffering during and long after the 2017 disaster in Lima (Moncada et al., 2018). Many people perceived an absolute loss of livelihoods and goods and felt abandoned by government authorities. At the same time, some family groups and communities benefited from strong social cohesion and mutual support, including through the sharing of experiences and feelings, care, and solidarity.

Relocation

Relocation of communities living by the sea is a possible consequence of exposure to multiple hazards, such as floods and storm surges, compounded by long-term development challenges. For example, after the impacts of the 1982–1983 El Niño, the Government attempted to relocate one fishing community to higher ground (Sperling et al., 2008). However, the long distance from the coast and fear of theft resulted in most people returning and few leaving permanently. The community perceived the relocation as an "action against them", since designated at-risk areas do not easily receive public funding (Sperling et al., 2008, p. 43).

Relocation also occurs in desert areas. For example, the village of Chato Grande suffered frequently from flooding. After a disaster in 1983, 24 per cent of the community was relocated to Nuevo Chato Grande (Sperling et al., 2008). The new village received some infrastructure but lacked electricity and was located farther from livestock and workplaces, raising transportation costs and the risk of theft. Consequently, some villagers maintained "dual residencies" while others refused to move. The old community lamented the adverse impacts on its social cohesion. Similarly, after the 1997–1998 El Niño, some planned relocation occurred in Lambayeque (Ferradas, 2015) and Piura (Oft, 2009 and 2010). In the districts of Cura Mori and El Tallán, several villages had to be relocated due to flooding. Despite acknowledging the exposure, some people continued to live in the old villages and refused to move, arguing they "had their house[s] and land there … and would not move away" (Oft, 2009, p. 95). Another relocation resulted in villagers facing prohibitively long distances from their fields, on which their livelihoods depended. As the relocation sites were not suitable for agriculture, people decided to stay. French and Mechler (2017) observe that in 2015, *huaicos* killed and displaced several people in Lurigancho-Chosica, located in a valley outside of Lima. The affected neighbourhood was designated as a high-risk zone and relocation was planned, but most locals refused to participate. Ultimately, the Government installed physical barriers, with mixed effects: the walls protected the community from the 2017 event but required costly maintenance and likely conveyed a false sense of security that could ultimately attract new migrants. The 2017 El Niño resulted in heavy flooding in the settlements of Cuatro de Mayo, in the Castilla District of the Piura Region (Venkateswaran et al., 2017). As many of the poorer residents lived in exposed informal housing by the riverbed, around 500 homes were damaged or destroyed. People were evacuated to emergency camps. About 300 families required relocation or assistance to withstand periodic flooding; however, land conflicts made service provision to the community difficult. The authors mention previous attempts to relocate parts of the flood-prone population in Castilla in preparation for the (ultimately moderate) 2015–2016 El Niño, yet many returned to their homes, given the availability of livelihood options and the relative inexpensiveness of houses by the river.

2.2.2. Highlands

Most of the studies on the nexus between climate-related hazards and mobility had the highlands as their geographical context. The review identifies 38 relevant studies, 12 of which merely provide further analysis of data collected in some of the other 26 studies. More than half of the studies are peer-reviewed journal articles. Many use strong survey (e.g. Adams, 2016; Koubi et al., 2016) or multi-method approaches (e.g. Ho and Milan, 2012; Milan and Ho, 2014; Milan, 2016). Various methodologically strong qualitative studies complement their findings (e.g. Alata et al., 2018; Lennox and Gowdy, 2014). There are, as well, many non-peer-reviewed studies of varying quality, strong examples of which include the works of Cometti (2015a, 2015b and 2018) and Sperling et al. (2008).

Wheat harvest in the Cordiliera Negra, Peru. © Shutterstock/Mikadun

Livelihoods

Most highland communities studied rely mainly on crop and livestock farming for their livelihood (Perez et al., 2010; Oft, 2010). Many of these families are smallholders who own livestock and use traditional farming practices, relying mostly on rain-fed crops and limited irrigation (Aragón et al., 2018; Heikkinen, 2017). Several studies confirm the dominance of agriculture, with few complementary activities, among villages in Áncash, Junín, Puno and Piura (Altamirano Girao, 2012; Altamirano Rua, 2014; Oliver-Smith, 2014; Sperling et al., 2008; Oft, 2010; Heikkinen, 2017; Cavagnoud, 2018). The same is true for villagers of eight highland communities in the Cusco Region (Lennox, 2015; Lennox and Gowdy, 2014). Due to climate change challenges and market opportunities, they have been gradually reducing the share of staple crops and increasing that of forage grasses to boost dairy production. In some cases, the shares of crop and livestock farming can differ considerably even in the same region and at similar altitudes. Sperling et al. (2008) observe that out of six Puno highland communities at different elevations and locations, two mixed crop and livestock farming to similar extents, two others prioritized crop farming over livestock farming, and the remaining two concentrated on livestock over crops.

Elevation usually plays an important role in determining livelihood options, with increasing pastoralism and reduced crop farming in higher altitudes. For example, three studied villages in Junín engage in crop farming at high and livestock farming at very high elevations above 3,900 masl (Milan and Ho, 2014). Agricultural activities and cattle herding in extensive communal lands were the most and second most important economic activities for these communities. For communities at between 3,200 to 3,600 masl, crop farming in very small land holdings ranked first and second, respectively. Magallanes (2015) observes the same pattern for other villages in Junín, as does Oliver-Smith (2014) for several sites in Áncash and Cusco. At the highest altitudes, for example, in studied villages in the regions of Áncash (Alata et al., 2018; Oliver-Smith, 2014), Cusco (Orlove, 2009) and Huancavelica (López-i-Gelats et al., 2015), pastoralism is often the first and sometimes the only livelihood option. Some villages, for example, in Huancavelica (Crespeigne et al., 2009), hold land across different ecological floors for different livelihood activities.

In some areas, households engage in off-farm activities as additional income sources if proximity to opportunities permits. For example, livelihoods in three villages in the Rímac river valley were mostly agricultural, but households combined these activities with incomes from mining on the one hand, as well as from commerce and transportation, thanks to the proximity of Lima City (Adams, 2012 and 2016; Adams and Adger, 2013). Similarly, villages with viable commuting options in Junín complemented crop and livestock farming in different ecological topographical zones with urban activities such as construction work, as well as work in more remote coffee-growing areas (Milan and Ho, 2014). For villages located at relatively lower elevations, off-farm diversification is common, given the proximity to urban opportunities, and incomes from non-agricultural activities prevailed. Cometti (2015a, 2015b and 2018) also observes mostly mixed livelihoods of livestock and crop farming in five communities in Cusco, with some villagers temporarily working in tourist services in the city. About one third of respondents in the study in Puno by Cavagnoud (2018) received some additional off-farm incomes from social programmes (25%), construction (19%), mining (18%) and trade (10%). Koubi et al. (2018; 2016) surveyed both urban and rural populations, including in some highland cities. They find an overall 33 per cent employment in crop and livestock farming and fishing, with the rest being employed in elementary occupations or business sales, or as craft or trade workers or civil servants. Altamirano Girao (2012) indicates tourism and commerce as off-farm activities beyond crop and livestock farming in one community in the Áncash Region, but also notes 60 per cent unemployment or underemployment. In one village in Puno, some farmers complement their livelihoods with handicraft production (Sperling et al., 2008), as in one district in highland Piura, where ceramics production also complements agricultural activities (Oft, 2009 and 2010). Although some studies indicate hunting and fishing (Altamirano Girao, 2012), and other unspecified complementary activities (Cavagnoud, 2018), most focus on crop and livestock farming.

Exposure to hazards

The studies note a multitude of hazards that communities must confront, often revolving around water. In most cases, people face multiple hazards, sometimes concurrently or in short subsequent periods (Perez et al., 2010). Of the 203 respondents in Cavagnoud's (2018) study of five Puno villages, all face at least one hazard and 76 per cent face at least three. Climate change often amplifies existing risks: in Oft's (2009) larger-scale survey in Piura, 91 per cent of households report that the climate has been changing in the last 20 years. In addition, hazards are locally diverse. In a study in the Puno Region, six communities recalled disaster events and ranked them according to severity; all communities listed at least five different disaster types affecting them (most often, frost, drought, flood, hail, snow and wind) and had different perceptions of severities (Sperling et al., 2008).

Numerous studies highlight exposure to changing temperatures. (Sections 3.1.1 to 3.1.3 feature a contextual analysis of observed warming temperatures, especially in high elevations, and projected changes in Peru.) Aragón et al. (2018) examine the impacts of high temperatures and of extreme heat on agricultural livelihoods in the highlands. In a survey by Alata et al. (2018), 94 per cent of 89 respondents reported increasing heat. Besides overall warming conditions (Oliver-Smith, 2014), daily and seasonal extremes are also increasing, resulting in colder nights and warmer maximum day temperatures in some study sites in Áncash (Wrathall et al., 2014) and Piura (Oft, 2009 and 2010). In addition to rising temperatures, people, animals and crops in the highlands are exposed to stronger solar radiation (e.g. López-i-Gelats et al., 2015; Adams, 2016).

Studies discuss glacier retreat as another major topic in relation to temperate changes (and some other factors). (Section 3.1.4 and Text box 2 provide a more in-depth analysis that highlights the observed severe retreat and projected future losses). Some studies focus on this type of hazard (Altamirano Rua, 2014; Orlove, 2009) and related risks of glacial lake outburst floods (GLOFs) (Altamirano Girao, 2012; Wrathall et al., 2014), but most mention glacier retreat alongside a multitude of parallel hazards, most prominently rainfall changes (e.g. Heikkinen, 2017; Magallanes, 2015; Charbonneau, 2008).

Many communities are exposed to cold temperatures. For example, Koubi et al. (2016) note the effects of cold weather in Cusco. In a study by Cavagnoud (2018), the largest number of respondents in Puno – almost 62 per cent – rank cold spells as the first, 34 per cent as the second and 3 per cent as the third most important environmental problem they faced. Cold spells are commonly perceived to be mostly short-term events, but 24 per cent of families also qualify them as long-lasting. Several studies also mention the hazards of frost – thin-layered ice on the soil – as well as ice (e.g. Crespeigne et al., 2009; Lennox and Gowdy, 2014; Lennox, 2015; Adams, 2016), alongside snowfall (Sperling et al., 2008). (Refer to Section 3.1.3 for a more contextual analysis of hazards related to cold temperatures, which already affect 7 million people in Peru nowadays (SINAGERD et al., 2014).)

The studies often discuss changes in rainfall patterns and the resulting impacts. The reviewed studies mention shifts in the rainy or wet season, as well as changes in the availability and intensity of precipitation. (Sections 3.1.1, 3.1.2 and 3.1.6 feature a more detailed analysis of diverging trends for observed long-term annual rainfall and runoff, as well as regional future projections.)

Many studies describe changes in seasonal rainfall patterns. These changes include delays in the onset of the rainy season (López-i-Gelats et al., 2015), abrupt seasonal shifts (Adams, 2016) and other shifts (Milan and Ho, 2014). In one study in Áncash, 55 per cent of respondents note shorter rainy and longer dry seasons, while 20 per cent indicate no changes in patterns (Alata et al., 2018).

Several studies examine changes in rainfall availability. Around 70 per cent of respondents in the same study in Áncash note that rainwater availability has decreased (Alata et al., 2018). Cometti (2015a) also mentions periods with unexpectedly more or less precipitation than usual in his study sites in Cusco. Reduced rainfall can result in water scarcity and drought (e.g. Adams, 2016; Milan and Ho, 2014). For example, López-i-Gelats et al. (2015) note a greater frequency of drought in six communities in Huancavelica; several authors observe droughts harming communities in Puno (e.g. Sperling et al., 2008; Koubi et al., 2016; Cavagnoud, 2018); Oft (2009) registers unusually long and pervasive droughts in the Piura Region, as do Koubi et al. (2016), who also note droughts in the Lima Region. Of the more than 200 respondents in the Puno study by Cavagnoud (2018), 32 per cent rate droughts and water scarcity as their most important problem, while 34 per cent rate it as their second, 26 per cent as their third and 7 per cent as their fourth. Almost equal shares of respondents qualify these problems as short-term and long-lasting. One other study mentions decreasing water availability related to periodic drought (Kuznar, 1991).

Besides changing average rainfall, the studies also note changing rainfall intensities (e.g. López-i-Gelats et al., 2015). Wrathall et al. (2014) describe more frequent and extreme rainfall events in one zone of Áncash; 59 per cent of respondents in a study by Alata et al. (2018) note lower rainfall intensity in another zone. Many authors also mention flooding, for example, in Arequipa (Koubi et al., 2016), Piura (Oft, 2009), Junín (Milan and Ho, 2014) and the highland Lima Region (Adams, 2016), sometimes contributing to mudflows and landslides (López-i-Gelats et al., 2015; Adams, 2016). According to Oft (2009), majority of households surveyed in Piura lived in areas exposed to flooding without adequate physical protection.

Some studies also mention exposure to other hazards. These studies report that communities face hailstorms (Cavagnoud, 2018; Lennox, 2015) and strong winds (Adams, 2016; Sperling et al., 2008), as well as thunderstorms and electrical storms (Cavagnoud, 2018; Alata et al., 2018).

Text box 2. No-analog threat: Water insecurity through rapid deglaciation

In a future with high greenhouse gas emissions and growing populations, rapid deglaciation, combined with rising water demand in Peru, would result in a no-analog threat to water security that could have large economic impacts and result in displacements. Some authors already refer to a "water crisis" in Peru (Paerregaard and Andersen, 2019; Paerregaard, 2019). Examples of areas already experiencing water stress include the very poor southern rural highlands (Buytaert et al., 2017), an area subject to recurrent droughts, low base flows in rivers and low groundwater availability (Buytaert et al., 2011). Growing demand will be a major driver of risk for increased water stress. Demand for already stretched resources rises as populations grow, especially in cities, alongside higher levels of use in industries, hydropower generation and extensive irrigation in the coastal zone (Buytaert and Bièvre, 2012; Buytaert et al., 2017). Deglaciation will amplify water stress. Warming has already triggered an extensive retreat of the tropical Peruvian glaciers (National Institute for Research on Glaciers and Mountain Ecosystems (INAIGEM), 2018). Peak river runoff is projected in 20–50 years in most areas (Adams et al., 2014), and volume losses could range between 78–97 per cent by 2100 even in low- and medium-emissions scenarios (Radić et al., 2014; Marzeion et al., 2012).

The ongoing retreat of Peru's glaciers has many direct and indirect effects on downstream ecosystems and communities (Veettil and Kamp, 2019; Vuille et al., 2008; Seehaus et al., 2019). Current glacier retreat first increases water availability, most importantly during the dry season, which might enhance economic opportunities and productivity in some areas in the short term (Vuille et al., 2018; Veettil and Kamp, 2019). If glacial loss reaches a tipping point, meltwater runoff will decrease dramatically (Seehaus et al., 2019; Veettil et al., 2019; Vuille et al., 2018). In the Cordillera Blanca, at least seven watersheds have already crossed peak flow; once the glaciers feeding these rivers are gone, dry season average discharge may decrease by up to 30 per cent (Baraer et al., 2012). Future glacial reductions would not necessarily reduce total water yield in Peru, but dry season runoff and seasonal buffering capacities may sink, especially if rainfall becomes even more seasonal in parallel (Buytaert et al., 2017). Besides reduced streamflow, deglaciation can exacerbate water quality issues. Meltwater can also accumulate in glacial lakes that carry risks of outburst floods (i.e. GLOFs) (Carey et al., 2012; Emmer et al., 2016; Frey et al., 2016), with potentially high levels of damage (Carrivick and Tweed, 2016). GLOFs threaten Huaraz, a regional capital with over 100,000 people (Frey et al., 2018), as well as Carhuaz (Schneider et al., 2014) and others (Haeberli et al., 2016). Glacial loss will also speed up soil erosion and affect Andean moorlands that are important for local hydrological cycles (Adams et al., 2014). Beyond the loss of glacial meltwater, rapid deglaciation will also result in severe non-economic losses. Many glaciated mountains are perceived as sacred homes of spirits (Paerregaard, 2013 and 2016) and provide important aesthetic and spiritual ecosystem services to the surrounding communities (Adams, 2016). Glaciers and landscapes dependent on them are also important tourist destinations, and their loss will reduce incomes from tourism-related jobs.

Glacial loss will result in at least six specific vulnerabilities in Peru. First, loss of glacial melt will be problematic, especially during dry conditions (Buytaert et al., 2017). In the peak dry month in a normal year compared to the yearly average, six times as many people use meltwater domestically, three times more land is irrigated with it, and meltwater is used 52 times more for hydropower across the tropical Andes. In a drought year, the numbers escalate even more. Second, rural smallholders at higher elevations tend to rely on high shares of glacial melt for domestic consumption and agriculture (Buytaert et al., 2017). They are often poor and have limited capacity to adapt to the consequences of eventual glacial loss. Third, while cities, especially those along the Pacific coast, can usually buffer seasonal variations in water supply, the loss of glaciers could threaten the viability of interannual buffering systems (Buytaert et al., 2017). Deglaciation would raise water scarcity during dry times in densely populated areas. In Lima, for example, meltwater contribution to surface water rises from 1 per cent on average to 4 per cent during drought peaks. Expectable strong demographic growth in Lima will accentuate already high competition for freshwater between human use and intensive agriculture (Buytaert and Bièvre, 2012), especially during dry conditions. Fourth, glacier disappearance could threaten irrigation for the coastal agroindustry. For example, average meltwater contribution to the large, 458 km^2 Chavimochic irrigation scheme skyrockets from 7 per cent to over 50 per cent during peak drought months – if half of the irrigation water is lost, production would face severe challenges (Buytaert et al., 2017). Fifth, some of Peru's water-intensive mining could suffer from increased water stress, especially during dry months. Reduced meltwater can increase costs of water for production and processing, as well as induce allocation conflicts with nearby users (Odell et al., 2018). Peru has experienced numerous conflicts related to mining, with water quality and availability issues driving some of them (Salem et al., 2018). Sixth, hydropower generation could suffer from reduced streamflow in some zones. For example, the input into hydropower generation rises significantly in extremely dry months, although it remains below 6 per cent of the total input.

Local adaptation may help to reduce some of the losses, but when hazard impacts overwhelm adaptative capacities, displacement can ensue. The challenges related to glacial loss call for rigorous mitigation and adaptation strategies (Veettil and Kamp, 2019). Water-saving measures, such as more efficient irrigation, more resilient crops and water-harvesting techniques, alongside the use of other water sources (for example, groundwater) will only go so far. Highland subsistence farmers who are highly dependent on meltwater will have limited means to adapt in place and probably need to move, especially during dry conditions. For cities, the effects will depend on the management of rising demand alongside investment in buffering capacity, which comes with its own challenges and costs. Some larger highland cities that are extremely dependent on meltwater will face substantial challenges, especially as they simultaneously grow in population, partially driven by migration. Beyond strongly reduced streamflow, some zones in highland cities will also face risks of GLOFs. For these cases, the necessity of planned relocation, compared with other disaster risk reduction measures, remains unclear. Impacts on irrigation schemes in the coastal zone and mining activities in the highlands could also displace livelihoods and many people.

Vulnerabilities

Vulnerabilities often relate to people's socioeconomic situation. In many highland areas, poverty, insufficient property and resource rights, poor soil quality, poor basic infrastructure and services, and lack of quality education raise vulnerabilities (Oliver-Smith, 2014; Koubi et al., 2018; Oft, 2010; Sperling et al., 2008). Aragón et al. (2018) observe a 55 per cent poverty incidence in their large-scale survey of more than 46,000 farmer households across the Peruvian highlands. Many surveyed households in Piura could hardly cover living expenses, most had no financial savings or liquid assets and lack access to credit (Oft, 2009 and 2010; Koubi et al., 2018). In a study in Puno by Cavagnoud (2018), almost two thirds of surveyed families had irregular incomes. Only one third could cover food expenses for all their children and only one third could cover their education costs. Virtually all households live in simple adobe houses, with a third lacking access to water (Sperling et al., 2008; Oft, 2009 and 2010).

Constrained livelihood options also raise vulnerabilities. Households in a study in Puno are mostly poor and have a heavy dependence on agriculture, with few diversifying their livelihoods (Cavagnoud, 2018). In another study, in Piura, livelihoods are vulnerable because they are heavily centred on one activity (Oft, 2009 and 2010): as much as 85 per cent of the surveyed households are completely dependent on farming, whereas only 6 per cent engage in an additional livelihood activity. The lack of diversification is worse in the highlands than in the lowlands of Piura. In addition, diversification of the labour force is also low, given that there is only one income earner in 44 per cent of households. Heikkinen (2017) notes the lack of rural opportunities as a factor increasing vulnerability. In her assessment, the vulnerability of small-scale farmers is due to "a complex network of social, economic and political problems that climatic changes only trigger" (Heikkinen, 2017, p. 85). The vulnerability of highlanders is often a function of the extent, quality and location of household resources, including land and livestock, and demographic factors such as family size, age and health. The higher the elevation or altitude of a community, the more limited its resources usually are, which increases vulnerability. Most vulnerable are households with very little land and livestock. Conversely, Milan and Ho (2014) observe that their study households tend to have relatively high levels of diversification options and assets. Incorporating off-farm activities into their livelihood strategies has lowered some of the farmers' vulnerability to food insecurity. Finally, vulnerabilities are also differentiated within households: for example, illiteracy is especially high among women and malnutrition particularly affects children (Oliver-Smith, 2014).

Further contextual factors can result in vulnerable situations. Oliver-Smith observes that the vulnerability of highland communities to climate change has increased, given "socioeconomic changes in land tenure, migration, market competition and increased input costs" (2014, p. 87). Globalization is also mentioned as a factor that gives rise to market opportunities and challenges that shape people's vulnerabilities (Lennox, 2015; Lennox and Gowdy, 2014). For example, Oft (2009) explains how globalization has entailed agricultural opportunities and challenges in Piura. She shows how governance in Peru often follows globalization trends, with an orientation towards open markets since the 1990s. However, smallholders usually cannot compete in these export markets. Besides challenges and opportunities of market economy integration, López-i-Gelats et al. (2015) note how several non-climatic stressors, such as rural population growth, renunciation of traditional practices and institutions, as well as a lack of State presence and public services interact with newer climate impacts. The lack of State presence, combined with the remoteness of some communities, often plays a major role. In a study by Cavagnoud (2018), virtually all families (96%) indicate that they have never received information on environmental hazard prevention, and 92 per cent have never received any external assistance to confront these hazards. Unfortunately, information on gendered vulnerabilities is scarce in the studies.

Impacts

Hazards can have widespread impacts on people's lives and livelihoods in the highlands. For example, Cavagnoud (2018) finds that several communities in Puno strongly feel the impacts of a range of hazards. Close to 80 per cent of respondents report crop loss and reduced crop yield; 69 per cent, reduced quality of agricultural produce; 58 per cent, infectious diseases, with 26 per cent reporting other health impacts; 41 per cent, losses of animals, 30 per cent, biological diseases in cultivations; 25 per cent, losses of biodiversity; 23 per cent, prevalent diseases; 20 per cent, damages to housing; 3 per cent, loss of electronic appliances; and as much as 3 per cent report the death of a child due to environmental problems.

Aragón et al. (2018) project an increase in "harmful degree days" and exposure to extreme temperatures in the highlands, and that growing "degree days" may rise simultaneously.[13] They find that moderate temperature increases can benefit agricultural productivity; however, productivity thresholds can be reached fast, with +1°C beyond the optimal level reducing productivity by 7 per cent. Increasing temperatures can reduce crop growth and crop yield. In Piura, upland farmers witness more impacts of temperature increases on crops than lowland farmers (Oft, 2009). Conversely, the study reports that lowland farmers are more heavily affected by plant diseases than upland farmers; however, other studies indicate that changing temperatures can also increase crop plagues and animal diseases in the highlands (e.g. Cavagnoud, 2018; Oliver-Smith, 2014).

Streamflow increases as glaciers melt, eventually decreasing once a peak is crossed, which is especially serious in the dry season, when rainfall tends to be very scarce in the highlands (Orlove, 2009; Wrathall et al., 2014). Lower streamflow also results in contamination issues (Alata et al., 2018), as contaminants stored in the ice, such as industrial pollutants, mercury and pesticide residue, are freed. Glacier retreat can also induce conflicts over water use and shape the spiritual and cultural dimensions of people's lives in affected areas, as observed in Junín (Altamirano Rua, 2014). Finally, the loss of glaciers also affects tourism, a key sector in areas such as Áncash, as the melting diminishes their recreational and aesthetic ecosystem services (Altamirano Girao, 2012).

Changes in rainfall patterns affect people's livelihoods both directly and indirectly. In a survey of communities in Junín, 85 per cent of respondents report that rainfall pattern changes over the past two decades have affected their food production "a lot"; 41 per cent, "a little"; and only 5 per cent felt "no impact" (Ho and Milan, 2012; Milan and Ho, 2014). Elevation matters: rain-fed crop farming, which is vulnerable to precipitation changes, is more common at altitudes of 3,200 to 3,600 masl, where 62 per cent of households respond with "a lot" and 30 per cent with "a little" when likewise asked if their food production has been affected. In communities above 3,900 masl, where cattle herding is the dominant livelihood strategy, 35 per cent and 61 per cent of households – lower than those in 3,200–3,6000-masl communities, but still high – report large and small effects, respectively. Conversely, especially in the very high-elevation communities (above 3,900 masl), more than half of the households (53%) have experienced food shortages at least once in the five years preceding the surveys. The percentage was 36 per cent in the 3,200–3,600-masl communities. Longer dry seasons can reduce the quantity of natural pastures for livestock feeding and deteriorate their quality (Alata et al., 2018). Such changes can also result in the loss of crop varieties and the emergence of new diseases and plagues (Altamirano Girao, 2012). Rainfall pattern changes (alongside other reported impacts, such as increased hailstorms and frosts) can also induce shifts in livelihood sector, as shown by a study in Cusco, where farmers move to livestock-based economies to survive – with long-term consequences for ecosystem governance and future vulnerabilities (Lennox and Gowdy, 2014). Studies do not extensively discuss other impacts, such as thunderstorms, hailstorms and plagues, or link them to migration (Alata et al., 2018; Cavagnoud, 2018).

13 According to the authors, degree days (DD) "measures the cumulative exposure to temperatures between a lower bound, usually 8°C up to an upper threshold" whereas harmful degree days (HDD) "captures exposure to extreme temperature" above that threshold (Aragón et al., 2018, p. 11).

Coping and adaptation

The literature shows that households have distinctive ranges of coping and adaptation strategies. López-i-Gelats et al. (2015) describe four clusters of pastoralist households in six communities in Huancavelica – market-dependent, diversified, extensive and accumulating – as a function of their differential access to assets (land, livestock and labour); the type of commerce they engage in; participation in textile manufacturing; and the range of available livelihood options. These types pursue different adaptation strategies: wealthier households accumulate livestock, produce fibre and manufacture textiles, whereas less wealthy households attempt to integrate more into markets and diversify their assets. The poorest households with weak asset bases try to pursue economic activities with more added value, reducing their reliance on pastoralism or sometimes even abandoning it completely. In another study, in slightly lower highland areas in the Quillcay river basin in Áncash, small-scale farmers facing variations in precipitation and glacier retreat migrate to urban areas to look for alternative livelihoods, change irrigation infrastructure and mix crops differently (Heikkinen, 2017). The author emphasizes, however, that the range of adaptation options is limited for vulnerable groups, who are often deprived of needed skills and capital. Alata et al. (2018) observe that the risk reduction strategies of some high-altitude pastoralists in Áncash are a function of ecosystem opportunities and access to off-farm livelihoods. Ex-ante risk-coping strategies include saving money and goods for times of shock. Over the longer term, pastoralists also try to diversify their incomes within livestock activities, for example, by diversifying the animals raised, investing more in their care and quality, and spreading the derived outputs across various goods such as wool, meat, milk and cheese. By contrast, some indigenous communities in Cusco have not undertaken any larger efforts to adapt their agricultural and pastoral techniques to climate change (Cometti, 2015a, 2015b and 2018). Paradoxically, in their worldview, it is exactly these types of changes from traditional ways of life that cause climate change. Therefore, they have so far only implemented smaller changes, such as building housing in higher altitudes.

Few studies have explored coping and adaptation strategies to temperature changes. One extensive analysis across 46,000 Peruvian highland households shows that farmers coped with extreme heat by selling livestock, making their children work and investing extra time in off-farm activities to smooth income losses (Aragón et al., 2018). Farmers switch to more resilient and versatile crops and use more land when anticipating extreme heat. Pertinent data derived from the study does not allow for a detailed analysis of migration, which is discussed in the next section.

When affected by water scarcity, 59 per cent of households across several highland communities surveyed in Piura rated their ability to cope as "bad", with only 10 per cent rating it as "good" (Oft, 2009 and 2010). To cope, 44 per cent asked their peers for help. As much as 18 per cent did nothing because they lacked options; 10 per cent asked for credit, borrowed money or cut down on food expenses; 8 per cent performed extra work; and 5 per cent sold livestock. Temporary migration follows next, with 4 per cent of respondents reporting that they use it as a coping strategy (discussed in the next section: Human mobility and its consequences). About 3 per cent each asked for help from civil society organizations, cut down on other expenses, or delayed paying bills. A study of three communities in Junín facing precipitation changes and food insecurity shows that elevation matters in coping responses (Milan and Ho, 2014). When communities at elevations between 3,200 and 3,600 masl face food insecurity, the dominant household responses, in descending order, are as follows: diversifying livelihoods, reducing expenditure and seeking external assistance. In very high zones (above 3,900 masl), households also mostly try to diversify livelihoods. However, the second most important strategy is migration of household member(s) (discussed below), followed by a reduction in food consumption. When asked for adaptation practices farmers would apply to future droughts, more than half (54%) of highland households in the study in Piura replied they would stop growing anything and 17 per cent would diversify crops (Oft, 2009 and 2010). As much as 13 per cent would not implement any changes, while 6 per cent would look for new jobs and 8 per cent rely on other strategies. Only few would migrate temporarily, as discussed below. Over half (54%) of respondents claim that they have a longer-term capacity to adapt to climate change, while a little more than one third (36%) note that nothing could be done. Among the desired longer-term strategies, treating crops with fertilizer and pesticide was preferred over shifting to other crops or cropping schedules. Lennox (2015) examines small-scale farmers in eight communities in the Cusco Region who use traditional techniques in a struggle to adapt to escalating changes in rainfall patterns and increasing hailstorms and frost, in parallel to globalization and social change. In her words, with failing standard techniques, many "did not have any method for combating climate change, except to rely less on agriculture and plant fewer crops" (Lennox and Gowdy, 2014, p. 161). Farmers use fewer traditional crops, rely on new plants with different irrigation needs and abandon traditional crop rotation techniques, which can affect soil quality. Wrathall et al. (2014) explore strategies of households in mountainous areas in Áncash. In some zones, glaciers have crossed their peak streamflow and are reaching later stages of retreat characterized by lower dry season glacier discharges. Here, households tend to switch to rain-fed agriculture, despite the fact that climate change will also affect rainfall patterns in these areas. Households also increasingly migrate.

Shorter-term coping to floods is perceived as very difficult by 54 per cent of households surveyed farmers in highland communities across Piura: only 13 per cent state that they feel well equipped to cope with such periods (Oft, 2009 and 2010). On the other hand, 43 per cent of households ask for support from friends and relatives to help them cope, and as much as 22 per cent do nothing due to the absence of options. Further, 11 per cent seek credit, 10 per cent reduce expenses, 6 per cent do extra work and 5 per cent sell livestock. As in the case of drought, temporary migration as a coping strategy comes last, at 4 per cent. For future flood cases, 56 per cent of respondents indicated they would try to adapt by diversifying crops. However, slightly more than one quarter of respondents (26%) would not change anything as regards their crops and 10 per cent would stop growing anything, because they lack solid options, feel "powerless", or think everything will depend "on nature and the will of God" (Oft 2010, p. 75). 2 per cent would look for new jobs, but not use temporary migration.

The longer-term consequences of the various coping strategies can be mixed. Oft (2009 and 2010) reports that in times of either water scarcity or abundance, surveyed households in Piura could usually only recover 76 per cent of incurred losses. Aragón et al. (2018) argue that most adaptation practices have limits, given the projected magnitude of future changes and constraints such as the amount of available land. López-i-Gelats et al. (2015) also argue that climatic and non-climatic stressors overwhelm communities' adaptive capacity, potentially resulting in a downward spiral of poverty. Lennox (2015) shows that in some areas in the Cusco Region, giving up traditional crop rotation to cope with losses can deteriorate soil quality and impair future production potentials. As another consequence of adaptation efforts, some farmers increasingly depend on milk as their single market product and are thus subject to increased competition and price volatility. In the future, adaptation pathways away from traditional practices could also "endanger the governance of human created ecosystem services of the region and … limit future economic development opportunities". (Lennox and Gowdy, 2014, p. 161). Oliver-Smith (2014, p. 96) highlights the emotional impact of some efforts to cope or adapt, stating that highland farmers "fear" that they will be "forced" to switch livelihoods and lose their traditional way of life. As mentioned above, some indigenous highland communities in Cusco believe that changes in their traditional ways of living have caused climate change to occur in the first place (Cometti, 2015a, 2015b and 2018).

Human mobility and its consequences

Migration

Migration – motivated by various reasons – is often part of the social fabric in highland communities. For example, in Cavagnoud's (2018) survey of five villages in Puno, virtually all households have migrant members. About three quarters have between one and four migrant members, while some have up to eight. Migrants tend to be of working age and slightly more of them are male than female. They usually head to urban areas in Peru. Slightly less than half (46%) of respondents indicate work as the motivation, while better living and study conditions also play a role. Beyond these, some migrant family members move for reasons such as lack of land, marriage, family conflict or military service. Sizeable shares of migrants' family members also indicate "environmental problems" as playing some role in migration decision. Besides permanent migration, circular movements are also common. Sperling et al. (2008) describes customary youth migration for jobs in Puno and Piura. Heikkinen (2017) highlights that youth from some villages in Áncash frequently move away in search of education and work. Given the market disadvantages of small-scale farmers, entire families sometimes leave to improve their incomes. As described in another study in Junín (Milan and Ho, 2014), mining, export-oriented agriculture and migration (whether for education or labour, seasonal or temporal),[14] are often part of a community's social fabric. Some households close enough to cities commute daily, constantly or sporadically. Some migrate cross-border, but most (37% of migrants), especially youth, migrate to Lima temporarily. In addition, the central jungle is a destination for seasonal harvests. Communities in high-altitude zones are more isolated and have no possibility of commuting. As such, seasonal migration is less common among people here. About one fifth of members of one community do have some temporal migration experience as shepherds in the United States, under contracts generally lasting three years. Some women move to Argentina, while others go to Lima. Crespeigne et al. (2009) distinguish two common seasons for migration from Huancavelica, mainly, the school break from December to April, and, to a lesser extent, that from July to August. Demographic stress and lack of land have contributed to emigration. A study of five indigenous highland communities in Cusco describes transhumance as an inherent feature of their lifestyles (Cometti, 2015a, 2015b and 2018). However, growing populations and aspirations for better work and education have contributed to large circular and permanent emigrations towards cities. Many engage in seasonal work as shamans in Cusco. Others leave their villages four to five times a year for work, in periods lasting from several days to several weeks. People who have permanently left these communities mostly moved to other destinations (local or regional) within Peru.

Some highland communities use migration to anticipate or react to hazards. In terms of temperature-related hazards, Sperling et al. (2008) mention outmigration from highland communities in Puno, especially of young people, with frost driving migration in all six communities. Crespeigne et al. (2009) state that after an investigated cold spell in a community in Huancavelica in 2007, 31 per cent of respondents migrated or sought work as vendors, servers and shoe-shiners to smooth income losses in places such as Lima and other cities, or by working in mines and in the agroindustry. In more regular times, temporal migration was also among the main diversification strategies of highland subsistence farmers: 54 per cent of households had at least one member who was a temporal migrant. The use and duration of such migration increased when harvests were unsatisfactory. The authors suggest that temporal migration is usually a last-resort option. As mentioned previously, Aragón et al. (2018) do not examine migration as a response to extreme heat and the related remittances in detail; their limited analysis of migration proxies in their large-scale survey does not yield significant findings.

One study of Áncash smallholders finds that glacier retreat results in greater reliance on migration and remittances, especially in later stages of retreat, when peak flow has been crossed and water levels have sunk during the dry season (Wrathall et al., 2014). Family members – often young adults – are asked to migrate to urban areas to send remittances back home to support their families. This is evident in the fragmented population pyramids in the sending areas studied, whose populations have higher proportions of the elderly and lower proportions of working-age people. At the same time, the study notes that the migration of people living in these glacier systems was driven by many societal variables beyond issues of water supply. Further anecdotal evidence points to likely more migration due to water scarcity related to glacier retreat and changing rainfall patterns in a village in Junín (Altamirano Rua, 2014) and another in Cusco (Orlove, 2009), as well as some villages in Áncash (Altamirano Girao, 2012). The latter study emphasizes the multicausality of migration, but also names a glacier-related example of climate migration: some tour operators and their employees migrate after losing income opportunities due to deteriorating environments. Oliver-Smith (2014) mentions a similar example. Orlove (2009) argues that low stream levels due to glacier retreat will deteriorate pastures and make herding impossible for pastoralists in Cusco, making outmigration of already mobile

14 Milan and Ho (2014, p. 59) distinguish between temporal migration "during at least six months per year", whereas seasonal migration is "yearly recurring migration over periods of less than six months a year." (de Haas, 2003, p. 414).

pastoralists to other regions more likely. At most, some pastoralists may be able to stay in the highlands during the rainy season but will have to migrate during the dry season. Orlove also argues that tapping into existing social networks with neighbouring communities will be of limited use, as they will likely suffer from similar water shortages.

When faced with water scarcity due to rainfall deficiencies, 4 per cent of respondents in a large survey in Piura indicated temporary migration as their short-term coping strategy and 2.5 per cent as their long-term adaptation strategy (Oft, 2009 and 2010). Most move to areas spared by the hazards that affected their homes to work there temporarily, in some cases as day labourers. Sperling et al. (2008) note the occurrence of outmigration due to drought, especially of young people, from highland communities in all six of their Puno study sites. Besides Puno, the only highland study site in Piura also saw a large volume of emigration related to drought, for example, during the severe one in 1968. Most migrants from this site in Piura moved to cities in the Amazon to find other income sources. Overall, the authors emphasize that disasters often make mutual support difficult, as they affect large shares of families in one place, highlighting the importance of networks outside hometowns to confront losses. Respondents in a study in Junín report rainfall changes and food security stressors as a more important driver of migration than aspirations for different living conditions and lifestyles (Milan and Ho, 2014; Ho and Milan, 2012). Especially for very high mountain communities above 3,900 masl, migration is the second most important coping strategy when confronted with food scarcity, as reported by almost 30 per cent of respondents. Conversely, at elevations between 3,200 and 3,600 masl, only 9 per cent of households use migration as a coping strategy to address food scarcity. Heikkinen (2017) finds that rural–urban migration is among the key adaptation methods of small-scale farmers in her study sites in Áncash who face rainfall changes and glacier retreat. Her qualitative methods suggest that climate change is a principle driver of these movements, while her quantitative methods reveal that climate change "add[ed] to the myriad causes enhancing emigration" (Heikkinen, 2017, p. 85), which include the search for work, education and new lifestyles, as well as challenges for smallholders (compared to large-scale producers) to access markets. A large-scale survey by Koubi et al. (2016) finds that migration decisions are a function of how people perceive environmental hazards, especially the rate at which they develop. Gradual, more long-term climatic changes, such as drought, make migration less likely. The authors argue that in these cases, people tend to invest first in adaptation efforts in their home villages. By contrast, more abrupt and rapid-onset events, such as floods, make mobility more probable. Two other studies contain anecdotal evidence on drought-induced emigration from the Cordillera Negra mountains in Áncash to the city of Huaraz, leaving behind increasingly abandoned communities (the so-called "towns of the padlocks") (Oliver-Smith, 2014, p. 94; Altamirano Girao, 2012). The review by Perez et al. (2010) – without presenting new evidence – also concludes that temporary migration figures in among key strategies to adapt to crop failure in the highlands.

Few studies discuss mobility induced by flooding. Sperling et al. (2008) report the emigration of younger villagers from two of six study sites in Puno due to periodic floods. Temporary migration is used as a coping strategy for flooding by about 4 per cent of highland households in a Piura survey; none of the households, however, report migration as a longer-term adaptation strategy (Oft, 2009 and 2010). The percentage of households reporting migration is consistently smaller among highland than lowland communities.

Some studies investigate general "environmental problems", but do not explain which of them drive migration through which channels.[15] In a survey by Cavagnoud (2018) in five communities in Puno, "environmental problems" come in second (21% of respondents), behind work, as the main motivation for migration. An additional third of respondents indicate that environmental issues play some role in their migration decision. Many people also point to work or remittances as migration motivations; however, the study (as most other studies) does not investigate whether environmental factors may have influenced this stated need to search for income sources outside of home communities. Another study shows that changing rainfall, glacier retreat, frost, freezing, hail and other hazards are among key factors causing people to leave five indigenous communities in Cusco, alongside population growth and the search for other opportunities (Cometti, 2015a, 2015b and 2018). Climate change is a second main reason (4 out of 11 respondents), after education, behind the movement of those who have already left. Permanent migrants maintain a network with their areas of origin and frequently visit them. Five out of 11 interviewed prospective migrants cite climatic changes as their migration motivation. In their new destinations, they mostly intend to expand activities they have engaged in during previous, temporary stays, such as shamanic practice and sales or construction work. Those who wish to reside in the villages of origin still temporarily migrate multiple times to cities. They perceive that others migrate mostly for education and less often due to climate change. As mentioned previously, indigenous peoples also perceive the reciprocal relationship between humans and nature to be eroding because community members have converted to other religions and abandon traditional local rituals and religious practices. Emigration from their ancestral domains and, thus, away from their rituals (or instrumentalizing these rituals for income generation), especially among youth, is seen as another factor in the deterioration

15 Other studies are so unspecific that they are not discussed here in detail. For example, one refers to general "mounting effects of climate change [that] have laid ruin to farmers' livelihoods" and resulted in outmigration from a village in the La Libertad Region, alongside other causes, but does not specify the relationship or the specific climate impacts (see, for example: Stein (2017 and 2018)).

relationships with nature. In these communities' worldview, climate change occurs exactly because of this erosion of their culture and traditions.

In other areas, climate impacts only add to other main drivers of out-migration. Alata et al. (2018) find that while climate change impacts are tangible for two highland pastoral communities in Áncash, the observed population decline is more related to demographic and aspirational changes. Pastoralists have traditionally relied on livestock as assets for economic accumulation and later economic consolidation, often with the eventual aim of leaving the highlands so their children can have better lives. Over time, more and more young families have left the communities to earn wages outside of the highlands because they consider herding as an overly difficult activity resulting in a cycle of deprivation. Since it is mostly older people who stay behind, birth rates have fallen and population growth in these communities have dropped below replacement level. The oldest people ultimately also leave because they are overwhelmed by the demanding agricultural tasks. Ultimately, a cycle of depopulation takes hold.

Some authors assess possible future trends. Two of them use agent-based models (ABMs).[16] Milan (2016) presents an ABM on possible future emigration from his three study sites in Junín. Under two test scenarios – varied and constant drying rainfall – the model predicts that less households will be resilient than today, and long-term migration from such households may increase. Conversely, the model does not predict overall "depopulation and agricultural abandonment" (Milan, 2016, p. 110). However, the ABM does not present the full picture, since shorter-term and shorter-distance movements are not simulated – even as previous surveys have found them to be especially significant among communities located relatively close to urban opportunities. Magallanes (2015) also models future migration in highland Junín. The fieldwork to parametrize the model shows that in an increasingly water-scarce future, migration by people born in the cities is more probable than by either relatively recent urban dwellers or people living in rural areas. Rural dwellers, for one, do not expect to have better access to water elsewhere. Urban residents indicate that scarcity for more than four years would constitute a grave problem and that they would consider migrating if they experience six scarcity events. The model, fed with this and other data, simulates the melting of the close-by Huaytapallana Glacier while populations continue to grow, ultimately resulting in severe water scarcity during the dry season. Large migration flows are predicted 30 years into the future, with people mostly leaving for Amazonia and Lima. The model also indicates that social conflict may occur due to the frustrations of people wanting to leave but are unable to do so, as well as due to relative deprivation. Finally, several authors speculate, albeit without rigorous methodological assessment, that migration will become more likely in the future, given increasing climate challenges and limited diversification potential in the highlands (e.g. Oliver-Smith, 2014; Altamirano Rua, 2014; Orlove, 2009).

Household types and communities employ migration differently when confronting hazards. It is often the young who leave when communities are hit by environmental change, as reported in six communities studied in Puno and one in Piura (Sperling et al., 2008), eight communities in Cusco (Lennox and Gowdy, 2014; Lennox, 2015), and another one (Crespeigne et al., 2009) in Huancavelica, three study sites in Junín (Milan and Ho, 2014) and in an unspecified number of villages in Áncash (Wrathall et al., 2014). The same studies also point to the finding that the poor are more likely to migrate. Sperling et al. relate this to the lack of livelihood options in-place, as well as of quality land and support systems, resulting in rural–urban migration which is described as "forced" (2008, p. 28). Crespeigne et al. (2009) argue that poorer families and those who cannot access traditional strategies of risk-sharing are more likely to migrate. Resource constraints seem to play a smaller role than previously assumed among people who are considering leaving (Adams, 2012) (discussed in the last paragraph of this section). Out of the 617 people (among them 316 migrants) surveyed by Koubi et al. (2016), 535 are classified as poor, 23 have no education and 165 have only primary education. Likewise, in the study of three villages in Junín by Milan and Ho (2014), household profiles qualified whether migration was an option for confronting rainfall changes: households below the poverty line, especially the landless and poor smallholders, are two times as likely to migrate. The study also show that migration is gendered, with slightly more male migrants. Unfortunately, although shown to be important in other contexts as well (Gioli and Milan, 2018), few studies in Peru consider gender dimensions. Finally, elevation and proximity to urban livelihood options influence the use of migration (Adams, 2016; Milan and Ho, 2014). In some cases, proximity to cities can make commuting and shorter-term migration more feasible.

16 ABMs try to model behaviour of autonomous individuals confronted with changing surroundings (see, for example: Sherbinin and Bai, 2018).

The results of migration are often mixed because they depend on diverse localities, timeframes, hazards and household-specific variables. Outcomes depend partially on the type(s) of hazard encountered (Koubi et al., 2018): sudden-onset events can have devastating impacts but usually affect people in the same area similarly. Thus, they result in less relative deprivation than longer-term, gradual environmental change, for which people have dissimilar adaptive capacities and exposures. In the authors' view, those who fail to adapt to such gradual changes are more likely to be relatively deprived and, therefore, migrate. In addition, the reasons for these people's failure to adapt in the first place can also influence migration outcomes. One example where mixed consequences of migration are observed is found in the Cusco Region. A study here describes migration partly as a response to changing climate and market conditions, offering a chance to earn and smooth incomes, but ultimately "becoming more of an imperative to maintain livelihoods than a way to enhance well-being." (Lennox, 2015, p. 793). Migration also triggers change: with the departure of people, there is a labour shortage in agriculture, and traditional planting practices, rituals and knowledge is lost, all of which could ultimately raise future vulnerability (Lennox and Gowdy, 2014; Lennox, 2015).

On a more positive note, migration is usually engrained in communities and can allow them to access different livelihood and education options, adapt to change or, at least, move away from hazards. Milan and Ho (2014) show that migration outcomes depend on the household profile: migration, as a strategy to cope with rainfall pattern changes, or food or livelihood insecurity can be "adaptive", "for survival" or "erosive" (Warner and Afifi, 2014). "Content migration" occurs when poor but resilient households (e.g. those with education, access to assets and livelihood options) succeed in gaining new skills, diversifying livelihoods and improving health through temporal migration, and thus raise household resilience. When people with fewer assets and options (for example, from land-scarce households) migrate during the hunger season to find food or money to buy food, their migration is "for survival" and, thus, does not increase resilience. "Migration as erosive coping" refers to vulnerable households (e.g. the landless who have little to no education) moving during shocks or hunger seasons and able to remit little or nothing back home, leading to lower labour supply for food production in their communities. Thus, such migration reduces resilience. In their three sites in Junín, Milan and Ho (2014) mostly find successful "content migration" that allow people to manage risks and diversify livelihoods.

On the more negative side, Sperling et al. (2008) describe migration as an unwanted strategy of last resort. In Puno, school desertion is often a result of migration as a response to frost (as noted in five out of six communities) and hail (one community). Some outmigration has deteriorated local knowledge, including for the prediction of weather. Similarly, López-i-Gelats et al. (2015) find that migration may weaken adaptive capacity in sending areas, as traditional knowledge and labour resources are lost. According to Adams (2012 and 2016) and Adams and Adger (2013), those currently satisfied where they live will unlikely be happy to migrate. They note that when people migrate as a coping or adaptation strategy, such migration cannot provide redress for non-economic losses due to climate change specific to their previous home environments; in these cases, people may experience strong declines in well-being. Sometimes, migrants who leave environmental stress end up in hazard-exposed zones, according to anecdotal evidence from Huaraz City in Áncash, where migrants often migrate to informal settlements on riverbanks, unstable slopes and water-scarce lands that also face GLOF risks (Altamirano Girao, 2012; Oliver-Smith, 2014). Gendered migration flows can also have ambivalent consequences. In three villages in Junín, for example, as mostly male youth and adults have left, the women staying behind take on extra work and emotional burdens (Milan and Ho, 2014). Having to leave and settle in a new place can also influence conflict dynamics. A large survey by Koubi et al. (2018) across various areas of Peru shows that environmental migration can contribute to social conflict in certain situations. Exposure to environmental hazards in their original places of residence can induce grievances and relative deprivation among environmental migrants – and more likely so for those dealing with slow-onset than sudden-onset changes. Some of the feelings of anger and injustice held by environmental migrants may persist at their destinations, and these feelings can precede real conflict. From a different angle, Wrathall et al. (2014) argue that increasing climate change hardened widespread inequality in terms of access to resources and power in Áncash, thereby leaving people with few choices aside from emigration.

Even in areas affected by climate change, many people opt to stay, at least at the beginning of gradual changes. Koubi et al. (2016) find that people usually try to adapt to gradual environmental changes in place until certain thresholds are crossed – whereas rapid-onset changes usually trigger immediate movement. Similarly, Adams' (2012) survey in the Lima Region highlands finds that around every second villager has considered migration in the five years prior to the survey but stayed. Most choose to stay because of high levels of satisfaction. To a lesser extent, those staying behind have low mobility potential because they feel positively attached to their places or origin, fear leaving or are disinterested, or have obligations that tie them to their communities. The smallest share of respondents who stay do so because of resource constraints. The study highlights that instrumental and affective bonds can bind people to places that are already marginal and continue to be a strong link even when climate impacts make these places even more marginal. However, thresholds of place satisfaction may be crossed eventually. Another important insight from Adams' (2016) work is that people derive a sense of well-being from the many non-economic ecosystem services where they live. Such recreational, aesthetic and other services are also under threat of climate change; the loss of such services could drastically decrease people's perception of place utility and thereby shape the migration decision processes of more people than usually discussed.

Displacement and relocation

The reviewed studies seldom make distinctions between migration and displacement. Koubi et al. (2016), for example, examine gradual changes such as drought in contrast to sudden-onset events such as floods. Although the latter usually result in displacement, the authors do not distinguish between types of movements. Generally, research on internal displacement in Peru is scarce and mainly centres on the internal armed conflict of the 1980s and 1990s (Ministry of Women and Vulnerable Populations (MIMP) and IOM, 2015). Similarly, the identified studies do not cite examples of planned relocation in Peru's highlands.

2.2.3. Amazon lowlands

A sizeable number of methodologically robust studies have examined the linkages between hazards and mobility in the Amazon lowlands. Seven studies have been published as articles in peer-reviewed journals. Two of them rely on survey approaches (Coomes et al., 2010; Takasaki et al., 1999). Several of the other peer-reviewed, qualitative studies rely on participatory rural appraisal methods (e.g. Sherman et al., 2016; Hofmeijer et al., 2013). Grey literature studies with solid methodologies and comprehensive primary data include three master's theses (Langill, 2018; List, 2016; Manzi, 2005).

Livelihoods

Almost all studies contain solid information on livelihoods, most of which focus on rural communities. Only one work mentions urban activities (Rojas-Medina et al., 2008). The study survey notes that 43 per cent of respondents were unemployed before flooding hit, but that they earned some income through ambulatory sales and crafts-making. By contrast, rural communities in the studies mostly rely on a mix of crop and livestock farming, complemented by fishing, resource extraction and other activities.

A neighbourhood by a river in Iquitos, Peru, in the Amazon rainforest. © Shutterstock/Evan AUSTEN

For rural communities not directly located by a river, food production systems are usually centred on three sub-systems: forest, farming and externally sourced (Zavaleta et al., 2018). If proximity to a river permits, fishing is usually valuable to many communities. In the two riverine communities examined by Manzi (2005), 44 per cent of the total income accrues from agriculture and 18 per cent from fishing. Likewise, Sherman et al. (2015 and 2016) studied one riverbank village mostly dependent on subsistence agriculture and fishing, and, to a lesser degree, hunting and other activities such as seasonal migration (discussed in the section: Human mobility and its consequences). Similarly, in most of Coomes et al.'s (2010) seven study sites situated on two rivers, agriculture – consisting of annual cultivation of the floodplain and small animal husbandry – is key, accounting for at least 50 per cent of household incomes. Fishing comes in second, contributing to between 15 per cent and 89 per cent of total income. The next most important income-generating activities are forest product extraction (0–23%), hunting (0–6%) and, in some cases, agroforestry. In others, day and wage labour play a role in addition to agriculture and fishing (Langill, 2018).

These average values should not obscure the fact that the relative importance of different livelihoods – both in terms of participation rates and shares of total income – can vary considerably across villages. In a study by Coomes et al. (2010), participation rates in agriculture and fishing are found to be 100 per cent or close. Similarly, four villages have participation rates of above 90 per cent in livestock farming, whereas two others have only 81 per cent and 46 per cent, respectively. On the other hand, no respondent from one village engage in forest product extraction at all, while another village has an 88 per cent participation rate in the said activity. Primary livelihoods are mainly agricultural in four villages, mixed between various activities in two others and fishing in another village. Similarly, one of two villages examined by Hofmeijer et al. (2013) depended mostly on fishing and agriculture, with complementary seasonal migration, handicrafts production and trade. The other village rely mainly on hunting, fishing, gathering and crop farming.

Land elevation and flood cycles also influence livelihood options, besides other factors such as preferences, history and ecosystem opportunities. If possible, farmers take advantage of the differences in characteristics of different ecological zones during the growing season, yet some farmers are confined to certain elevations. Lowland farmers rely on different agricultural production systems and methods than upland farmers, whose fields are not affected by either the positive or negative effects of floods (Langill, 2018; List, 2016). Agricultural activities are complemented by fishing and forest extraction, among others. In an investigation by Takasaki et al. (1999), one lowland village practices mixed agriculture, fishing and gathering; one lowland village with fishing; one village with mostly lowland agriculture; and one village with upland agriculture. Across the villages, crop farming contributes to about half of the total income and fishing to about one third. Finally, in many communities living on floodplains, livelihoods are rotational and adapt to the flood cycle of the rivers: riverine people (Spanish: *ribereños*) raise agricultural production during flood recession and increase fishing activity during floods (Langill, 2018).

Exposure to hazards

Many researched communities are recurrently exposed to multiple hazards. In a large survey of almost 4,000 households, well above 80 per cent experienced at least one hazard within the 12 months prior to the survey; over 60 per cent experienced at least two hazards; and over 40 per cent, at least three hazards (Langill, 2018). Hazards are often related to the increasingly unpredictable and erratic rainy season (Zavaleta et al., 2018; Langill, 2018): rainfall pattern changes, including those in the upper Andean catchment (List, 2016), trigger hazards during periods of both water abundance and water scarcity.

Peruvians are accustomed to annual floods but are becoming more exposed to extreme flooding. Section 3.1.6 gives a more detailed analysis of intense rainfall and flooding, highlighting that about one in three Peruvians are frequently exposed to hydrometeorological hazards (SINAGERD et al., 2014) and flood risks are set to increase. People are familiar with the impacts of the annual flood cycle, which can especially benefit lowland agriculture by leaving fertile alluvium, which raises productivity (Takasaki, Barham and Coomes, 1999; Sherman et al., 2015). However, periodically heavier rainfall can result in exceptionally high and long floods and related hazards (Takasaki et al., 1999; Sherman et al., 2015). Langill (2018) distinguishes between hazards caused by high, long, early and late floods. All identified studies investigate floods, such as the 1993 flooding in the Ucayali Region (Coomes et al., 2010; Takasaki et al., 1999), the 2010–2011 floods in Ucayali and Loreto (Sherman et al., 2015; Sherman et al., 2016), the 2012 flooding, again in the Loreto Region (MIMP and IOM, 2015), and the 2011 and 2014 flooding, again in the Ucayali Region (Langill, 2018). For example, in a study by Coomes et al. (2010), 26 per cent and 82 per cent of all households along the Ucayali River and the Marañón River, respectively, have experienced at least one major disruptive flood in their lives. In Langill's (2018) study, 65 per cent of respondents have experienced large floods. In another study (List, 2016), 90 per cent of the surveyed population have been affected by flooding.

Location influences flood exposure. Communities on main river channels can be more exposed than those along tributaries, as was the case during a flood in 2011 (Langill, 2018). Flood exposure (Takasaki et al., 1999) is also shaped by land type, increasing in the following order: upland, high levee, low levee and back slope; the latter are flooded annually, the first never. Consequently, people with assets or housing in lowland communities tend to be exposed more strongly to flooding. For example, a 2011 flood adversely affected 75 per cent of lowland compared to 49 per cent of highland households (Langill, 2018). The location in different river basins can also matter, although less in terms of overall exposure than in prevalence of specific impacts (Langill, 2018) (discussed in the section: Impacts). List (2016) found that cultivation on the active channel involved high exposure and commonly severe losses, since higher water sometimes arrived before the harvest. Still, rice crops usually matured with a 70–90 per cent likelihood prior to annual floods. In urban areas, lower areas by riverbanks also tend to be more exposed (MIMP and IOM, 2015; Rojas-Medina et al., 2008).

In dry seasons, lower average rainfall, drought and lower water levels pose problems but are less researched in the identified studies. Severe drought is sometimes related to shifts from El Niño to La Niña; in these cases, drought and flooding can occur immediately after each other, as was the case with the 2010 drought and the subsequent 2010–2011 floods (Sherman et al., 2015; Sherman et al., 2016). However, drought can also occur independently of ENSO, as the 1964, 1980 and 2005 droughts showed (Marengo et al., 2011). They usually have strong, negative effects on people in Amazonia regardless of their specific location, but the impacts are different for lowland and upland livelihoods. In a study by Langill (2018), 34 per cent of surveyed households have experienced bad drought. List (2016) observes the impacts of drought on 58 per cent of all surveyed respondents. Some studies also mention a general exposure to higher temperatures overall (Hofmeijer et al., 2013; Zavaleta et al., 2018). In addition, some areas are exposed to strong winds. In one study, almost half of all respondents suffer from this hazard (Langill, 2018). Chapter 3.1.5 provides a contextual drought analysis for further reading that shows how millions of Peruvians are now already exposed.

Other water-related hazards are riverbank slumps, erosion and fluvio-geomorphological changes, as described in several studies (Coomes et al., 2010; Manzi, 2005; Langill, 2018; List, 2016). In List's (2016) study, 39 per cent of all respondents have been affected by riverbank slumps; 21 per cent of the households have been affected by riverbank erosion in Langill's (2018) study. Flood stage reversals (*repiquetes*) also affect some communities (List, 2016), in which retreating floodwaters suddenly augment for a short period, reversing stage changes, and then continue with the former trajectory of flood ascent or recession. Several rivers also have low gradients that result in meandering and rivers changing course (Sherman et al., 2015; Sherman et al., 2016).

Finally, non-climatic stressors and shocks also affect people strongly. In some areas, their impact on food security surpass climatic factors (Zavaleta et al., 2018). In List's (2016) study, 75 per cent of all households are affected by commodity price fluctuations and 65 per cent by disease. Further examples of non-climatic stressors include financial loss, population growth, accidental forest fires, natural resource degradation and land degradation (Zavaleta et al., 2018; List, 2016; Coomes et al., 2010).

Text box 3. No-analog threat: Extreme heat and Amazon dieback

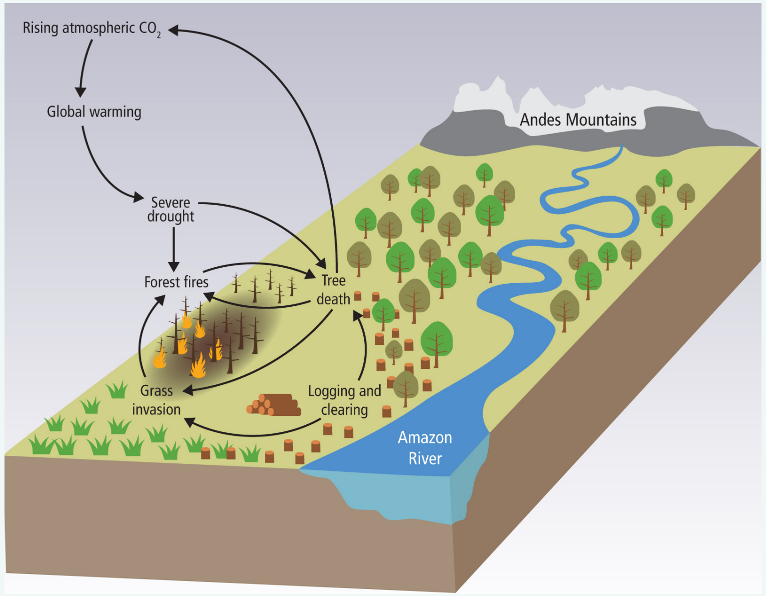
Beyond the hazards examined in the reviewed studies, climate change and deforestation pose no-analog threats to the habitability of Peru's rainforest. In a high-emissions pathway, the rainforest could degrade massively or die back[a] (Masson-Delmotte et al., 2018) while in tandem, the risk of extreme heat stress could escalate in the Amazon basin (Mora et al., 2017b; Andrews et al., 2018). These combined developments would have drastic consequences for ecosystem services, biodiversity, livelihoods and human health. The exposed population could be large: 15 per cent of the total population of Peru, or over 4 million people, live in the vast Peruvian rainforest nowadays, a number that has grown by 10 per cent over the past decade (INEI, 2018) and will likely continue to grow.

On the one hand, climatic changes or deforestation – or a combination of both – may bring the rainforest to a dieback tipping point at which it risks turning into savannah-like vegetation. Deforestation and climatic changes will likely interact in "self-amplifying feedbacks… [that] represent a substantial risk of large-scale Amazon dieback" (Adams et al., 2014, p. 49), as Figure 25 shows. First, regional warming of more than 4°C above pre-industrial and global warming of more than 3°C by 2100 could result in several climatic changes such as stronger El Niño events with more frequent drought that degrade the rainforest and eventually push it over a tipping point (Masson-Delmotte et al., 2018). More wildfires in a hotter world could speed up the process (Lenton et al., 2008; Borma et al., 2013; Malhi et al., 2009). Second, the forest cover could also die back if an estimated deforestation threshold of 40 per cent is crossed (Nobre et al., 2016).[b] Reduced forest cover raises drought risks because the forests can no longer recirculate rainfall sufficiently. More recent estimates warn that negative feedbacks with climate change and wildfires could mean that the threshold for tipping may be as low as 20–25 per cent deforestation. In all countries taken together, 17 per cent has already been lost. In Peru, more than 7 per cent of the rainforest had already been destroyed by 2014; the main cause of such deforestation is agricultural expansion, partially driven by migrants (MINAM, 2016b).

Notes: [a] There is no consensus on its definition, but Amazon dieback can be understood "as the process by which the Amazon basin loses biomass density as a consequence of changes in climate" (Vergara and Scholz (2010, p. 1)).

[b] In future tree growth scenarios, there is still uncertainty about (a) the fertilization effects of increased CO_2 levels and (b) rainfall projections that could affect tree growth, including changes in dry season length and recurrence of extreme drought years (Rammig et al. (2010); Adams et al. (2014)).

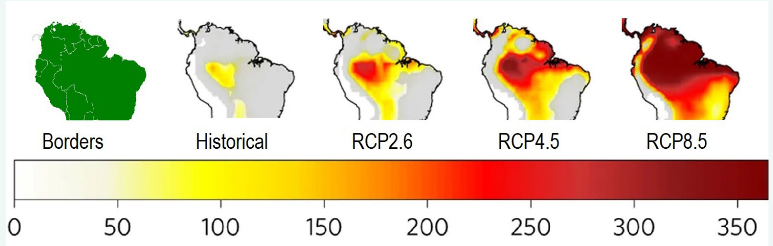
Figure 25. A possible Amazon basin tipping point



Source: Settele et al., 2014, Figure 4-8. Reproduced with permission of the IPCC Secretariat.

On the other hand, climatic changes can result in extreme heat stress in the Amazon basin. Conditions that are too hot, too humid or both can threaten workability and survivability (Andrews et al., 2018). There are many ways in which heat can be deadly for the human body (Mora et al., 2017a). Already, temperatures and humidity nowadays are high in the Peruvian rainforest during much of the year, resulting in a high risk of occupational heat exposure even in the shade during the hottest part of the day in the hottest month of the year (Andrews et al., 2018). Climate change will escalate this heat stress. Heat extremes in tropical areas of South America have already intensified and will likely rise more over the next decades (Feron et al., 2019; Adams et al., 2014). By 2100, the risk of lethal heat is projected to increase strongly in the Amazon region (Mora et al., 2017b): in some areas, global warming of even just around 2°C would result in a sharp increase in the number of days per year when temperature is above the deadly threshold (Figure 26). Across Peru, such conditions would expose more than 10 million people to extreme heat stress (Andrews et al., 2018). In a high-emissions scenario, people in some areas of Peru's rainforest would be exposed to deadly heat almost all year round (Mora et al., 2017b).

Figure 26. Recent and projected extreme heat stress in northern South America



Sources: Borders: Wikimedia Commons. South America, showing national borders only. Copyright-free material (Recreated by user: Stannered (2008). This artwork is in the public domain.

Historical, RCP2.6, RCP4.5 and RCP8.5: Mora et al., 2017b, Figure 3 (cropped from original). Reproduced by permission from Springer Nature Customer Service Centre GmbH: Springer Nature. "Global risk of deadly heat", Mora et al., *Climate Change*, 2017.

Note: The figure shows the number of days per year exceeding the threshold of temperature and humidity beyond which climatic conditions become deadly, averaged between 1995 and 2005 ((a), historical experiment), and between 2090 and 2100 under RCP 2.6 (b), RCP 4.5 (c) and RCP 8.5 (d). Results are based on multi-model medians. Grey areas indicate locations with high uncertainty.

If deadly heat and degradation combine, they can severely reduce the habitability of the Peruvian rainforest and thereby displace at-risk people. The loss of biomass could result in a vast substitution of rainforest through savanna and grassland (Lyra et al., 2017). Even at 1.5–2°C global warming, losses in biomass could be severe. Forest resources would decline severely and livelihoods dependent on these resources would erode. Losing parts of the rainforest would also disrupt hydrological cycles and thereby damage local agricultural productivity. For global warming of 2°C, species range losses in the Amazon may deprive 18 per cent of insects, 8 per cent of vertebrates, and 16 per cent of plants of over half of their climatically determined geographic range (Masson-Delmotte et al., 2018). Adding atop eroded ecosystems, the health impacts of the extreme heat and humidity could be severe. Open-air manual labour, such as in agriculture, could become unbearable (Dunne et al., 2013). For many poor people, indoor ventilation would be prohibitively expensive. The full consequences of such a scenario are difficult to estimate. The combined impacts of deadly heat and rainforest degradation could displace a gradually increasing number of at-risk groups, such as subsistence farmers from the rainforest, while many others could end up trapped in dire circumstances.

Aerial shot of Río Huallaga and the town of Yurimaguas, Loreto, Peru, during a period of high water after the rainy season. © Shutterstock/Kocheise Lea and Lennart

Vulnerabilities

Vulnerabilities in the studied lower Amazon communities exist along social, cultural and economic lines. Some of these factors can "force people to live in suboptimal conditions, partake in dangerous activities, and engage in unhealthy behaviours", including direct exposure to hazards due to inadequate housing (Hofmeijer et al., 2013, p. 957). In the example of the 2012 flooding affecting Belén, 38 per cent of the dwellers in this marginalized urban zone lived in poverty (MIMP and IOM, 2015). The distribution of people's assets also plays a role. People with less-exposed upland assets are usually less vulnerable (Takasaki et al., 1999). While the amount of available land matters, the degree of vulnerability is not predetermined: even if people hold more plots, but if there are more exposed plots among them, they may become more vulnerable to shocks. Landholdings can also be linked to vulnerabilities. The size and quality of landholdings are strongly linked to wealth trajectories, and determines exposure to hazards, as well as the range of reaction strategies (Langill, 2018). Age can be a line of difference as well: the mobile and healthier youth are described as being able to confront floods more easily, while the elderly suffer disproportionately because of their limited capacity to move and work, and because they have more health challenges (Langill, 2018; Takasaki et al., 2010). Gender influences vulnerabilities as well. Women tend to suffer more mental health diseases than men after a 2006 flood (Rojas-Medina et al., 2008), yet gendered vulnerabilities are not predetermined, and men can also be more vulnerable in some situations. In addition, Langill (2018) find that while almost half of her surveyed households self-identified as belonging to an indigenous group, household impacts of the 2011 flood were largely the same for indigenous and non-indigenous groups. For two other indigenous communities, Zavaleta et al. (2018, p. 1) observe that both climatic and non-climatic factors raise food insecurity and simultaneously "mutually reinforced key maladaptation trajectories". Maladaptation is linked to social and food policies by the State that undermine the communities' social cohesion, indigenous disaster risk management knowledge and traditional institutions. Such policies can also incentivize people to sacrifice resources for educational opportunities, which may ultimately erode adaptive capacity, given the often-scarce payouts in terms of jobs or food security. Finally, policies have contributed to demographic growth and increased natural resource degradation in areas of limited diversification options. These cultural, socioeconomic and environmental trajectories have increased social and nutritional vulnerability to climate change.

Vulnerabilities can differ between migrants and receiving communities. Migrants often live in highly exposed areas, such as on riverbanks (MIMP and IOM, 2015; Rojas-Medina et al., 2008). However, for example, Langill's (2018, p. 55) large survey shows that "households that formed in the community were much more likely to be adversely impacted by the 2011 flood… compared to… households that had moved to the village". Conversely, in her focus study site of Éxito, new migrants were more vulnerable to flooding since they lacked knowledge, preparation, equipment and assets. Newcomers were not as "resilient and environmentally knowledgeable" as others (Langill, 2016, p. 114), especially in their first year, although learning lowered their vulnerability over time. The study also shows that not only the length of residence, but the age of the community can influence vulnerabilities: households in the oldest and the newest communities were least likely to have suffered from the 2011 flood.

Impacts

Exceptional floods can have devastating impacts on communities. An exceptional flood in 1993 led to extensive crop failure along the Marañón River, where households rely on crop farming for half of their income (Takasaki et al., 1999). In Tingo María, a flood affected 4,500 people and damaged 715 houses in 2006 (Rojas-Medina et al., 2008). In Belén, the heavy flooding in 2012 destroyed many houses, compromised people's human and food security, and resulted in criminality during and after the disaster (MIMP and IOM, 2015). In Uyucali, the 2010–2011 floods affected almost 60,000 people, caused 6,700 injuries, damaged or destroyed 22,500 houses, and resulted in the loss of 30,000 animals and 40,000 hectares of agricultural areas, as well as great damage to infrastructure (Sherman et al., 2015). The floods did not only destroy livelihood assets, but also inhibited people's working conditions for most livelihood activities long after the event. For the same 2010–2011 floods, Langill (2018) shows that different types of exceptional floods – high, long, early and late floods – carried different impacts. All of these types strongly impaired health, safety and food provision. The author also shows that the location in different river basins can play a role in the prevalence of specific impacts. For example, households in the Amazon River basin noted close to double the prevalence of lost houses and much higher livestock losses than all other basins. While people most often indicated lost crops across all study sites, they were less common in some basins such as the Lower Pastaza and Upper Ucayali river basins. Moreover, lowland households lost disproportionately high amounts of livestock, while other impacts were similar across upland and lowland households (Langill, 2018). In addition, floods can have negative impacts on household savings and mutual assistance (Coomes et al., 2010). Flooding disasters can also strongly deteriorate mental health. For example, people affected by a flood in the city of Tingo María showed a 65 per cent prevalence of acute stress disorder 20 days after the event, and 28 per cent had a comorbidity with major depressive disorders (Rojas-Medina et al., 2008).

Simultaneously, floods can have some positive impacts. Floods, for example, can increase opportunities for fishing as fish diffuse in the floodplain forests (Coomes et al., 2010). Floodwaters can also improve access to and opportunities for forest product extraction and hunting. Flooding can also increase inundated areas suitable for floodplain farming (List, 2016). Although all forms of floods – even exceptional ones – can carry limited positive side effects, one larger scale survey found that their negative impacts on health, safety and food provision – described sometimes as "near-devastating" – tended to outweigh the positive ones (Langill, 2018, p. 123).

Warming temperatures and diminishing rainfall can also cause damage, yet the identified literature explores their impacts less. Droughts lower flow discharges, increase ecosystem vulnerability, raise tree and fish mortality, increase forest fire risks, and affect hydropower generation, as well as fluvial transportation networks (Langill, 2018). The duration and causes of droughts shape their impacts. Hofmeijer et al. (2013) find that droughts worsen growing conditions in their study sites, reduce crop yield size and quality, limit wild fruit alternatives, increase weeds and pests, and raise heat stress for farmers. These impacts stress food security, income generation and purchasing power. Drying rivers and resulting ponds can also increase vector-borne diseases.

Riverbank slumps, erosion, river course changes and flood stage reversals can add to the hazards. For example, flood stage reversals (*repiquetes*) can affect wildlife and swamp newly planted areas at the beginning of the growing season, resulting in crop loss and/or damage in riverside plots (List, 2016). Fluvio-geomorphological changes can restrain the access to navigable water ways and ultimately make land uninhabitable (Manzi, 2005; Sherman et al., 2016).

Coping and adaptation

People usually have strategies to adapt to normal annual flood cycles, but exceptional floods require exceptional responses and sometimes exceed their capacities. Coomes et al. (2010) distinguish ex-ante and ex-post strategies. Before a flood, upland (tierra firme) communities have the ex-ante option to plant crops above flood levels. They can also rely on the ex-ante option of precautionary savings, by storing food, livestock and financial assets. These strategies are unavailable for many lowland communities – because they do not always have upland holdings and their precautionary savings tend to be destroyed during flooding. After flood waters peak, ex-post strategies include switching livelihoods to activities in the floodplain and rain forest. Along the Ucayali River and the Marañón River, 56 per cent and 42 per cent of all households, respectively, in the examined seven communities switched to fishing; 11 per cent and 26 per cent of the respondents along the two rivers, respectively, used hunting or forest product extraction; 34 per cent and 10 per cent, respectively, employed wage labour. Wage labour was only available to those living near urban areas, whereas others were too isolated. None of the surveyed households along the Ucayali River noted cropping on higher ground as a coping strategy, but 26 per cent of those along the Marañón River did. None of the households used formal or informal credit. Since the entire communities suffered from flood damages, mutual assistance was also not used. In another study, most people relied on labour supply when hit by flood shocks, namely, for upland cropping, resource extraction in fishing and gathering, and wage labour (Takasaki et al., 1999). They also used precautionary savings in the form of food stock, livestock and financial assets. The use of these strategies strongly depended on local environments, economic factors and access to resources. Similarly, a large-scale survey across communities found that households mostly shifted livelihood priorities at home after a flood in 2011 (Langill, 2018). Above all, people engaged more in fishing, but some also increased activities in day labour, hunting and farming. Another study mentions harvest delay, crop change and other adaptations to food insecurity (Hofmeijer et al., 2013). By contrast, List's (2016) study shows that the dominant coping response to agricultural shocks through flooding was doing nothing, with 71 per cent of respondents, which highlights their lack of risk reduction options and adaptation strategies. Some people sold productive assets to smooth income and switched livelihood activities, including to timber extraction and waged agricultural labour. Sherman et al. (2015) find that the 2010–2011 floods overwhelmed traditional adaptation strategies and triggered new responses, such as changes in crop mixes towards flood-tolerant varieties. Fortifying housing was also noted, with the potentially ambivalent outcome of protecting people but also inducing them to stay in exposed areas. The study emphasizes that people lacked the means to fully benefit from the positive side effects of the flood in terms of fishing and crop farming opportunities, owing to their poor market access, insufficient labour, limited equipment and seed supplies. All these studies noted different extents of migration responses, discussed further below.

Less literature explores reactions to other hazards. To react to drought, more than half of the respondents in one study did nothing (58%), while 36 per cent sowed again (List, 2016). Zavaleta et al. (2018) mention dispersion into the forest and gathering of wild foods as an adaptation strategy by some indigenous groups during a drought event and a related extreme fire. Manzi (2005) shows how responses to river-related hazards can have very different outcomes. One of the communities in the study reacted to changing river courses that lowered accessibility to waterways by changing their production towards cash crops and less perishable extractive resources. Additionally, the poor often shifted honey-gathering, while wealthier households relied more on firewood extraction. However, the coping could be described as unsustainable, since it depleted resources and ultimately resulted in a "downward spiral of environmental degradation and poverty" (Manzi, 2005, p. 156). In response to riverbank slumps in 1998, one community relocated across the river increased its participation rate in fishing and also coped by specializing in different singular-income activities. Before the shock, only 14 per cent had specialized their livelihoods; afterwards, a total of 57 per cent did: 35 per cent in fishing, 11 per cent in planting maize, 8 per cent in rice and 3 per cent in manioc. The natural disturbance ultimately improved access to land, resources and markets, empowering and benefiting people. A different study of riverbank slumps finds that almost half of the respondents migrated (43%), while almost as many did nothing (39%) (List, 2016).

Human mobility and its consequences

Migration

In many Amazonian settlements, inhabitants have migration experiences and live multi-site lives. Langill (2018) shows that in the village of Éxito, about half of the residents had migration experiences, sometimes in more than one place. The proximity to urban areas animates both permanent and temporary migration to access job and educational opportunities. Sherman et al. (2015) and Sherman et al. (2016) also find that migrants often move to urban areas for employment and education during normal flood years. Over half of the migrants in their study maintain multi-site lives and usually work several months in other rural areas of the Amazon. At the same time, the authors note that most of the higher-educated and -skilled individuals migrated to urban areas for good, and the permanent outmigration of young adults can prompt other family members to follow suit.

Seasonal migration plays a role for many livelihoods. Hofmeijer et al. (2013) observe in their study sites that the entire working-age population employs this strategy, particularly during the rainy season, when food insecurity rises. Seasonal migrants work in urban centres or seasonal harvests to gain cash income that allows mitigating food insecurities when rainfall constrains subsistence food production. Langill (2018) observes that the youth, especially, frequently migrate during the flood season to find other income sources and return home subsequently. Another study describes that as much as 75 per cent of households employ seasonal migration as a "pre-emptive risk management strategy" during the rainy season, using extended family networks for jobs, shelter and food while in their temporary homes (Sherman et al., 2015; Sherman et al., 2016, p. 561). In the year prior to the authors' survey, half of the households had one or more members working in other locations for a given time of the year. While some emigrate temporarily to the cities each year to avoid the flood cycle, other households also permanently move as a result of consecutive flood shocks (Sherman et al., 2015; Sherman et al., 2016, p. 561). In some of their study areas, those who lack social and financial resources to move opt to stay. Likewise, in another case, environmental changes that eroded traditional livelihood opportunities led to some permanent rural-urban migration (Hofmeijer et al., 2013).

Mobility also plays a role as a coping and adaptation strategy when facing intense flooding. As opposed to the more anticipatory migration described above, Sherman et al. (2015, p. 561) described this type of movement as an "almost-instantaneous response to flood conditions". In the case of a flood in 2004, one third of households in their study site left permanently to a close-by city (Sherman et al., 2015; Sherman et al., 2016). Similarly, the authors find that after the flooding in 2010–2011, subsistence farmers and fishers increasingly searched for jobs outside their home village because their marginal positions prevented them from profiting from opportunities created by the flood and limited their adaptation strategies. The authors describe migration as a coping strategy; however, finding income outside of their home village prove difficult, as many employers also suffered from flood damage. List's study (2015) finds that while most people (71%) lacked options to respond to intense flooding, another substantial share of 20 per cent temporarily migrated to find other income sources. In three study sites along the Ucayali River, 22 per cent of households used migration to cope with major floods, whereas in four other study sites along the Marañón River, the figure was only 6 per cent (Coomes et al., 2010). Takasaki et al. (1999) find a similar number in four villages along the Marañón River, affected by an unusually high and long-duration flood in 1993. Around 6 per cent of the households used migration, but the authors did not notice direct evidence of remittances as a coping strategy.

Other types of hazards may result in human mobility, yet fewer studies explore them. One study finds that migration was the dominant coping response for riverbank slumps across four villages along the Amazon River (List, 2016). Some 43 per cent migrated and almost as many did nothing. Conversely, migration does not seem relevant as a coping strategy for water insecurity and vector-borne diseases, according to another study (Hofmeijer et al., 2013). Similarly, a study of four villages along the Marañón River notes that health shocks are absorbed mostly through the selling of livestock and mutual insurance, but not through migration (Takasaki et al., 1999).

Some studies indicate that migration can reinforce precarious conditions. Sherman et al. (2015), for example, observe that seasonal migration did not help to lower the need for permanent migration among respondents in their study site. However, they also note that more permanent migrants often end up in "low wage and temporary" positions in small businesses or logging operations (Sherman, 2015, p. 2055; 2016). Migrants tend to lack skill sets for dignified jobs and face limited job options or unemployment in cities. When they do have jobs, incomes are often unreliable, and exploitation is widespread. Many of the migrants were previously subsistence farmers who now suffer from serious food insecurity because they cannot produce their own food anymore in the cities. The unfamiliar need to spend money on food is complicated by the fact that majority of migrants face financial challenges due to their precarious work conditions. Overall, the authors find that migrants are "unable to successfully leverage migration to increase their own resilience" and do not improve their well-being in the cities (Sherman et al., 2015, p. 2072). Another study notes that some households make their eldest children migrate to earn income, which deprives them of educational opportunities and could "degrade the household's asset base and reinforce the poverty cycle" (List, 2016, p. 84). Migration can also have strong economic impacts on those staying behind: Sherman et al. (2015) and Sherman et al. (2016) note that male outmigration raise food insecurity for family members left behind, who now lack the labour resources for fishing, tending crops and controlling pests.

The studies highlight the social and cultural effects of emigration. While moving sometimes allows for educational opportunities, it can also result in the separation of household members (Sherman et al., 2015) and the abandonment of older family members (Sherman et al., 2016). If older family members follow the migrants, local traditional knowledge and wisdom on community history is lost (Sherman et al., 2015). The authors also document limited possibilities of migrant networks to transmit financial remittances, social capital, innovation, technology, knowledge or skills back to their areas of origin. Relationships between migrants and those remaining behind were often stressed, given their lack of money and inability to provide for each other.

Displacement

Intense flooding that destroys or damages people's assets and health often results in temporary evacuation, displacement or relocation. For example, when a flood hit the city of Tingo María in 2006, more than 400 people who lost their homes were moved to a temporary shelter in a college in which they lived for two months (Rojas-Medina et al., 2008). Many people also abandoned houses that were not destroyed but "only" affected by the flood for fear of a new fluvial event. Similarly, in 2014, 860 families suffered from displacement in San Martín and 118 in Loreto, respectively, and with more displacements occurring in Madre Dios (MIMP and IOM, 2015). The authors discuss the case of Belén in more detail. When flooding hit the neighbourhood in 2012, more than 1,000 families had to move to shelters in close-by areas (MIMP and IOM, 2015). Many were displaced and some of them required relocation. Displacement occurred progressively, with some immediately fleeing to shelters whereas others persisted in risk zones and were eventually evacuated to schools. Those willing to relocate were transferred to relocation centres in the wastelands. Ultimately, the displacement resulted in diffuse spatial distribution: some people moved to second homes in other places, some to relatives in cities and some to camps. Still others joined surviving settlements or invaded new spaces to settle. Most movement occurred within the same district, but some was also directed to surrounding districts. Only a few moved to other regions, such as Lima. After the flood receded, most affected people went back to their homes even as flood risks persisted. Less people decided to settle permanently in their temporary homes.

Flood-induced displacement often compromises human security. Especially when flooding hits fast, people usually fail to save their possessions and suffer from food insecurity (MIMP and IOM, 2015). Health challenges after the flooding of Belén in 2012 included respiratory, stomach and skin diseases, and infections such as dengue, malaria and leptospirosis on the one side. On the other side, people also suffered from mental health issues such as post-traumatic stress disorder, depression and somatization. Temporary housing after the disaster offered inadequate basic services and did not allow people to access their livelihoods and markets, which resulted in people invading other zones or returning to flooded areas too soon.

Relocation

Several studies mention "relocation", although in most it remains unclear whether a relocation was implemented by the State – or if the villagers moved themselves and "relocation" is used synonymously for migration. For example, a village studied by Hofmeijer et al. (2013) "was forced to relocate" when the river meandered and changed its course (p. 960), but the study does not describe the movement in more detail. Similarly, List (2016, p. 15) mentions the upstream "relocation" of a village on the Amazon River, given the serious riverbank erosion. In another village, "continued erosion may force relocation" in the future (List, 2016, p. 17). Sherman et al. also notice that one community "has had to relocate several times due to shifts in river flow" (2015, p. 2053): first in 1940, temporarily to one city and in 1946 to another one, and then again in 2004. Another community may require relocation upland given its exposed location on a meandering river, if other pre-emptive mechanisms fail (Sherman et al., 2015; Sherman et al., 2016). Flooding in 2006 in the city of Tingo María also resulted in "relocations" (Rojas-Medina, Vargas Machuca and Trujillo, 2008). In all cases, it is unclear whether people moved themselves or were relocated. In addition, the studies do not describe the processes and third actors, if any, in more detail.

The examined "relocations" had ambiguous outcomes. One study finds that as much as 80 per cent of those relocated after a flooding event suffered from acute stress disorder, compared with 48 per cent of people whose houses were only damaged (Rojas-Medina et al., 2008). Comorbidity with major depressive disorders was also much higher for those who were relocated, with a 40 per cent prevalence, compared to 16 per cent of those who remained in their own homes. The authors explain these increased mental health challenges with the uncertainty of relocation, the unfamiliar new surroundings and the multiple unmet needs of those relocated. Note that it is unclear whether "relocated" in this study refers to all displaced people or only to those factually resettled by the State. Manzi (2005, p. 11) mentions how recurrent riverbank slumps forced a community to "relocate" upriver or "migrate elsewhere" in 1993. The "relocation" resulted in precarious and disordered living conditions. In 1998, the community had to relocate again due to a riverbank slump, this time across the river. This relocation eventually improved access to land, resources and markets, empowering and benefiting people. Again, it is unclear whether both described instances of movement constituted an actual relocation or if people moved themselves.


The Amazon rainforest in Tambopata National Reserve, Peru. © Shutterstock/Salparadis

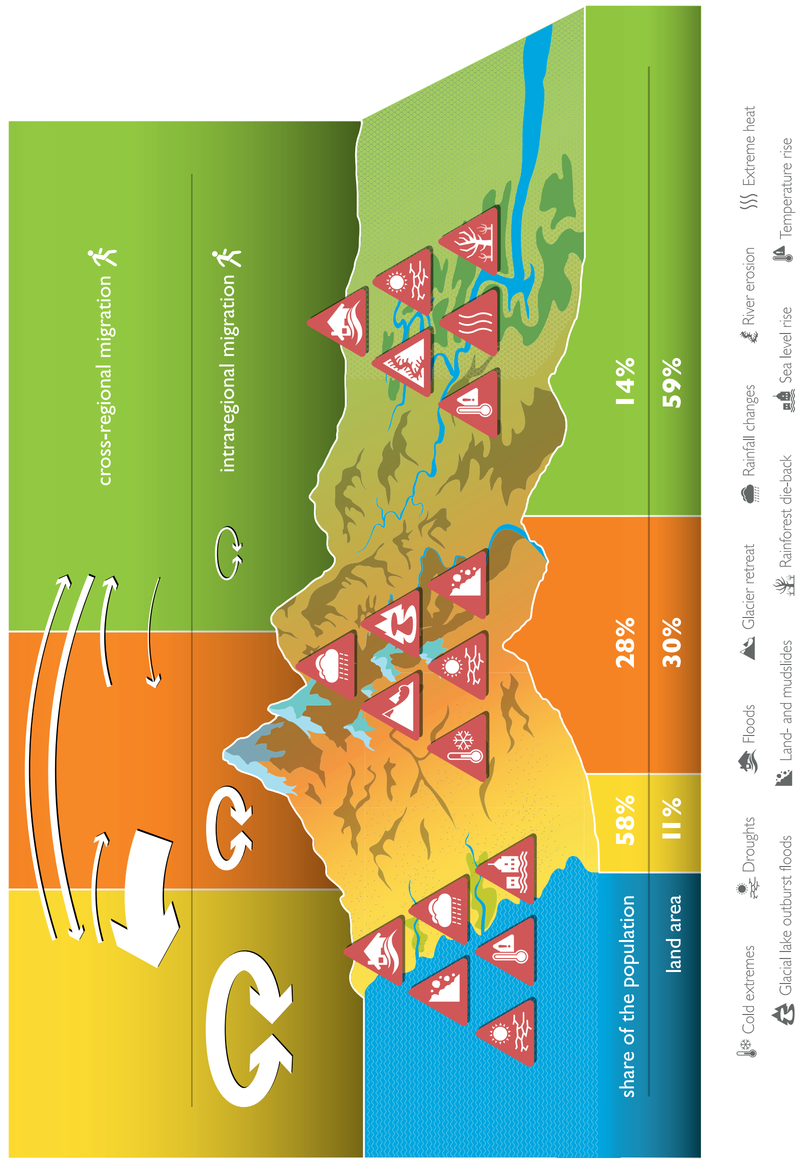
2.2.4. Climate risks and human mobility: A summary

In summary, research attention on the nexus between hazards and mobility has been strongest for the Peruvian highlands and weaker for the rainforest and the coastal zones, although the latter is home to most of the country's population and economy. For all regions, methodologically sound studies are available, while robustness varies greatly across all studies. In the study sites, people mostly rely on livelihoods from the primary sector. Typically, examined households are rural subsistence farmers who strongly depend on resources susceptible to climate impacts. Few studies mention or explore non-agricultural activities. In particular, poor smallholders often lack diversification, which increases their vulnerabilities to climate impacts. Vulnerable situations in the studies also relate to age and gender, but none of these factors – and others, such as ethnicity or physical ability – are explored in detail. In terms of hazards, the reviewed investigations on the costa focus on El Niño events and pay only some attention to other hazards, such as droughts and increasing temperatures, as well as the interactions between these slow-onset and sudden-onset events. In the sierra, studies examine some interactions. They mainly discuss glacier retreat and rainfall changes, but also temperature changes and a few others. In the rainforest, studies mostly investigate flooding and to a small extent reduced water availability and erosion. The studies show that people use a range of coping and adaptation strategies to deal with hazards locally. These range from changes within livelihood activities or inputs to targeting different ecosystem services, sectors or different areas of production. However, several studies warn that many people already lack options today and other studies mention an increasing failure of traditional techniques. Recovery from shocks is often partial and can result in downward spirals of poverty and deprivation. Several studies also highlight the limits of current adaptation practices given the magnitude of future changes.

People in Peru often lead multi-site lives or migrate for various reasons, including hazards. Across regions, findings indicate that people use temporary and permanent migration, among many other coping and adaptation strategies, when confronting hazards that erode livelihoods. Migration could also occur when hazards deteriorate people's place satisfaction, for example, when treasured environments erode or sacred glaciers disappear. Studies show that the use of migration depends on social lines of differentiation, for example, age (younger people leave more often), deprivation (the poor are more likely to migrate) and gender (slightly more men move), as well as on the degree of geographic isolation or connectedness. Examples of migration in the context of hazards on the coast include fishermen moving along the coastline as a function of ENSO-driven marine resource availability and farmers in Piura migrating for income diversification during droughts. In the highlands, climate change impacts accelerate large, existing emigration flows. Studies observe migration for work due to cold spells, freezing and frost in Cusco, Huancavelica and Puno. Migration in search of other incomes and remit money is also noticed due to water scarcity driven by glacier retreat in Áncash, Cusco and Junín, especially in later stages of retreat. These hazards often combine with widespread rainfall changes. Studies find that farmers migrate due to livelihood and food insecurity triggered by such rainfall changes and droughts in Áncash, Junín and Piura. Some evidence also exists on flood-driven migration in Piura. In the rainforest regions of Ucayali and Loreto, farmers preemptively and temporarily migrate during the rainy season to mitigate food insecurities. Consecutive hazards also drive permanent migration in these regions. Similarly, studies here observe migration to cope with single intense flooding events or erosion. Conversely, some cases of water scarcity in the regions of Ucayali and Loreto have not resulted in significant migration. In the past decades, Peru has already seen a redistribution of its population prompted by socioeconomic and human security reasons, mainly away from the highlands to the urban centres along the coast, and, to some extent, the rainforest. This pattern is likely to be intensified by climate impacts.

Figure 27 gives a schematic overview by overlaying general historical migration patterns across the three main topographical zones of Peru, showing the hazards mentioned most in the identified studies.

Figure 27. Net lifetime migration across Peru's three main topographical zones, with relevant hazards shown



Source: Conceptualized by Jonas Bergmann and produced by webreform GmbH.

Note: The width of the arrows is indicative of the relative magnitudes of migration within and between Peru's three main topographical zones (costa, sierra and selva), based on data from the last census (INEI, 2017). For the calculation, administrative regions were assigned exclusively to one of these three regions. (For example, regions in the selva were Amazonas, Loreto, Madre de Dios, San Martín and Ucayali.) The hazards indicated in the triangles are those most frequently mentioned in the studies reviewed.

The review shows that the differential consequences of such migration depend on hazards, household profiles, migration trajectories and timeframes, and characteristics of receiving areas. On the positive side, studies show that migrants can move out of harm's way. They can diversify incomes, learn new skills and send remittances to other vulnerable people. On the flipside, some studies indicate that migration can reinforce precarious conditions. It can erode local knowledge and adaptive capacity in some regions of Peru and deprive sending communities of workforce for labour-intensive agriculture. Migrants also often face demanding new surroundings and psychosocial challenges. Some bring skills with only limited transferability to cities. Overall, few studies look at the impacts on destination areas.

Studies on disaster displacement focus on impacts of intense rainfall, fluvial or pluvial flooding, as well as flashfloods by the coast and in the rainforest. Some people were also displaced due to wet mass movement and extreme temperatures. The studies show that these hazards can take a high psychosocial toll on people who lose their homes, livelihoods and assets. Examples include displacement after El Niño events in Peru's northern coastal regions and after intense flooding in the rainforest regions of Huánuco, Loreto, Madre Dios and San Martín.

Cases of planned relocation are often related to El Niño flooding and *huaicos* (flash floods), for example, in the desert regions of Piura and Lambayeque. Some cases in the regions of Huánuco, Loreto and Ucayali relate to riverbank erosion and changes in slumps or meandering, although in these studies, it remains unclear whether relocation was facilitated by the State or if people moved by themselves. The examples show that these relocations can carry substantial risks, as planners often overlook salient land and social issues and livelihood necessities, such as market access, as well as people's place attachment.

In parallel, the review suggests that even in areas affected by climate change, many people opt to stay, at least in the beginning of gradual changes. They often attempt to adapt locally first, yet climate change can also wear down the resources of at-risk groups to move in the first place, trapping them in increasingly dangerous areas. The poorest of the poor, who lack the resources to move away, are of concern. Many other people are also bound to their homes through place satisfaction, social obligations or fear of leaving, such as communities in the highlands of the Lima Region.

One consistent deficit across studies is a lack of detailed analysis of past and future climate risks. For example, Peru could confront three no-analog displacement threats, whose interplay has not been researched so far: pressure on the coastline through more frequent, intense El Niño events on top of rising sea levels; extensive deglaciation and resulting water scarcity; and extreme heat stress in tandem with the risk of massive Amazon degradation in the rainforest. The next chapter provides this type of climate risk analysis for three reasons: First, to embed the findings on the hazard–human mobility nexus in Peru in a larger context; second, to identify possible blind spots in the coverage of risks that can trigger human mobility; and third, to shed light on potential future flows.

The tropical Pastoruri Glacier at Huascarán National Park in Áncash Region, Peru. © Shutterstock/Von CAIOACQUESTA

3. ANALYSIS OF RISKS RELATED TO CLIMATE CHANGE IN PERU

Given the frequent lack of in-depth discussion of climate risks in the reviewed studies, the subsequent chapters provide a more detailed analysis. The first subchapters discuss climate change trends, projections and related hazards (3.1), as well as details about the ENSO phenomenon (3.2). Key hazards include extreme temperatures, glacier retreat, precipitation changes, droughts, intense rainfall and flooding, and sea-level rise. Subchapter 3.3 also provides a general vulnerability analysis. Subchapter 3.4 analyses impacts on agriculture and food security.

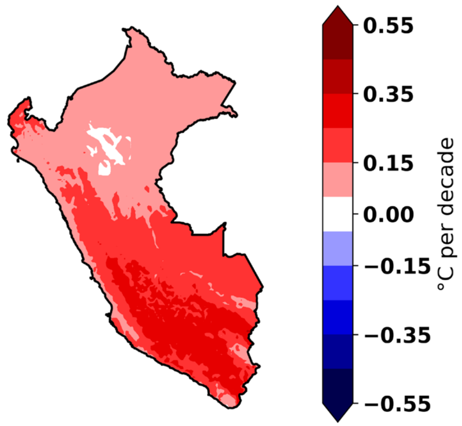
3.1. CLIMATE TRENDS, PROJECTIONS AND EXPOSURE TO HAZARDS

3.1.1. Observed temperature and rainfall trends

The temperatures in all of Peru have been rising during the last three decades, with regionally variable trends.[17] The strongest warming trend is observed in the southern Andes of Peru, where warming rates reach up to 0.3°C per decade since 1981 (Figure 28). Temperatures in the Amazon basin have increased only slightly. Generally, temperatures increased strongest in the austral winter (based on data from Peruvian Interpolated data of SENAMHI's Climatological and Hydrological Observations (PISCO) not shown in the figure) and in high elevations (Vicente-Serrano et al., 2018). The rising temperatures in the high Andes have contributed to the melting of Peru's glaciers, which are discussed in more detail in Section 3.1.4.

17 Note that past trends are subject to uncertainties: available long-term weather data limits the investigation of past climate trends. In a country with such complex topographies and climates such as Peru, weather stations can only tell a small part of the whole story. Since the late 1970s, satellites allow for more comprehensive monitoring, but the data is less reliable. Observational data sets that include information from satellites as well as weather stations provide comprehensive information with higher reliability. The Peruvian meteorological service has produced such a data set for temperatures (Huerta et al., 2018) and rainfall (Aybar et al., 2019) since 1981. This so-called PISCO data set allows for nationwide trend analysis, although there is still high uncertainty in the rainforest region due to data scarcity (Aybar et al., 2019).

Figure 28. Linear trend in mean surface air temperature, 1981–2016



Source: Produced by Stephanie Gleixner based on PISCO data (Aybar et al., 2019).

Observed long-term annual rainfall and runoff show a varied pattern throughout Peru. Whereas temperature responds rather directly to changes in radiative forcing and the observed increase in CO_2, the response of the hydrological cycle is far more complex and locally even contradictory among observational data sets (Hartmann et al., 2013). Due to the complexity of the Peruvian terrain, local precipitation trends vary strongly and trend analysis from gridded data sets like PISCO alone might misrepresent local trends. Therefore, most studies for Peru rely on station data, which then only represents a very local situation.

Average precipitation trends in the Peruvian costa show no significant trends in the past. The dry northern coastal regions show a tendency towards increased average precipitation, while the southern coastal regions shows a tendency towards decreased average precipitation, but those trends are not significant (Haylock et al., 2006). While average precipitation showed no significant trend, Heidinger et al. (2018) found an intensification of precipitation in the southern coastal basins. One long-term study analysing changes and trends of annual rainfall and runoff at basin level over the three drainages during the 1969–2004 period found no significant trend in mean annual rainfall and runoff in basins draining into the Pacific (Lavado-Casimiro et al., 2012), but they reported positive changes and trends in minimum annual runoff in almost all coastal basins. Rau et al. (2019) carried out hydrological modelling of Pacific basins in quasi-natural conditions and estimated a regional discharge to the Pacific Ocean with a significant increasing trend of about 43 m^3/s per decade over the 1970–2010 period, likely due to first stages of glacial melt.

Average rainfall and runoff show no significant trends along the Peruvian Andes (Huerta and Lavado-Casimiro, 2020; Lavado-Casimiro et al., 2013; Heidinger et al., 2018, by Segura et al., 2019). However, an intensification of precipitation in the Titicaca basin was reported, despite the lack of an overall precipitation increase (Heidinger et al., 2018; Fernández-Palomino and Lavado-Casimiro, 2016).

While many studies have found no significant change in average rainfall in the Amazon region (Heidinger et al., 2018; Haylock et al., 2006), a recent study based data investigated more regional trends within the Amazon basin. They found a significant rainfall increase in the southern rainforest regions (Southern Ucayali basin) and a weak decrease in the centrally located rainforest regions (Northern Ucayali basin) (Motta Paca et al., 2020). For the northern rainforest regions, a very wide-spread but non-significant increase in precipitation was found (Motta Paca et al., 2020). In contrast, Lavado-Casimiro et al. (2013) found a significant rainfall decrease in the Northern rainforest regions. A study at the basin scale reported a significant negative trend in both rainfall and runoff for the Peruvian Amazon basin at the Tamshiyacu hydrological station (Lavado Casimiro et al., 2012). Another study on this basin also reported a trend of -0.81 per cent per year in discharge time series over the 1970–1997 period (Espinoza et al., 2006).

3.1.2. Future temperature and rainfall trends

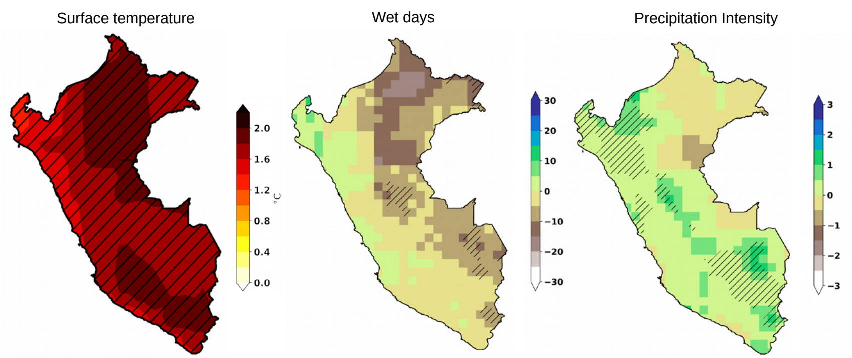
Future temperatures will continue to increase in all of Peru.[18] There is high model agreement that temperatures over the Peruvian landmass will continue to increase throughout the twenty-first century. Depending on the emissions scenario, even in low-emissions scenarios, local average temperature over the landmass could increase by 0.75–1.5°C by mid-century and by 1–1.75°C by the end of the twenty-first century – compared to the 1985–2005 average, not pre-industrial times. In a high-emissions scenario, average temperatures over Peru could increase by an additional 1–2°C by the middle of the twenty-first century (Figure 29, left) and 3.5–6°C by the end of the twenty-first century (not shown). However, the warming pattern differs between climate models. The average of four Inter-Sectoral Impact Model Intercomparison Project (ISIMIP) models shows

18 Outlooks towards the future climate rely on climate models with two limiting factors: model uncertainties and emission uncertainties. Simulated surface temperatures are more reliable than simulated precipitation. Recent climate models have used four scenarios to cover possible future emissions, the so-called representative concentration pathways (RCPs) (van Vuuren et al., 2011). RCP8.5 assumes the highest greenhouse gas concentrations, leading to a likely global mean surface temperature increase of 3.2 to 5.4°C for the end of the twenty-first century relative to 1850–1900 (pre-industrial times). Only RCP2.6, the most optimistic scenario that requires strong mitigation measures, shows a global temperature increase (0.9–2.3°C) staying well below the 2°C limit of the Paris Climate Agreement (Collins et al., 2013). This report refers to RCP8.5 as high, RCP6.0 and 4.5 as medium, and RCP2.6 as low-emissions pathways or scenarios. Even consistent implementation of current pledges in countries' Nationally Determined Contributions (NDCs) can lead to between 2.9°C and 3.4°C higher global mean surface temperatures above pre-industrial times by 2100 (World Meteorological Organization (WMO), 2019).

the weakest warming trends on the coast, likely due to the cooling effect of the ocean. This warming trend is also expected for daily minimum and maximum temperatures, with a strong increase in the number of tropical nights by 2100 (Marengo et al., 2009; Collins et al., 2013).

Future rainfall trends vary strongly between regions. In addition, projections on rainfall changes are generally much less robust than temperature trends. Nevertheless, models agree that Peru shows a general tendency towards fewer rainy (or wet) days, but more intense rainfall events (Giorgi et al., 2014; Christensen et al., 2013). In Figure 29 (middle and right), the average of four climate models shows a decrease in the number of wet days and an increase in rain intensity on wet days over most of Peru by the middle of the twenty-first century. This means fewer but more intense rainfall events. Regionally, climate models show an increase in average rainfall in the very dry northern coastal regions (Sörensson et al., 2010; Vera et al., 2006, ISIMIP models). The south-eastern Andes and the Titicaca basin would experience an increase in average rainfall, as well as longer dry spells; therefore, an increase in rainfall intensity is expected in the twenty-first century, particularly in the austral summer (Giorgi et al., 2014; Vera et al., 2006, ISIMIP models; Sörensson et al., 2010; Christensen et al., 2013). The sign of future changes in mean precipitation, as well as in precipitation extremes in the Amazon is highly uncertain (Cook and Vizy, 2008; Giorgi et al., 2014; Sörensson et al., 2010, ISIMIP models; Christensen et al., 2013).

Figure 29. Future temperature and rainfall trends



Source: Produced by Stephanie Gleixner. All 2030–2050 projections are based based on the average of four bias-adjusted CMIP5 models (GFDL-ESM2M, HadGEM2-ES, IPSL-CM5A-LR and MICROC5) from Phase 2b of ISIMIP (Frieler et al., 2017).

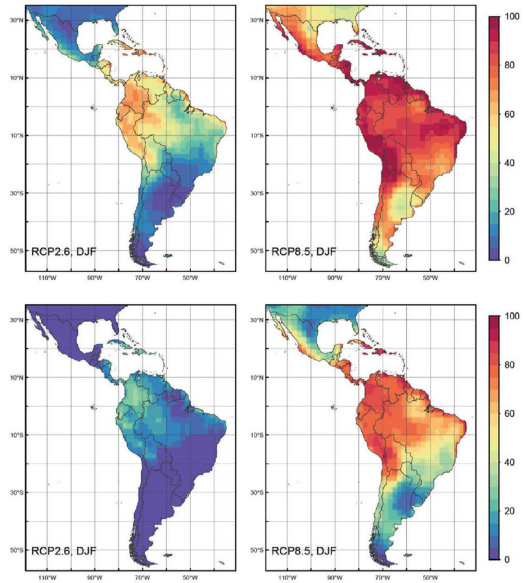
Notes: Left: Difference between 1985–2005 (actual) and 2030–2050 (projection under RCP 8.5) mean surface air temperatures.
Centre: Difference between 1985–2005 (actual) and 2030–2050 (projection under RCP 8.5) annual wet days.
Right: Difference between 1985–2005 (actual) and 2030–2050 (projection under RCP 8.5) mean precipitation intensity on wet days.

Long-term climate scenarios mostly show reductions of dry-season runoff and increases of wet-season discharge for both the 2050s and 2080s. Water yield assessment under climate scenarios is challenging and still limited for Peru. Existing studies agree that dry-season runoff could be significantly reduced, while wet-season discharge could be higher under low- and medium-high-emissions scenarios, with more critical changes for high scenarios by the end of the century in the Andean basins, such as the glaciated catchment of Llanganuco situated in the northwest of the Cordillera Blanca (Juen et al., 2007), the glaciated Vilcanota river basin in southern Peru (Andres et al., 2014; Lavado Casimiro et al., 2011), and the Chancay-Huaral river basin in the Lima Region (Pacific drainage) (Olsson et al., 2017). Main river basins of the Amazon, such as Marañón, Huallaga and Ucayali, do not show significant changes in mean runoff under different emissions scenarios in the future (Zulkafli et al., 2016; Lavado Casimiro et al., 2011). The projected wet season flood pulse in the Peruvian Amazon by the end of the century, however, will become more severe in a medium-emissions scenario and far more critical in a high-emissions future (Zulkafli et al., 2016). Research on hydrological changes in the Titicaca Lake basins is scarce. There is agreement on a temperature increase but significant discrepancy in the precipitation projections by climate model projections (Canedo et al., 2016).

3.1.3. Extreme temperatures

Evidence shows that temperature extremes have already increased and are set to rise further. Temperature extremes show corresponding warming trends throughout Peru. The number of cold nights has decreased, whereas the number of tropical nights and hot days increased, with the night-time extremes warming stronger than daytime extremes (Donat et al., 2013; Skansi, María de los Milagros et al., 2013). Extremely warm days have increased at least by a factor of two over recent decades in northern South America over the December–February period (Feron et al., 2019). Increases are visible especially from 1995 onwards (Ceccherini et al., 2016). The Global Facility for Disaster Reduction and Recovery (GFDRR, 2019) notes medium hazard levels of heat waves for Peru. Increased warming will make extremely hot temperatures more likely over larger land areas during the next decades. By 2050, in a medium emissions scenario, extremely warm days and heatwaves per season would increase 5–10 times at locations close to the Equator and in the Atacama Desert. In a high-emissions scenario, what is considered an extremely hot summer day in Lima today would become 11 times more frequent compared to 1961–1990 (Feron et al., 2019). By the end of the century, extremely hot austral summer months will be much more frequent, as depicted in Figure 30 (Adams et al., 2014). Tropical coasts such as that of Peru experience the largest increases in these summer month heat extremes.

Figure 30. Projected extreme hot summer months in Latin America and the Caribbean



Source: Adams et al., 2014, p. 46. This artwork is licensed under Creative Commons Attribution-NonCommercial-NoDerivs 3.0 IGO (intergovernmental organization) licence.

Note: These maps are for illustration purposes only. The boundaries and names shown and the designations used on these maps do not imply official endorsement or acceptance by the authors, the International Organization for Migration or the Potsdam Institute for Climate Impact Research.

The figures depict multi-model means of the percentage of austral summer months over 2071–2099 with temperatures greater than 3-sigma (top row) and 5-sigma (bottom row) for 2°C (left) and 4°C warming (right). In a stable climate, 3-sigma events would occur about once every 740 years. As 5-sigma events have a return time of several million years, they have been virtually absent so far. The bottom right graph shows that in a business-as-usual warming scenario, the unprecedented 5-sigma events could occur in about 70 per cent of Peru's summer months between 2071–2099.

3-sigma heat events,[19] still an exception nowadays (return time several hundred years), will be the norm in approximately half of the summer months at the end of the century. While 5-sigma events are virtually absent from current climatic conditions (return time: several million years), in a 2°C warmer world, these events will occur in 20 per cent of summer months. In a 4°C warmer world, most summer months will be warmer than 3-sigma and 70 per cent will be warmer than 5-sigma as well. Global risk of deadly heat – exceeding the threshold of temperature and humidity beyond which climatic conditions become deadly – by the end of the century will increase by between 48 per cent with drastic emissions reductions and 74 per cent with growing emissions (Mora et al., 2017b). The risk is projected to increase especially severely in Peru and its Amazon region (Andrews et al., 2018). Text box 3 in Section 2.2.3 provides more information on how extreme heat stress, combined with forest degradation, poses a no-analog threat to Peru's rainforest populations.

19 3-sigma or 5-sigma events are characterized by monthly and seasonal temperatures typically more than 3 or 5 standard deviations (sigma) warmer than the local mean temperature.

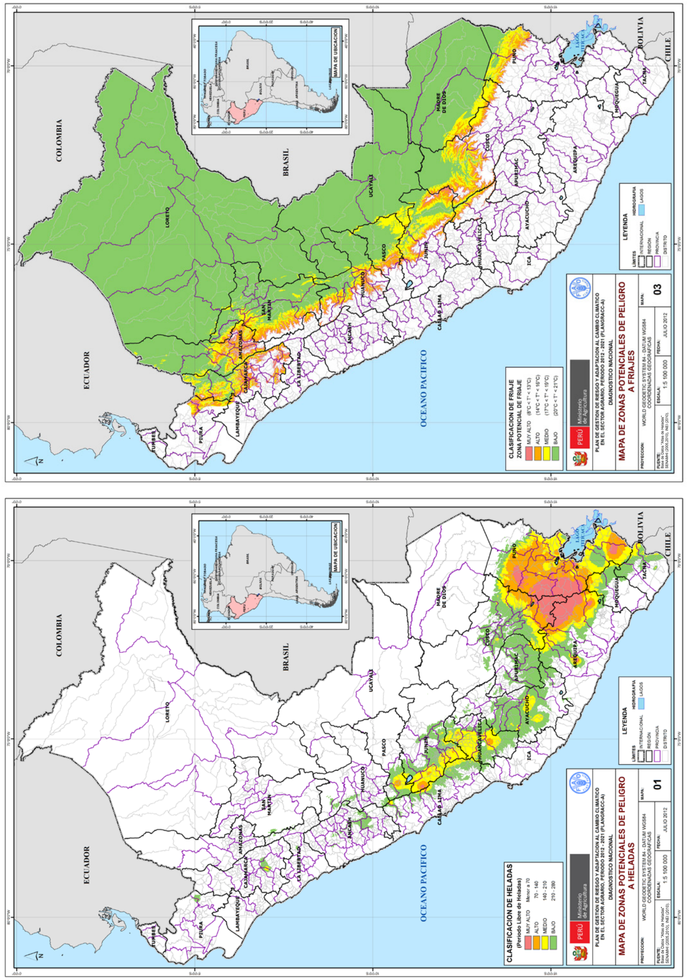
Besides heat, low and very low temperatures also affect many people in Peru. According to the Government, increased climate variability has resulted in more low temperature hazards since 2002. The total population exposed in 2014 was 7 million people across Ancash, Arequipa, Apurímac, Ayacucho, Lima, Cusco, Junín, Moquegua, Pasco, Puno, Tacna and Huancavelica (SINAGERD et al., 2014). Figure 31 shows the exposure to cold waves on the left and the exposure to *friajes* on the right.

Meteorological cold waves are called heladas in the highlands, usually when the temperature drops below 0°C (SENAMHI, n.d.).[20] They occur with clear skies or low cloud cover and usually at the end of the rainy season, in April and until September. Waves are usually coldest and most frequent in June and July. Exposure exists in almost all areas above 3,000 masl, but the southern highlands and the highest elevations are most exposed. Agrometeorological cold waves, which can kill plant tissues, refer to decreases in air temperature at individual critical levels of crops, which can be higher than 0°C. For example, in the northern highlands and part of the central sierra, although temperatures do not necessarily drop to or below 0°C, they do affect crops and health.

By contrast, meteorological *friajes* result when masses of cold air coming from the Antarctic enter the south of the continent through the La Plata basin and eventually the Peruvian territory via the Titicaca plateau. *Friajes* produce moderate to intense rains, strong winds, thunderstorms and sudden descent of temperatures outside the season in the rainforest (SENAMHI, n.d.). On average, maximum temperatures can sink by as much as 35–22°C because of cloudiness. The entry of cold reduces air minimum temperatures from 22°C to 11°C. Peru registers an average of between 6 to 10 *friajes* per year, which usually persist for about three to seven days and up to ten days, mostly between May and August (SINAGERD et al., 2014). *Friajes* can affect people's health, crops and livestock, as well as fauna and flora. In the rainforest, 3.2 million people recurrently experience *friajes*, mostly in Loreto and San Martín, followed by Ucayali and Madre de Dios. Amazonas, Huánuco, Pasco, Junín, Cusco and Puno are also exposed.

20 In some areas of the southern highlands, the normal minimum temperature is below 0°C, so danger occurs when the temperature drops below those normal values.

Figure 31. Exposure to frost and cold waves in Peru



Source: Ministry of Agriculture and Irrigation (MINAGRI), 2012, pp. 35 and 37. Reproduced with permission of MINAGRI.

Notes: These maps are for illustration purposes only. The boundaries and names shown and the designations used on these maps do not imply official endorsement or acceptance by the authors, the International Organization for Migration or the Potsdam Institute for Climate Impact Research.

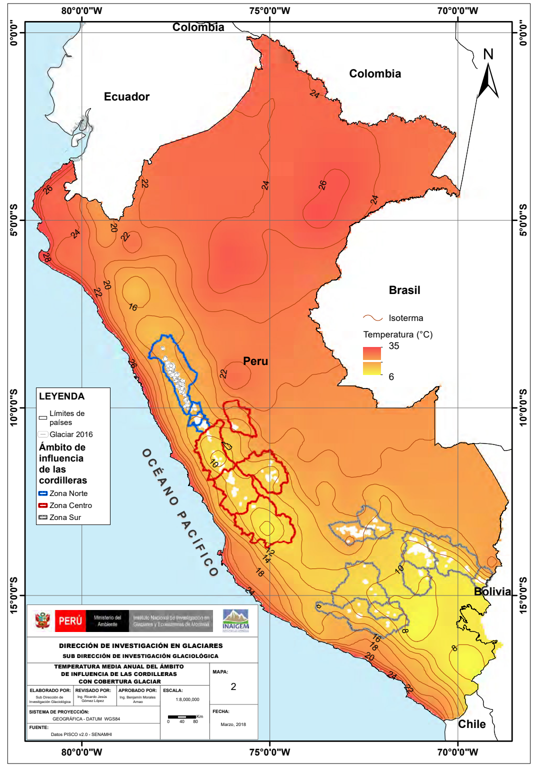
Left: Exposure to frost (*heladas*) in Peru. *Clasificación de Heladas (Periodo Libre de Heladas)*/Frost Classification (Periods Free from Frost): *Muy alto*/Very high, <70 days; *Alto*/High, 70–140 days; *Medio*/Medium, 140–210 days; *Bajo*/Low, 240–290 days. *Leyenda*/Legend: *Límites*/Borders – *Internacional*/Internacional; *Región*/Region; *Provincial*/Province; *Distrito*/District; *Hidrografía*/Hydrography – *Lagos*/Lakes. (Translation by the authors.)

Right: Exposure to cold waves (*friajes*) in Peru. *Clasificación de Friaje (Zona Potencial de Friaje)*/Cold Wave Classification (Potential Areas of Cold Waves): *Muy alto*/Very high, 6–13°C; *Alto*/High, 14–16°C; *Medio*/Medium, 17–19°C; *Bajo*/Low, 20–21°C. (Translation by the authors.)

3.1.4. Glacier retreat

The Peruvian Andes are home to more than 70 per cent of the world's tropical glaciers, which constitute one of the most important sources for water supply throughout the Andes (Veettil and Kamp, 2019; Chevallier et al., 2011; Takahashi and Martinez, 2018). In 2014, Peru had 19 glaciated Cordilleras, with 2,679 glaciers covering a surface of about 1,300 km^2 (ANA, 2014). Figure 32 shows their locations.

Figure 32. Peru's glacial mountain ranges and temperatures in their spheres of influence



Source: INAIGEM, 2018, p. 39. This artwork is licensed under the Creative Commons Attribution 4.0 International licence.

Notes: This map is for illustration purposes only. The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the authors, the International Organization for Migration or the Potsdam Institute for Climate Impact Research.

Leyenda/Legend: *Límites de países*/Country boundaries; *Glaciar* 2016/Glaciers in 2016; *Ambito de influencia de las cordilleras*/Sphere of influence of mountain ranges: *Zona Norte*/Northern Area; *Zona Centro*/Central Area; *Zona Sur*/Southern Area; *Isoterma*/Isotherm; *Temperatura*/Temperature. (Translation by the authors.)

Warming observed since the mid-twentieth century has been triggering a rapid retreat of the Peruvian glaciers. Many studies have reported that these glaciers have been experiencing a progressive and accelerating retreat since the mid-twentieth century (Bury et al., 2011; Georges, 2004; Hastenrath and Ames, 1995; Racoviteanu et al., 2008; Seehaus et al., 2019; Veettil, 2018). Glacier retreat varies among the Cordilleras, but percentage surface losses are at least 40 per cent for all glaciers (INAIGEM, 2018). Recently, a total countrywide glacier area loss of 549 ±66 km^2 (29%, at 34.3 km^2/year) during the 2000–2016 period was reported (Seehaus et al., 2019). Glaciers retreated 33.5 per cent between 1975 and 2016 in the largest range, the Cordillera Blanca (Veettil, 2018). In the second largest, Cordillera Vilcanota, observed glacier area loss was 32 per cent during the 1975–2016 period (Salzmann et al., 2013; Suarez et al., 2015). An even greater area loss of 79 per cent from 1975–2015 was observed in the Cordillera Carabaya (Veettil et al., 2017). The small glaciers Chila, Chonta and Huanzo are about to disappear, with below 10 per cent remaining glacier surface. Several other, slightly larger glaciers are already below 30 per cent (INAIGEM, 2018).

The recent severe glacier retreat is likely explained by two factors: the higher frequency of El Niño events and changes in its spatial and temporal occurrence since the late 1970s, together with a significant observed warming trend of 0.13°C per decade between 1950–2010 over the tropical Andes (Rabatel et al., 2013; Vuille et al., 2018; Vicente-Serrano et al., 2018). In addition, local conditions, including morphological and glaciological characteristics, affect glacier mass balance (Juřicová and Fratianni, 2018; Veettil and Kamp, 2019). Conversely, precipitation did not display a significant trend in the tropical Andes in the twentieth century and therefore cannot explain the glacier retreat (Rabatel et al., 2013).

Future glacier change might be dramatic given projected changes in temperature. The Nevado Coropuna may disappear completely around the 2120s if present rates continue (Kochtitzky et al., 2018). The Quelccaya Ice Cap could completely lose its accumulation zone before the end of the twenty-first century under a high-emissions scenario (Yarleque et al., 2018). A similar behaviour might be expected across tropical glaciers since model projections indicate continued warming of the tropical troposphere throughout the twenty-first century, with a higher temperature increase at higher elevations over the Andes (Vuille et al., 2008). Glaciers located below 5,400 masl are the most vulnerable to disappear (Rabatel et al., 2013). Even before their disappearance, runoff will decrease once peak flow is crossed, with potentially strong impacts on water security. Melting rates will accelerate in the near future, with peak river runoff projected in 20–50 years in most areas (Adams et al., 2014). Even for low and medium-emissions scenarios leading to 2° or 3°C warming above pre-industrial temperatures by 2100, volume losses are projected to be at 78–97 per cent for the Central Andes, while retreat in a high-emissions scenario inducing 4°C warming would be close to complete with 93–100 per cent (Radić et al., 2014; Marzeion et al., 2012). (Text box 2 in Section 2.2.2 provides a more detailed analysis of how glacier retreat and associated water scarcity will pose a no-analog threat to Peru's highland populations.)

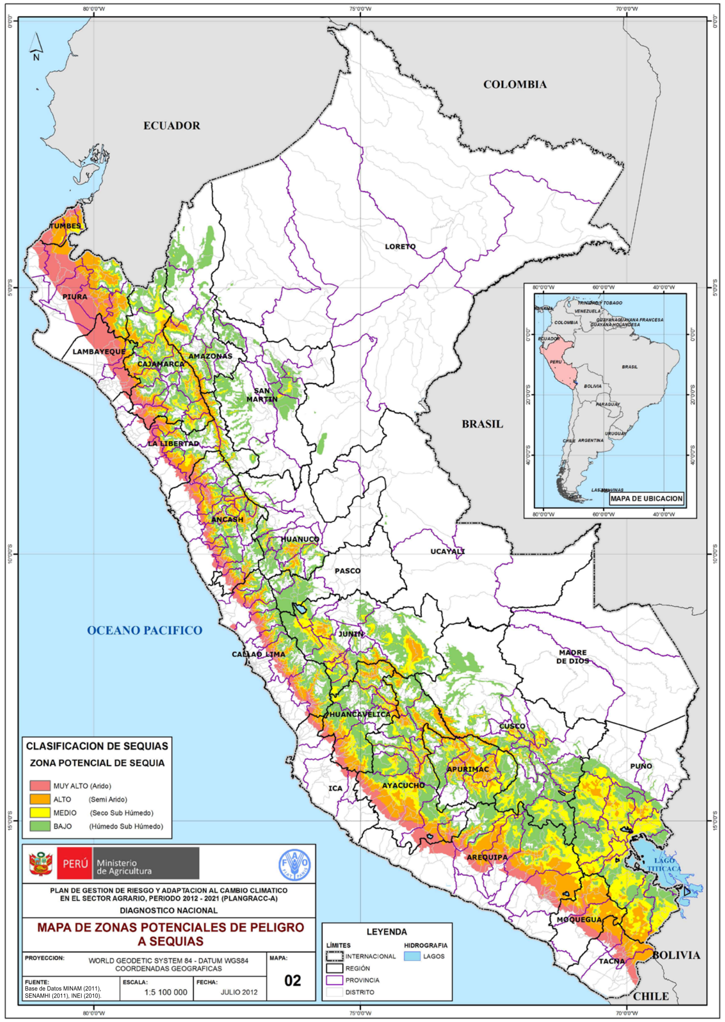
3.1.5. Droughts

Droughts reduce water supply for people, crops, livestock and businesses. Between 1981 and 2018, ten episodes of meteorological drought[21] occurred in Peru, excluding the coastal desert areas (SENAMHI, 2019).[22] Droughts had moderate to extreme intensities and their spatial coverage ranged from 13 per cent to 79 per cent. Most droughts were linked to the warm phase of ENSO.

Close to 13,000 communities with almost 3.5 million people were exposed to droughts in 2007, out of which 2.5 million lived in the agricultural zones of Peru (SINAGERD et al., 2014). Droughts usually hit the southern parts of Peru the hardest, particularly in the sierra of Huancavelica, Ayacucho, Apurímac, Arequipa, Cusco, Puno, Moquegua and Ica, as well as in some of their coastal territories. The highest number of drought events have occurred in the Altiplano and the northern high jungle (SENAMHI, 2015).[23] The longest durations are noted for the upper part of the northern Amazon basin and central coast. The greatest intensities of droughts have occurred in the southern coast and southern high rainforest. Drought events have intensified both in the southern coast and the Altiplano. Future drought risk will likely increase most in these two locations (greater frequency and greater intensity, but of short duration), as well as in the high and low rainforest. The National Disaster Risk Management Plan notes high drought risk for the regions of Lambayeque, Tacna and Ica, and medium risk for Áncash, Apurímac, Arequipa, Ayacucho, Cajamarca, Huancavelica, Junín, La Libertad Moquegua, Piura, Puno and Tumbes (SINAGERD et al., 2014). Figure 33 shows the zones with drought risk throughout the country.

21 Meteorological droughts mean a deficit of precipitation over a large area and for a considerable period of time. (Refer to the glossary for definitions of other types of drought.)
22 According to the Standarized Precipitation Index (SPI), using PISCO (Peruvian Interpolate data of the SENAMHI's Climatological and Hydrological Observations) monthly precipitation data.
23 The study designed eight regions according to shared drought characteristics.

Figure 33. Drought risk zones in Peru



Source: MINAGRI, 2012, p. 36. Reproduced with permission of MINAGRI.

Notes: This map is for illustration purposes only. The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the authors, the International Organization for Migration or the Potsdam Institute for Climate Impact Research.

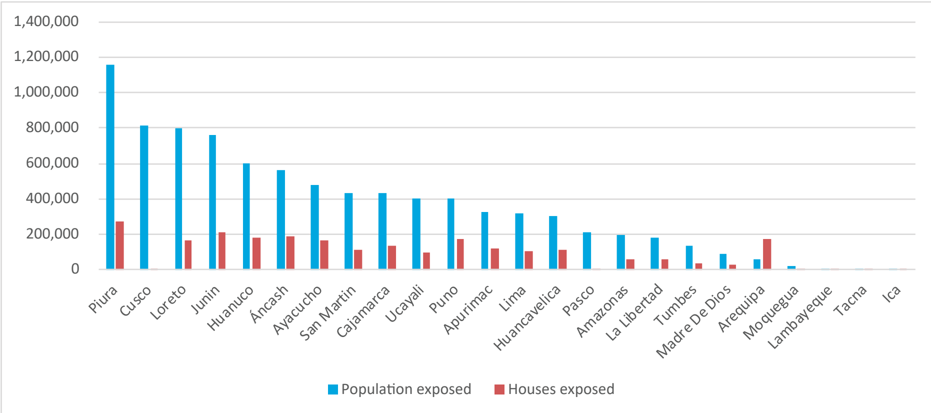
Clasificación de Sequias (Zona Potencial de Sequia)/Drought Classification (Potential Drought Areas): *Muy alto (arido)*/Very high (arid); *Alto (semi-arido)*/High (semi-arid); *Medio (seco, sub-húmedo)*/Medium (dry to sub-humid; *Bajo (húmedo subhúmedo)*/Low (humid to sub-humid). *Leyenda*/Legend: *Límites*/Borders – *Internacional*/Internacional; *Region*/Region; *Provincial*/Province; *Distrito*/District; *Hidrografía*/Hydrography – *Lagos*/Lakes. (Translation by the authors.)

Adaptation to dryness becomes increasingly important with ongoing climate change, for example, because glacial melt results in a diminishing water source for agriculture (Buytaert et al., 2017). Exemplary measures include improved water storage, water harvesting and better soil management practices (GTM-NDC, 2018). In the last decades, investments in irrigation systems have been made to overcome water shortages for agricultural production, yet they have also led to unsustainable water withdrawal rates. Conflicts over water and the negative environmental effects of development have resulted, for example, in the depletion of groundwater and saline intrusion, particularly in coastal catchments. Investments are needed to increase the currently low irrigation efficiency and more guidance needs to be provided to water-user organizations and farmers to improve the use and maintenance of irrigation schemes and reduce water waste (Lajaunie et al., 2013).

3.1.6. Intense rainfall and floods

Intense rainfall concern people across Peru. Such rain occurs mostly between September and May and may result in flooding, *huaicos* (flash floods) and landslides. In 2014, 9.2 million Peruvians (about one in three) were frequently exposed to hydrometeorological hazards (SINAGERD et al., 2014). Figure 34 shows the disparities between regions: Piura has the largest number of exposed people, followed by Cusco, Loreto and Junín. Several other regions also have medium-high exposure, while some others have only small numbers of people exposed, such as Ica and Tacna. Some of the most exposed basins are Mantaro, Ramis, Vilcanota, Majes, Santa, Mayo, Amazonas (Loreto), Marañón (Amazon) and Huallaga.

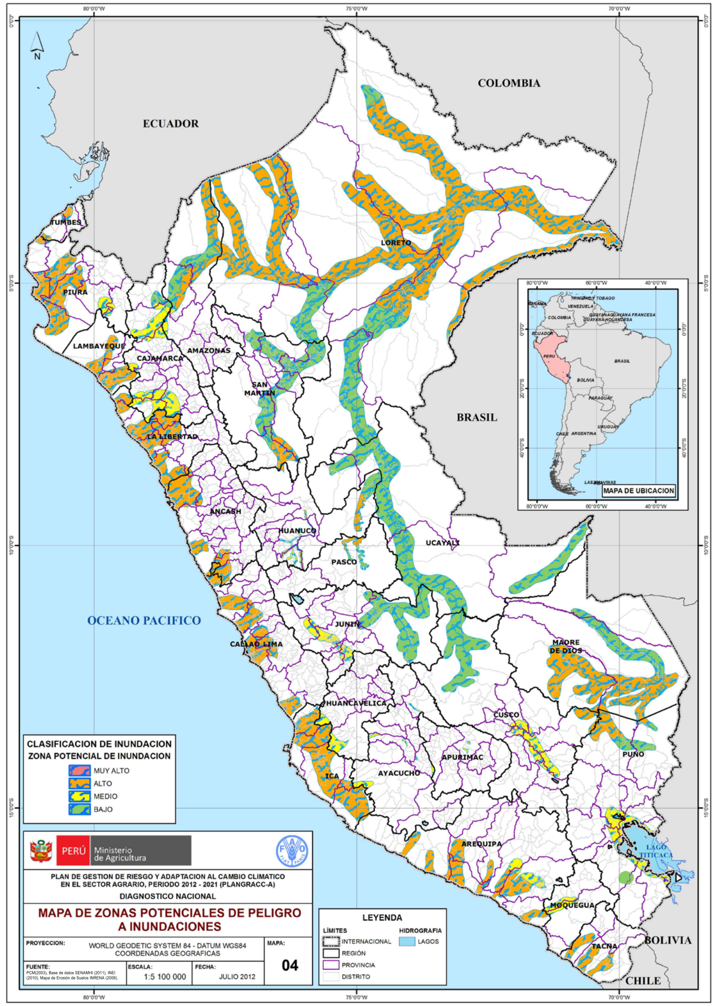
Figure 34. Population and houses exposed to hydrometeorological phenomena associated with intense rains by regions



Source: Produced by Jonas Bergmann based on data from SINAGERD et al. (2014, p. 25).

Flood hazards are already present in Peru and likely to increase displacement risk. Figure 35 shows current flood exposure. Flooding has been intensifying, especially in the Amazon (Gloor et al., 2013; Barichivich et al., 2018; Bodmer et al., 2018; Marengo et al., 2013), and flooding duration, as well as the number of affected areas, are expected to increase in many zones (Langerwisch et al., 2013). With limited agreement between models, precipitation trends only give indications of potential future change. Peru can expect fewer rainy days, but more intense rainfall events (Christensen et al., 2013; Giorgi et al., 2014) and, therefore, potentially also more flooding. As discussed in Section 3.1.4, especially strong Eastern Pacific El Niño events are also likely to increase over the coast (with less confidence, also Central Pacific El Niños and extreme La Niñas), potentially resulting in a higher frequency of extreme precipitation. The Global Facility for Disaster Reduction and Recovery (GFDRR) classifies hazard levels of river floods, urban floods and coastal floods as high for Peru.

Figure 35. Flood risk zones in Peru



Source: MINAGRI, 2012, p. 38. Reproduced with permission of MINAGRI.

Notes: This map is for illustration purposes only. The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the authors, the International Organization for Migration or the Potsdam Institute for Climate Impact Research.

Clasificación de Inundación (Zona Potencial de Inundación)/Flood Classification (Potential Flood Areas): *Muy alto*/Very high; *Alto*/High; *Medio*/Medium; *Bajo*/Low. *Leyenda*/Legend: *Límites*/Borders – *Internacional*/Internacional; *Region*/Region; *Provincia*/Province; *Distrito*/District; *Hidrografía*/Hydrography – *Lagos*/Lakes. (Translation by the authors.)

3.1.7. Sea-level rise

Climate change drives sea-level rise (SLR) for several reasons. It contributes to thermal expansion of the oceans, melts ice and changes terrestrial water storage (Masson-Delmotte et al., 2018). Associated impacts include salinization, coastal erosion, coastal flooding and storm surges, which can harm both human and ecological systems such as coastal settlements, low-lying land, infrastructure, health, heritage, freshwater, biodiversity, agriculture and fisheries.

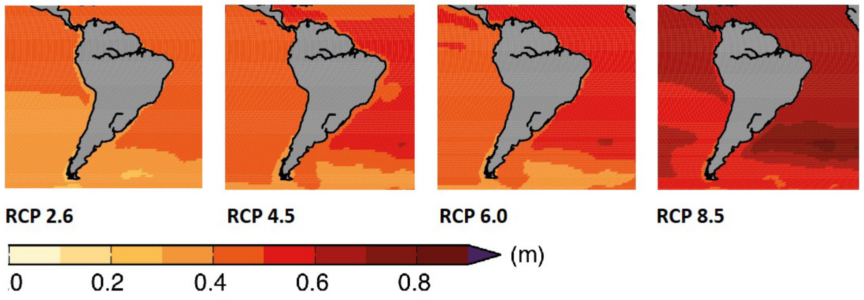
Global mean sea-level rise will depend on the greenhouse gas emissions pathway taken (Church et al., 2013). For 2100 compared to 1986–2005, the lowest pathway will likely result in global mean sea-level rises between 0.29–0.59 m and the highest pathway in between 0.61–1.10 m (IPCC, 2019). Sea-level rise remains a very long-term threat. After 2100, locked-in SLR will continue strongly. By then, in a high-emissions pathway, global mean sea-level rise is projected to reach 15 cm per decade (IPCC, 2019). The collapse of the West Antarctic Ice Sheet could add several metres in the long term. A loss of the Greenland ice sheet would add about 7 m on a timescale of centuries to millennia.

Regional trends can differ from global means. In Central and South America, the rate of SLR has already accelerated over the past decades (Magrin et al., 2014). For Peru, ensemble mean regional relative sea-level change modelling suggests that the highest-emissions pathway could result in SLR of about 0.7 m by 2100, as shown in Figure 36. With global rates reaching 15 cm per decade by then in a high-emissions pathway (IPCC, 2019), a 1-m rise could be reached over the next 100 years in Peru.[24]

Synergetic effects of rising sea levels and more strong El Niño events could worsen periodic coastal flooding in Peru (Reguero et al., 2015). Intervallic El Niño events can raise sea levels significantly for several months over the tropical west coast of South America. In the future, they will occur on top of substantially higher sea levels than in the past. An El Niño event similar to the one in 1998 on top of projected sea-level rise would significantly increase the exposed population along the west coast of South America and particularly in Peru. Climate change can also result in an increase of strong El Niño events (Cai, Santoso et al., 2015; Cai et al., 2018; Pörtner et al., 2019), as discussed in Subchapter 3.2.

24 Recent studies (see, e.g.: Pörtner et al., 2019) have shown that sea-level rise will be more severe than the sea-level rise of 0.60 to 0.81 m along the northern coast of Peru over the next 100 years expected by the Ministry of Environment several years ago (MINAM, 2010b).

Figure 36. Projected sea-level rise in Latin America



Source: Church et al., 2013, p. 1196 (cropped from original). Reproduced with permission of IPCC.

Notes: These maps are for illustration purposes only. The boundaries and names shown and the designations used on these maps do not imply official endorsement or acceptance by the authors, the International Organization for Migration or the Potsdam Institute for Climate Impact Research.

Ensemble mean regional relative sea-level change (in metres) between 1986–2005 and 2081–2100, evaluated from 21 CMIP5 models for the different RCP scenarios: 2.6, 4.5, 6.0 and 8.5 (from left to right).

Text box 1 in Subchapter 2.2 provides a more detailed analysis of how sea-level rise, together with periodical, stronger El Niño events, will pose a no-analog threat to Peru's coastline population.

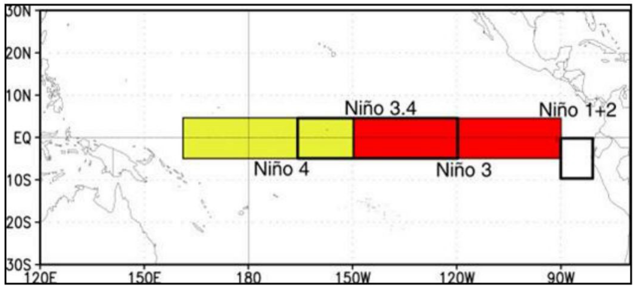
3.2. EL NIÑO AND COASTAL EL NIÑO

The El Niño Southern Oscillation (ENSO) is Peru's most important and consequential driver of natural climate variability. ENSO is characterized by warming (El Niño) and cooling (La Niña) events of the sea surface temperature (SST) in the equatorial Pacific, which are accompanied by atmospheric changes (Southern Oscillation). El Niño and La Niña events can profoundly modify the weather in Peru, especially the precipitation pattern. El Niño events occur irregularly every few years (in the last decades, every one to five years) and La Niña events usually develop afterwards. A less common phenomenon with a similar impact on Peru is the coastal El Niño, also discussed below.

3.2.1. El Niño Southern Oscillation (ENSO)

In years without El Niño or La Niña, the Eastern Pacific is relatively cold due to the upwelling of colder water. The trade winds push this water along the equator, warming it up during the journey, to the Western Pacific, where it piles up and forms a warm water pool. During El Niños, the trade winds are weakened along the equator and warm water migrates eastward, resulting in anomalous warming in the central and eastern equatorial Pacific and a reduction in the cold water upwelling (McPhaden et al., 2006). In contrast, during La Niñas, the trade winds are stronger and the eastern equatorial Pacific is colder than normal. El Niño is usually defined by the warming in the Niño 3.4 area (see Figure 37), which often also leads to a warming in the Niño 1+2 area off the coast of Peru and Ecuador. ENSO exhibits an asymmetry, with the largest El Niños being larger than the largest La Niñas.

Figure 37. The locations of the Niño areas



Source: Climate Prediction Center (NCEP), 2020. Reproduced with permission of NCEP. This artwork is in the public domain.

Note: This map is for illustration purposes only. The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the authors, the International Organization for Migration or the Potsdam Institute for Climate Impact Research.

There are two kinds of El Niños with different effects: Extreme El Niños tend to be characterized by peak SST anomalies in the far Eastern Pacific and thus are referred to as Eastern Pacific El Niños; conversely, the peak SST anomalies in the second type of El Niño are confined to the Central Pacific (Sanabria et al., 2018). These two kinds of El Niño have different effects on the precipitation in Peru. Strong Eastern Pacific El Niños lead to increased precipitation in the coastal (especially northern) regions, while in the southern Andes, Titicaca and Amazon regions, it results in decreased rainfall (Lavado-Casimiro and Espinoza, 2014). The rainfall decreases are pronounced in the Titicaca region because the El Niño events take place in the rainy season (December–May) (Lavado-Casimiro and Espinoza, 2014). Central Pacific El Niños are associated with decreased rainfall over upstream regions along the Pacific slope (Rau et al., 2017). In contrast, strong La Niña episodes lead to increased precipitation in the Amazon, Titicaca and Andes regions (Lavado-Casimiro and Espinoza, 2014). Besides the effects on land, El Niño also reduces the upwelling of nutrient-rich colder waters off the coast of Peru, especially in the north, which impacts the availability of plankton and thus the populations of fish such as anchovies (Ros-Tonen and van Boxel, 1999). Some studies also note possible positive side-impacts of El Niño events, for example, on scallop availability by the southern coast (Badjeck et al., 2009; Badjeck, 2008), and on longer-term availability of pasture, planting areas and refreshed forests in the north (Sperling et al., 2008). The predictability of El Niño is strongly hampered by the so-called spring predictability barrier: predictions that cross the boreal spring are especially challenging. This barrier limits the pre-warning time to about six months (Timmermann et al., 2018).

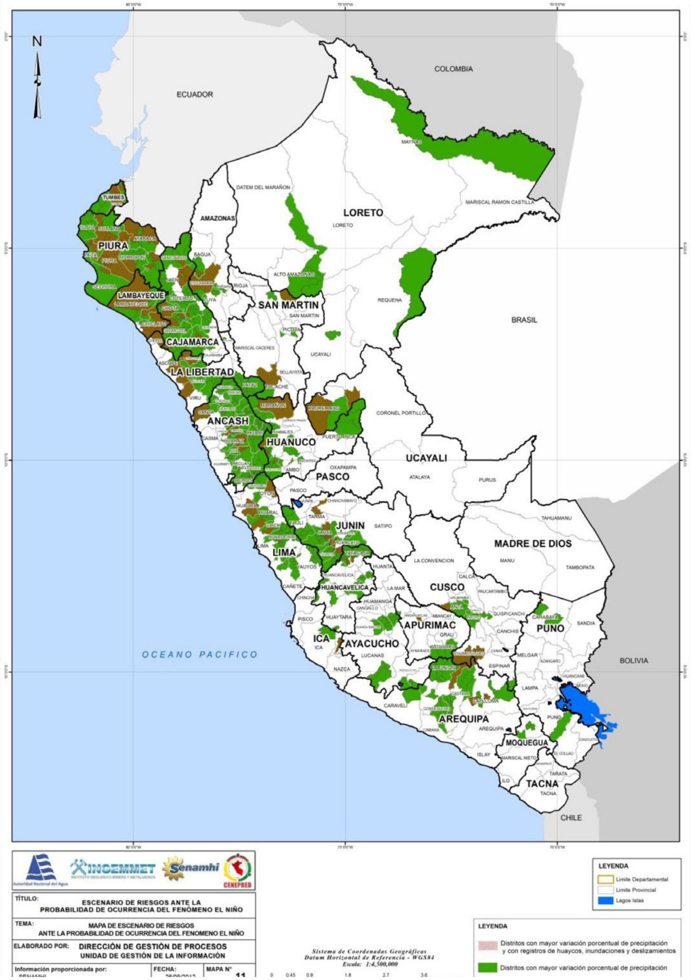
Paleo-climatic reconstructions based on fossil coral show a broad range in the natural ENSO variability in the past 7,000 years (Cobb et al., 2013). The twentieth-century ENSO variance is significantly higher than the preindustrial average; however, it is not unprecedented. Also, the observed ENSO variance of the last decades was significantly higher than in the previous centuries (McGregor et al., 2013).

Climate change will likely alter ENSO patterns. A majority of climate models project that the sea-surface temperature variability will increase, leading to an increase in the number of strong Eastern Pacific El Niños, although model projections do not completely agree (Cai et al., 2018). For example, Cai et al. (2018) find an increase of strong Eastern Pacific El Niños for the average of a selected set of models from about six in the twentieth century to about nine in the twenty-first century. For Central Pacific El Niños and extreme La Niñas, models also project increased frequencies under greenhouse warming, however, with a weaker inter-model consensus (Cai, Wang et al., 2015; Cai et al., 2018). The IPCC (2019) has medium confidence that extreme El Niño events will occur about as twice as often under both low- and high-emissions pathways in this century as compared to the last one. These increases could imply that the frequency of extreme precipitation associated with strong ENSO events like the ones of 1982–1983 and 1997–1998 could also increase, but not all strong El Niños have the same extreme impact on Peru (Sanabria et al., 2018). For example, the strong El Niño of 2014–2016 was more similar to Central Pacific El Niños than the previous extreme El Niños and had less effect on Peru.

3.2.2. El Niño Southern Oscillation hazards

Phenomena associated with El Niño and La Niña can have devastating impacts. For example, the 1982–1983 El Niño cost Peru an estimated USD 3.283 million and the 1997–1998 El Niño, over USD 3.5 million, which corresponded to 11.6 and 6.2 per cent of the respective annual GDPs (Sanabria et al., 2018; Vargas, 2009). Not counting droughts, 734 districts, close to 2 million homes with over 7 million people are exposed (SINAGERD et al., 2014). The regions with the highest number of exposed people are in the north of the country: Piura (1.7 million), Cajamarca (1.2 million), Lambayeque (0.9 million), Áncash (0.8 million), La Libertad (0.5 million) and Junín (0.4 million). 150 districts are likely exposed to floods, landslides and mudslides with a population of about 0.7 million. Figure 38 and 39 show risk scenarios of El Niño events and numbers for population and housing exposed. Text box 1 in Subchapter 2.2 provides a more detailed analysis of how periodical, stronger El Niño events, on top of permanent sea-level rise, will pose a no-analog threat to Peru's coastline population.

Figure 38. Risk scenario for El Niño occurrence in Peru

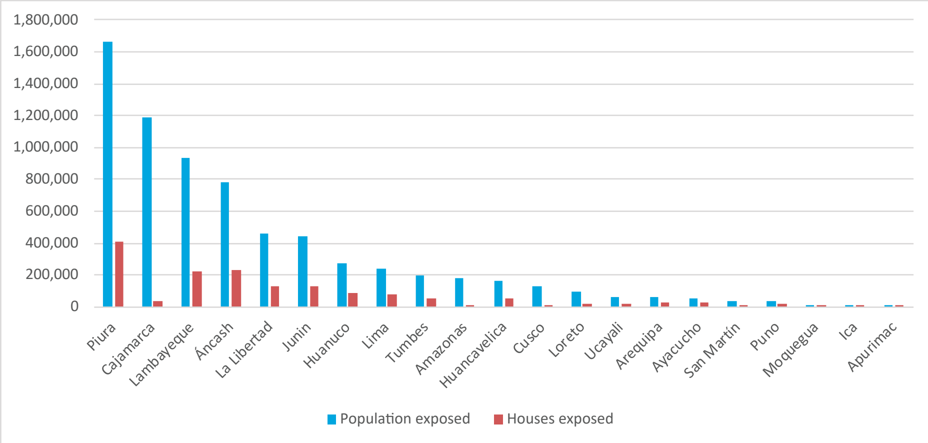


Source: SINAGERD et al., 2014, p. 26. Reproduced with permission of SINAGERD.

Notes: This map is for illustration purposes only. The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the authors, the International Organization for Migration or the Potsdam Institute for Climate Impact Research.

Leyenda/Legend: *Límite departamental*/Departmental boundary; *Límite provincial*/Provincial boundary; *Lagos islas*/Lakes Islands. *Distritos con mayor variación porcentual de precipitación y con registros de huaicos, indaciones y deslizamientos*/Districts with highest percentage variations of precipitation and records of flash floods, floods and landslides. *Distritos con mayor variación porcentual de precipitación*/Districts with highest percentage variations of precipitation. (Translation by the authors.)

Figure 39. People in Peru exposed by probability of ENSO events



Source: Produced by Jonas Bergmann based on data from the Peruvian National Centre for Disaster Risk Estimation, Prevention and Reduction (CENEPRED) (SINAGERD et al., 2014).

Note: The data does not include exposure to ENSO-related droughts.

3.2.3. Coastal El Niño

A coastal El Niño (in the narrow sense) can be characterized by strong warming in the Niño 1+2 area off the coast of Ecuador and Peru with no associated warming in the Niño 3.4 area (see Figure 37). If the El Niño 3.4 area also exhibits warming, the El Niño would be regarded as a common "Pacific-scale" El Niño. During the warming, the temperatures in the Niño 1+2 area have to exceed the convective threshold, that is, the temperature where air can rise up to a high altitude (approx. 27°C in the current climate) (Peng et al., 2019). Coastal El Niños occur most likely between January and April, when the sea-surface temperatures off Peru reach their annual maximum and additional warming can move them above the convective threshold. Model experiments indicate that two components are important to cause the sea-surface temperature increase necessary for extreme coastal El Niños: downwelling ocean waves caused by strong westerly wind events over the equatorial Pacific and local northerly alongshore wind anomalies. This coincidence of two different processes may explain the relative rarity of extreme coastal El Niños. A forecast of extreme coastal El Niños with up to one-month lead time might be possible.

Extreme coastal El Niños cause a dramatic increase in the rainfall off Peru and Ecuador. Extreme coastal El Niño events are rare; the last ones before 2017 occurred in 1891 and 1925 (Takahashi and Martínez, 2019). The coastal El Niño of 1925 was the third strongest El Niño (coastal or Pacific-scale) in the twentieth century according to its impacts in the Far Eastern Pacific associated with severe rainfall and flooding in coastal northern Peru and Ecuador. In March 2017, the sea-surface temperature off Peru rose above 28°C, causing torrential rains, extreme flooding and widespread landslides that killed at least 200 people and damaged or destroyed hundreds of thousands of homes (Garreaud, 2018). It led to close to 300,000 displacements (IDMC, 2019b). The northern coastal parts of Peru were most affected and estimates of economic damage ranged from USD 3.1 billion (1.6% of Peru's GDP) (Macroconsult, 2017) to USD 6.0–9.0 billion (French and Mechler, 2017) Usually, strong warming in the Niño 1+2 area is linked to a Pacific-scale El Niño (Hu et al., 2019). However, in the case of the extreme coastal El Niño of 2017, this was not the case.

In a future warming climate, the majority of climate models project an increase in the frequency of extreme coastal El Niños (Peng et al., 2019). The average estimate of an ensemble of models leads to about three more extreme coastal El Niños per century when the twentieth and twenty-first centuries are compared. However, the change estimates of the individual models range from -12 up to +14 coastal El Niños per century. The frequency changes of extreme coastal El Niño may be independent of the Pacific-scale ENSO changes.

3.3. VULNERABILITY ANALYSIS

People do not experience hazards in the same way – some are in more vulnerable situations than others. Vulnerability is "the propensity or predisposition to be adversely affected" (IPCC, 2018a, p. 560). Differential susceptibility to harm, as well as capacity to cope and adapt, depend on human development, inequalities and other factors. The Peruvian Government notes that causes of vulnerability include the lack of training to face disasters; of access to protection mechanisms; of access to financial mechanisms for self-protection; and of means to build adequate housing (SINAGERD et al., 2014). The latest Peruvian National Human Rights Plan emphasizes that climate-related hazards can result in violations of human rights and calls on the State to reduce the percentage of the population in conditions of vulnerability from 61 per cent in 2012 (SINAGERD et al., 2014) to 25 per cent by 2020 (MINJUSDH, 2018).

Peru's resilience has improved according to some indicators, whereas others show stagnation in progress or even worsening (Notre Dame Global Adaptation Initiative (ND-GAIN), 2020). For example, while the share of Peru's population at vulnerable ages and dependency on imported energy and external health services has sunk over the past two decades, rising dependency on food imports points to a challenge. Similarly, while indicators for Peru's adaptive capacity have improved, including better agricultural capacity, more medical staff, as well as better access to water, sanitation and electricity, others indicate continuous challenges. For example, high child malnutrition rates suggest a lack of capacity to meet basic nutritional needs, insufficient water storage capacity reveals challenges for buffering water scarcity, and inadequate transportation infrastructure impedes effective mobility and resource distribution. While Peru has made relative progress compared to other countries, aggregate vulnerability remains significant and subnational discrepancies are large. For example, one in five Peruvians live in districts highly or very highly vulnerable to food insecurity given recurring hazards and socioeconomic challenges, especially in highland and rainforest provinces (World Food Programme (WFP) and CENEPRED, 2015).

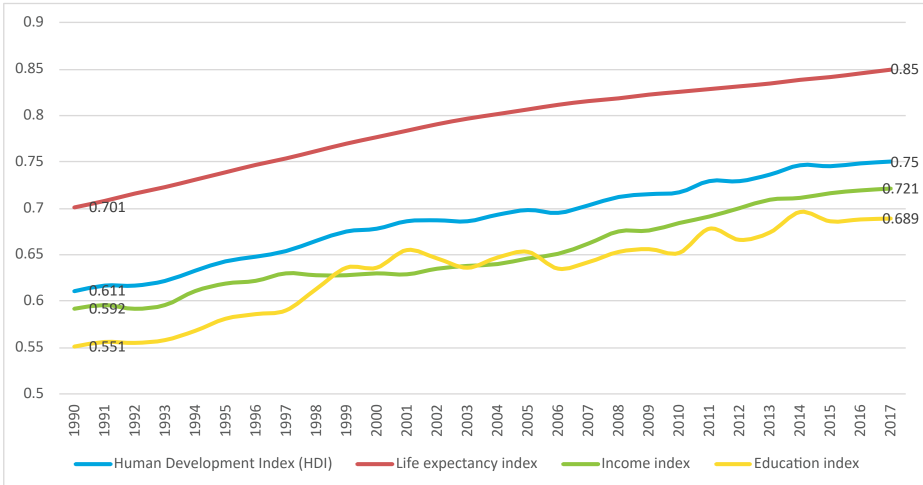
The sections below show that Peru has made rapid progress in human development and thereby reduced vulnerabilities to climate impacts, a closer look reveals some groups remain excluded from this progress, and, in the future, climate impacts may leave people more vulnerable than before. With about one in five Peruvians being poor, high rates of incidence for rural areas, the urban poor, and significant inequalities between ethnic groups and genders, there are some segments of society that will be particularly vulnerable to climate impacts, as they are deprived of assets, skills, voice and access to services. A major concern is that climate change threatens to nullify much of Peru's recent progress and push numerous people into new vulnerabilities. The COVID-19 pandemic showed that external shocks can undermine previous development gains and that migrants and displaced persons are among the groups that can be at particular risk because of lack of acces to basic services and information asymmetries (UNDP, 2020a).

3.3.1. Overall human development

Peru ranks in the second most advanced human development category, at position 89 out of 189 in the 2018 assessment by the United Nations Development Programme (UNDP, 2018a).[25] The Human Development Index (HDI) contains proxies for the long-term opportunities and choices that people have to live the lives they value. It sums proxies for three dimensions: (a) decent standard of living (income), (b) a long and healthy life (health), and (c) access to knowledge (education).

Over the past three decades, Peru has significantly improved in terms of human development, yet remains behind its peers. Figure 40 shows how Peru's HDI increased by almost 23 per cent from 1990 to 2017. In this period, absolute gross national income (GNI) per capita increased by 135 per cent; life expectancy at birth augmented by almost ten years; and the average years of schooling, as well as expected years of schooling mounted by 2.6 and 1.9 years, respectively. Peru's HDI ranks below the regional average for Latin America and the Caribbean.

Figure 40. Peru's human development trends, 1990–2017



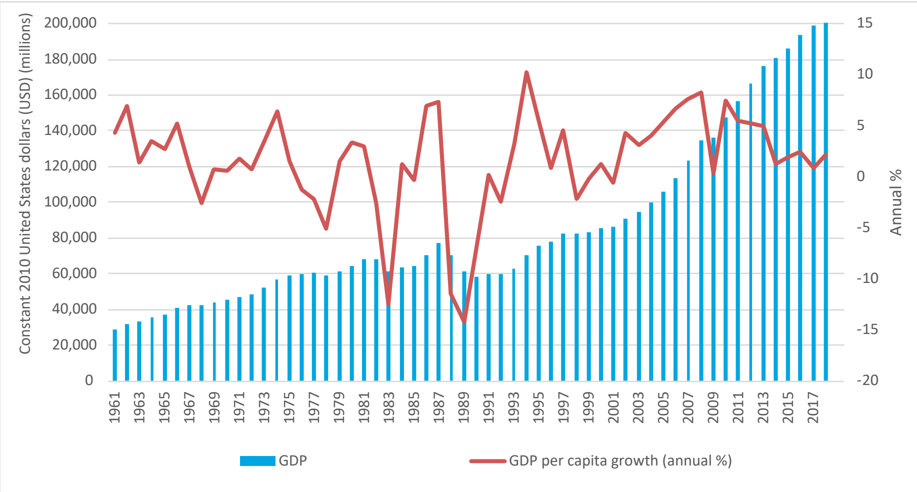
Source: Reproduced by Jonas Bergmann based on data from UNDP (2018a, p. 2).

25 Peru ranks as "high human development"; the other categories are "very high", "medium", and "low human development."

3.3.2. Poverty and deprivations

Peru has reduced income poverty over the past decades, but large challenges persist and the negative economic effects of the COVID-19 pandemic have hit the country hard. Peru is classified as an upper middle-income country by the World Bank (World Bank, 2017 and 2019). The average annual growth rate of gross domestic product per capita (GDP per capita) has been around 4 per cent. Per capita income reached about USD 6,450 in 2018 (GDP per capita, constant 2010 dollars). The Peruvian per capita income is below the average of USD 9,550 (constant 2010 dollars) for Latin American and Caribbean countries and only about one sixth of the average for member States of the Organisation for Economic Co-operation and Development (OECD). Relatively higher incomes can mean improved access to goods and services that shield from climate impacts, but not in all cases. For example, while an urban migrant may have a higher nominal income, higher costs of living in the city, informal employment and poorer social networks may result in new vulnerabilities. The external shock of the public health crisis revealed the differential vulnerability of various economic groups.

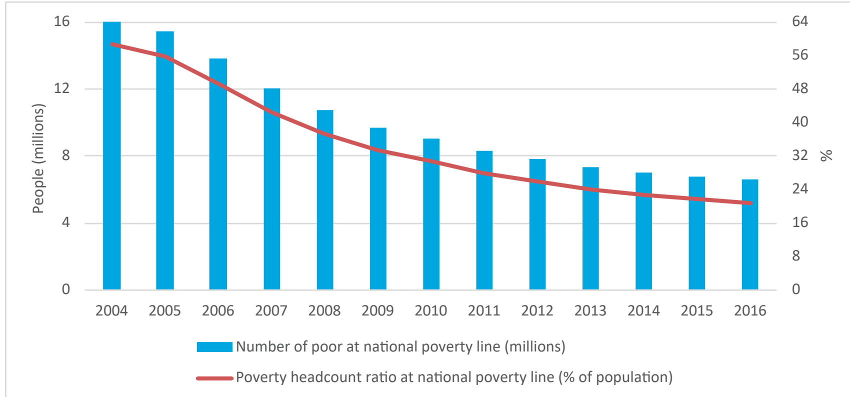
Figure 41. Peru's GDP and GDP per capita annual growth, 1961–2017



Source: Produced by Jonas Bergmann based on data from the World Bank (2019).

While income poverty in Peru has fallen greatly, it still affects certain segments of the population strongly. In 2004, 59 per cent of the population (as many as 16 million people) lived below the national poverty line (World Bank, 2019). The percentage was halved by 2010 and reduced to about 21 per cent or 6.6 million people in 2016. In about a decade, almost 10 million people moved out of poverty, as depicted in Figure 42. At international poverty lines, Peru's poverty headcount ratios were about the same as the Latin American and Caribbean averages in 2015: 4 per cent below USD 1.90 per day; 10 per cent below USD 3.20; and 24 per cent of the population below USD 5.50 a day (all at 2011 purchasing power parity (PPP)). The full effects of the COVID-19 pandemic are yet to be analysed, but it is likely that a share of the population has been pushed back into poverty.

Figure 42. Peru's poverty trend (millions of people and % of population), 2004–2016



Source: Produced by Jonas Bergmann based on data from the World Bank (2019).

Not all economically poor people are equally poor in Peru and they are located unevenly across segments of society. The percentage of the rural population living below the national poverty line has remained three times higher than that of urban dwellers: an estimated 46 per cent of the rural population were poor compared to 15 per cent of the urban population in 2014 (World Bank, 2019). The poverty gap for the rural poor is on average 14 per cent below the national poverty line, whereas only 3 per cent for the urban poor. Above the poverty line, four out of ten Peruvians remain at risk of falling into poverty if hit by a negative shock (World Bank, 2017).

Poverty is more than financial deprivation (Alkire and Jahan, 2018). In the Multidimensional Poverty Index (MPI), Peru ranks 49th out of 110 developing countries assessed (UNDP, 2018b). In 2016, 13 per cent of the Peruvian population or 3.95 million people were multidimensionally poor – they experienced deprivations in one third or more of the weighted indicators. About as many people were vulnerable to multidimensional poverty, meaning that they were close to the multidimensional poverty line.[26]

One important example of deprivations concerns the housing sector. Housing patterns have resulted in increased susceptibility to harm in Peru. Data shows that still over one third of urban dwellers lived in slums in 2014 (34%) (World Bank, 2019), down from 46 per cent in 2000 and almost halved from 66 per cent in 1990. While the relative share decreased, the total urban population has grown. This growth has translated into a threefold increase of informal settlements between 1993 and 2012, almost doubling the "slum" population in Peru (Calderón et al., 2015). Four out of five houses in Peru are self-constructed, with limited oversight or control of building codes (Calderón et al., 2015). This has resulted in inadequate infrastructure, as well as in precarious housing with poor materials and lack of access to sanitation. According to the authors, Peru has improved the living conditions of dwellers in such areas considerably, with rising access to pipe water and electricity, as well as more durable materials. However, informal expansion continues, accompanied by plot trading and other challenges, such as clientelist State behaviour and unequal access to opportunities. The vulnerability of these new settlements is known but remains unattended (French and Mechler, 2017).

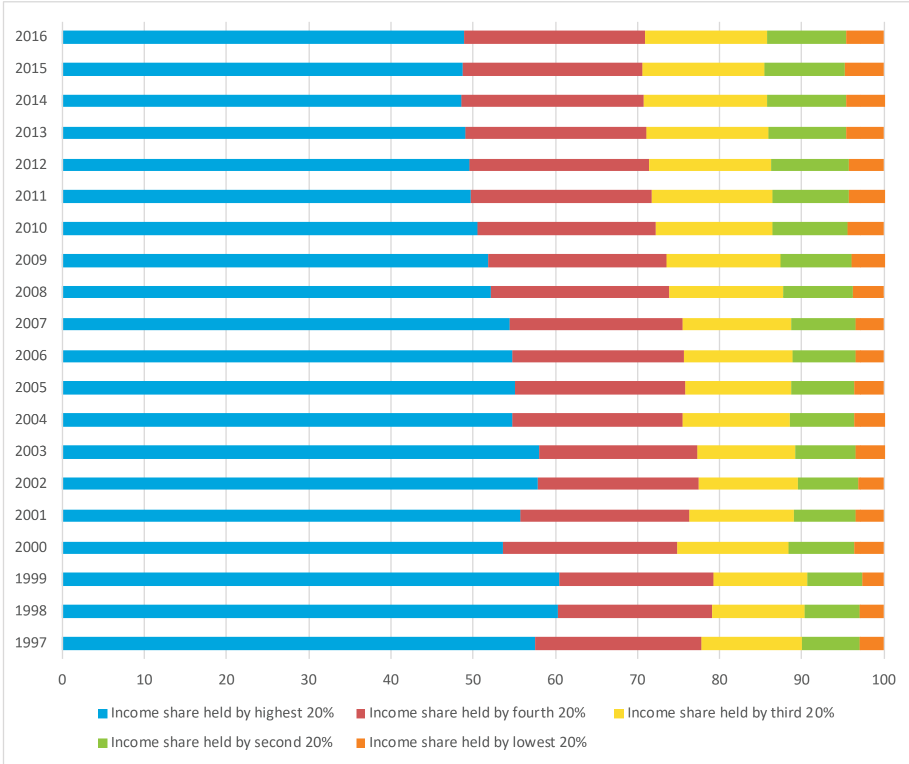
3.3.3. General inequality

The analysis shows that inequalities are still persistent across all dimensions of human development. When inequalities are accounted for, Peru's 2017 HDI sinks by 19 per cent (UNDP, 2018a). In Peru, the strongest losses are due to inequalities in income with 28 per cent. Inequalities in the indicators for health and education amount to losses of 13 per cent and 15 per cent, respectively. Peru's inequality loss in HDI is lower than the average losses for all regional peers (with 22%), but higher than the 16 per cent average loss for all high HDI countries.

A more detailed analysis shows advances but continuing high levels of income inequality. Overall, the country has moved to a more equal distribution of incomes over the past decades (World Bank, 2019). Between 1998 and 2016, the Gini coefficient[27] fell from a maximum inequality value of 56 to 44. Most of South America tends to be rather unequal. Globally speaking, however, Peru was ranked the forty-second most unequal country out of 177.[28]

Another indication of income inequality is the distribution by quintiles of the population. Figure 43 shows that over the past two decades, the richest 20 per cent have continuously held more than or around 50 per cent of all income. The poorest 20 per cent of the population has slightly increased its share but still holds less than 5 per cent of overall income. The poorest 40 per cent of the population earns only 14 per cent of the overall income, almost the same as two decades ago.

Figure 43. Peru's distribution of income by population quintiles (%), 1997–2016



Source: Produced by Jonas Bergmann based on data from the World Bank (2019).

26 "Vulnerable to multidimensional poverty" is defined as being deprived in between one fifth to one third of the weighted indicators.
27 The Gini coefficient measures how strongly the distribution of income among the population differs from a perfectly equal distribution. Values closer to 100 mean a more unequal, and those closer to 0 a more equal distribution. The Gini coefficient measures relative not absolute wealth, so different income distributions can give rise to the same coefficient.
28 According to World Bank 2016 data for Peru; not all countries have data or data for the same year.

3.3.4. Social inequalities

Gender inequalities are also visible in Peru's human development dimensions: The country had an absolute deviation from gender parity of 5 per cent between genders (UNDP, 2018a). This value puts Peru in the second lowest country group of "medium gender equality". Peru's deviation from gender parity in HDI achievement is more severe than that the one of its regional peers (only 2.3%). The roots of gender inequalities extend long into the past (Constant, 2016). Since the 1990s, Peru has had a quota system for the political system, but in the Peruvian parliament, less than a third of seats (28%) were held by women in 2017. Peru has a female participation in the labour market of 69 per cent opposed to 85 per cent for men (UNDP, 2018b), which is better than the regional average. In 2010, women in Lima earned only two thirds of male salaries and tended to be almost two times more often unemployed (Constant, 2016). In Peru in 2017, 68 women died from pregnancy related causes for every 100,000 live births (slightly worse than the regional average) and the adolescent birth rate was 48 births per 1,000 women aged 15–19 (better than the regional average) (UNDP, 2018b). Fifty-seven per cent of adult women reached at least secondary education in Peru, much lower than the value of 69 per cent for men. In comparison, the regional percentage point difference between men and women is below 1 per cent and 6 per cent for high-HDI countries. By 2010, slightly more women completed tertiary education than men, reversing previously strong discrepancies (Constant, 2016). Analphabetism concerned about 18 per cent of the total population and 40 per cent of the rural population in 1981. Women were still about three times more likely to be illiterate in 2007 than men, although Peru's overall illiteracy rate since has decreased to 6 per cent in 2016 (World Bank, 2019).

Development inequalities are also persistent between ethnic groups. In the past censuses of 1993, 2007 and 2017, between 20 and 16 per cent of the population named a Peruvian language other than Spanish as their first language (INEI, 2018).[29] The percentage was as high as 37 per cent in rural areas and as low as 8 per cent in urban areas in 2017. The same year, 22 per cent or 5.2 million people older than 12 years self-identified as Quechua, 4 per cent as descendants of Afro-Americans and 2 per cent as Aymara. About 80,000 people in Amazonia considered themselves as natives. Inequalities are strong: in 2015, people growing up with a Peruvian first language other than Spanish had a poverty incidence of 33 per cent, as opposed to 19 per cent for those with Spanish (INEI, 2016b). Exclusion, discrimination and other reasons drastically reduce mean labour incomes (Barrón, 2008). Education provides another example: Most groups who identified another language than Spanish as their first language or auto-identified as indigenous have worse educational opportunities across educational levels (INEI, 2018).[30] People identifying as native Amazonian had the highest rates of illiteracy among all ethnic groups. Inequalities in health are similarly persistent. Lack of access to health services further increase the risks posed by infectious diseases like COVID-19.

3.4. IMPACTS ON AGRICULTURE AND FOOD SECURITY

The review shows that the agricultural sector is key towards understanding climate vulnerability and human mobility patterns in Peru. Employment is large: Since 2007, agricultural workers have been below 30 per cent of the total workforce, reaching 27 per cent in 2019 (World Bank, 2019). In 2012, about 2.5 million people were permanently remunerated in agriculture (INEI, 2013 and 2014), around one third of them women. With 61 per cent, most permanently employed agricultural workers are located on the coast, followed by the sierra and the selva with about 19 per cent each. During the agricultural campaign from August 2011 to July 2012, the agricultural sector employed 13.9 million temporary paid workers, of which one quarter were women. Of the 2.2 million producers in Peru in 2012, 73 per cent were active in both crop and animal farming, 21 per cent in only crop farming, and around 5 per cent in only animal farming. Agricultural production in Peru is largely characterized by smallholder farming, with 80 per cent of farmers in Peru practicing subsistence farming (USAID, 2017). In 2017, agriculture accounted for 8 per cent of Peru's GDP (CIA, n.d.).

The agricultural system is spread across the different landscapes of Peru, subject to different climates and different climate impacts. On the coast, rainfall and natural vegetation are sparse, but agricultural resources are tapped into by means of irrigation. In some desert areas, intensive groundwater-irrigated and export-oriented agroindustries have emerged and developed (Mächtle, 2016). Andean agriculture is mainly based on field crops and livestock farming. The Amazon Basin features two landforms: the extensive alluvial floodplains by the river (Várzea) with annual flooding, and the surfaces above the highest flood levels (terra firme). An increasing share of the land has been used for agricultural production of crops and livestock, agroforestry, and resource extraction such as timber and non-timber forest product extraction.

29 Nationwide, next to Spanish came Quechua, with 17–13 per cent, Aymara, with 2 per cent, and other indigenous languages, with 1 per cent. In regions such as Apurímac and Puno, 72 per cent had another mother tongue than Spanish. (INEI, 2018.)

30 Two exceptions are the Tusan (Chinese ancestry) and Nikkei (Japanese ancestry), according to INEI (2018).

In Peru, only 19 per cent of the total land area is used for agriculture. The largest part of this area (approx. 80%) is pastureland and about 20 per cent of the agricultural area is used for crop production (FAO, 2016). Apart from livestock and crop production, fishing has become a central part of the Peruvian economy with one of the world's richest fisheries off its coast. Growing conditions throughout the country are very diverse depending on the climate, soil and landform characteristics of the different agroecological zones.

Peru's soil offers agricultural and pastoral opportunities, yet also challenges (ONERN, 1982; CEPLAN, 2011; FAO, 1995). Peru has 7.6 million hectares suitable for agricultural production, around 17 million hectares can be used for pasture, around 55 million hectares are protected land, and around 19 million hectares are natural areas. Of the total agricultural area, the coast has 12 per cent, the highlands, 55 per cent, and the rainforest, 32 per cent (INEI, 2013). The agricultural area not used in the early 2010s was almost 0.8 million hectares, mostly due to lack of water and lack of credit, but also due to lack of labour and seeds, erosion and saltiness. In other words, the State estimates that less than 6 per cent of the national territory is useable for crop farming. The rest is composed of 14 per cent suitable for pastures; 38 per cent for forest production; and 42 per cent are protected soils without the possibility of agricultural, livestock or forestry use, but susceptible to being used for other activities (CEPLAN, 2011; INEI, 2013).

Land availability and quality for agricultural production is threatened by various factors. Salinization on the coast (related to irrigation and drainage inefficiencies) affects about 40 per cent of the land of the best quality. Sixty per cent of the agricultural soils in the highlands are impacted by water erosion due to unprotected slopes and burning for the preparation of the land for agriculture. In the Amazon, soil fertility is affected by deforestation, which removes vegetal cover and organic matter.

Desertification is also a major concern in Peru. Thirty million hectares or 24 per cent of the total area are in the process of desertification and 3.8 million hectares are already desertified (INRENA, 1996 and 2006; MINAM, 2016a; CEPES, 2015). Human factors for desertification include overgrazing, deforestation, water and wind erosion, and salinization. Climate change adds pressure to these processes. Consequences include the loss of soil fertility and productivity, of raw materials for industry and agroindustry, of grassland, of pasture, and of biodiversity.

3.4.1. Crop production

In 2017, the most grown crop in Peru was maize, followed by coffee, rice, potatoes, plantains, cocoa and wheat (FAO, 2017). Many of these crops are grown for self-consumption, which makes their production crucial for the food security of poor smallholders (World Bank, 2019). Farmers often use traditional practices for crop production. Despite the slight increase in the productivity of staple crops (Ray et al., 2012), yields still have a considerable upward potential (van Ittersum et al., 2013).

Human interventions also stress ecosystems and agricultural livelihoods. Mächtle (2016), for example, mentions deforestation resulting in additional emissions, land-use conflicts, threatened biodiversity and changed hydrological regimes. Land-grabbing and the production of crops for bioethanol and palm oil may also compete with food production. The overuse of resources (e.g. overgrazing), can result in erosion and loss of soil. The use of pesticides and fertilizers, together with water overuse in the export-oriented monocultures in the coast, often adds to water stress, declining water quality and salinization of soils. Some aquifers are already depleted (Damonte and Boelens, 2019) or may be depleted in the coming decades.

Farmers in Peru always have had to deal with natural phenomena such as El Niño and extreme weather events, but climate change will add on top of these existing hazards. Worldwide, crop yields have already decreased in several regions due to climate change (Lobell and Field, 2007) and this trend can be expected in the future as well. On average, each increase of 1°C in global mean temperature would reduce wheat yields by 6 per cent, rice yields by 3.2 per cent, maize yields by 7.4 per cent and soybean yields by 3.1 per cent (without effective adaptation, genetic improvement and CO_2 fertilization) (Zhao et al., 2017). Water supply is one of the main constraints for the dry coastal regions. Agriculture here mostly relies on irrigation with water coming from glacial melt of the Andes. Average rainfall in the dry northern coastal regions is projected to increase, but the high dependency on Andean water resources threatened by glacier retreat poses major risks (see Section 3.1.4) (Liersch and Gornott, 2015). Expected climate impacts in the highlands are mixed. The highlands have lower temperatures due to their higher elevation, which makes them suitable for barley, oat and potato production. With rising temperatures due to climate change, C4 plants such as maize become more suitable for production here. To some extent, farmers may try to cultivate C3 plants such as potatoes in higher elevations, but plagues and diseases (such as the potato pests) will also become more likely. Glacier retreat and related water scarcity will also threaten agriculture in the sierra, which is particularly challenging in the dry season when water is needed for the irrigation of crops. The projected increase in rainfall intensities, particularly during the austral summer, makes agriculture in these areas more vulnerable to soil erosion and land loss (Liersch and Gornott, 2015). In the rainforest, temperature increase could have negative consequences for cocoa and coffee production, particularly for the coffee variety Arabica, which is sensitive to high temperatures (Liersch and Gornott, 2015).

Future risks for crops vary by region and hazard (SINAGERD et al., 2014). A high risk due to drought is particularly pronounced in Ica, Lambayeque and Tacna, by the coast. Most other regions have medium levels, except for Amazonas, Cusco, Lima and Pasco, which register low levels. High risks due to flooding exist in Huánuco, La Libertad and Pasco, while most other regions have medium levels (except for Junín and Moquegua, which have low levels). A medium risk due to cold waves exists in the regions of Cajamarca, Piura and Puno, whereas the other regions have a low level of risk or no risk of cold waves. High risk due to *friajes* exist in Cajamarca, Cusco, Huánuco, Junín, Pasco and Piura. Amazonas, Ayacucho, La Libertad, Loreto, Madre de Dios, Puno, San Martin and Ucayali have medium risk levels, whereas *friajes* do not affect other regions.

3.4.2. Livestock production

Close to three quarters of all agricultural producers were active in animal farming in 2012 (INEI, 2014). Livestock production is still mostly done by rural small-scale farmers, especially in the highlands, whereas some intensive agribusiness production has emerged along the coast for poultry and milk (FAO, 2005). Peru's livestock production accounts for roughly 3 per cent of GDP.

Animal farming involves the breeding and reproduction of animals for the use of derived products in food and industry. Predominant species in Peru are cattle, sheep and pigs. The coast has few pastures and mainly produces cattle with crop fodder and food for meat and milk production, as well as poultry. In the Andean region, household-based livestock production is extensive on natural grasslands and pastures in highlands and valleys. Sheep and cameloids are also important. In the Amazon region, farmers mostly use higher zones for livestock. Between 1994 and 2012, cattle numbers have risen by 15 per cent, while ovine livestock declined by 21 per cent (INEI, 2013). Both are concentrated in the sierra. Costa and selva share the rest of cattle population, while the rest of sheep population is almost only located on the coast. Camelids have risen by 50 per cent since 1994 and are only found in the sierra. The amount of pigs has been mostly stable, half of which are in the sierra. Poultry population has risen by 69 per cent and is highly concentrated on the costa.

Climate change impacts on livestock, both direct and indirect, are diverse (Adams et al., 2014). They include alterations of quantity and quality of feed; the grazing season; heat stress; lack of drinking water; and impacts on animal health. Studies on climate change impacts on animal farming are scarce but indicate that rising temperatures and changing rainfall may reduce cattle and pig productivity, whereas sheep may be better able to deal with these changes.

Future risks for livestock vary by region and hazard (SINAGERD et al., 2014). Areas at high risk of drought include Cusco, Huancavelica, Huánuco, Ica, Lambayeque, Puno and Piura. The other regions have a medium level of risk, with the exception of Amazonas (low risk) and Loreto and Madre de Dios (no risk). A high risk due to floods concerns Ayacucho, Cusco and Huánuco. The other regions show a medium level, with the exception of Áncash and Madre de Dios, which have a low level. Cajamarca, Cusco, Pasco, Huancavelica and Piura have a medium risk level due to frost, while most other regions have low levels. Very high-risk levels due to *friajes* concern Piura, while Pasco faces a high risk. Amazonas, Cajamarca and Cusco have medium risk levels, and Ayacucho, Huánuco, Junín, Loreto and Madre de Dios are low-risk regions.

3.4.3. Fisheries

As Peru has some of the world's richest fisheries off its coast, fishing has become a central part of the Peruvian economy. Fisheries are key to foreign currency (i.e. through exports) and are important for employment, food security and subsistence (FAO, 2010 and 2019). Total catches of the fishing sector in Peru amounted to about 3.8 million metric tons in 2016, and the country exported fishery products worth over USD 2,736 million in 2017. Peru is nowadays the world's largest producer and exporter of fishmeal. Peruvians have one of the largest annual consumption of fish food per inhabitant, especially in the Amazon region. Fisheries also yield essential income to large populations. In 2014, the fishing sector provided jobs for about 11,000 aquaculturists and about 99,000 positions in extractive work at sea and in inland fisheries. Marine fishing is dominant, but inland fisheries and aquaculture are also important. At sea, the most important activity is pelagic industrial fishing, followed by demersal or coastal trawling. Landings from artisanal fisheries are smaller but provide important sources of income and and food for direct consumption for some 200 fishing villages along the coast of Peru. In 2005, about 38,000 artisanal fishers lived in Peru. Inland fisheries are mostly located in the rivers and swamplands of the Amazon region, as well as Lake Titicaca and minor lakes of the highlands to some extent. Inland catches amounted to 22,100 metric tons in 2016. Aquaculture occurs both in marine and inland waters and yielded about 100,000 metric tons in 2016.

Fisheries are at risk due to stressors, such as overfishing and pollution, as well as due to climate change (Adams et al., 2014). Overall, Peru's fisheries are among the world's most vulnerable to climate change (Allison et al., 2009; Magrin et al., 2007 and 2014). The Humboldt Current System off the coast of Peru, which provides fertile grounds for fisheries, is very susceptible to climatic changes and natural variability. For example, ENSO reduces the upwelling of waters with nutrients through the inflow of warmer surface waters by the northern coast. As climate change can lead to more extreme El Niño events, fisheries may face stronger fluctuations. Ocean waters have warmed steadily, disturbing fisheries (Adams et al., 2014). Increasing CO_2 levels and the resulting acidification will also have an overall negative effect on marine species, with 40 per cent of species negatively affected in relatively low CO_2 concentration scenarios already and twice as much in higher scenarios. These changes interact with higher sea-surface temperatures, insufficient oxygen, changing salinity and reduced availability of nutrients.

The effects of climate change on upwelling and related ecosystem services are uncertain. No regional projections of future fishery catches exist, but global studies indicate that marine landings in Peru may decrease by up to 30 per cent (Cheung et al., 2010). As fish may migrate to colder waters in the southern regions of Latin America, there may be some increases towards Peru's southern coast. Artisanal fishers may suffer most from local reductions because they cannot easily take advantage of potential increases of productivity further offshore (changing oceanic conditions induce shifts of fisheries to higher latitudes). The Exclusive Economic Zone of the Humboldt Current System may see decreases of about 35 per cent in the overall biomass of fish under 2°C warming by 2050 (Blanchard et al., 2012). Local reductions of productivity could also worsen further overfishing (Adams et al., 2014). Freshwater fishing in the Amazon region is also at risk given rising temperatures that overwhelm the temperature tolerance of species, multiply the toxicity of pollutants such as heavy metals, and reduce oxygen solubility. In the coastal zone, fishing plays a central role not only for the economy but also as a food basis for many inhabitants. The limited adaptation potential of this sector makes climate impacts here particularly severe (Allison et al., 2009).

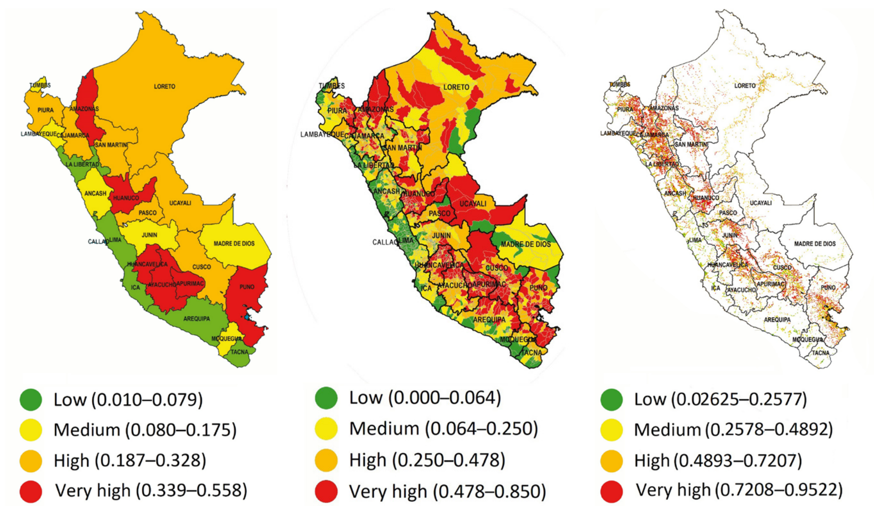
3.4.4. Food security

With 80 per cent of farmers in Peru practicing subsistence farming, increased climate risks in the agricultural sector will directly affect food security and livelihoods of the farmers (USAID, 2017). Food security is multidimensional and involves four pillars: availability, access, utilization and stability (Ecker and Breisinger, 2012). Apart from food availability, limited access to food also contributes to low food security in Peru (WFP, 2017). Food that is not covered by subsistence farming must be purchased. Given lower population densities, inadequate infrastructure in many regions in the sierra and the selva hampers the distribution of food and access to markets. Higher transportation costs also raise prices of agricultural products (Ortiz, 2012).

Between 2014–2016, about 11 million people in Peru (38% of the population) did not meet the minimum daily calorie intake, and at least 8 per cent of the population suffered from undernourishment (IFPRI, 2012). Chronic child malnutrition has been halved since 2007, yet it continued to affect 226,000 children under five (13.1% of the total) in 2017, with strong spatial variations (WFP, 2017). Anaemia levels among children between 6 and 36 months old have stagnated at 43–45 per cent in past years. At the same time, obesity and overweight concerns more and more people, including, for example, over 32 per cent of children aged 5 to 9 years. Poor dietary diversity due to lack of access to food and poor eating habits are main drivers of these health problems.

In 2014, 7.1 million Peruvians, or about 1 in 5, lived in districts with high or very high food insecurity in the face of recurring hazards (WFP and CENEPRED, 2015). Figure 44 shows the highly variable spatial distribution of vulnerabilities at different levels. All regions in the rainforest and highlands show high or very high food insecurity. Very high food insecurity exists in the regions of Huancavelica, Apurimac, Huanuco, Puno, Amazonas and Ayacucho. Close to 26,000 towns (*centros poblados*) with more than 50 inhabitants are in a state of high or very high food insecurity, mainly in the rural areas, representing 70 per cent of all towns in Peru. Cold waves and anomalous rains threaten food security most severely. Cold waves impend the food security of 5.3 million people in 902 districts highly or very highly, while anomalous precipitation affects the food security of 9.3 million people in 562 districts highly or very highly.

Figure 44. Vulnerability to food insecurity in Peru



Sources: Left: WFP and CENEPRED, 2015, p. 1 (translated into English). Reproduced with permission of CENEPRED.

Centre: WFP and CENEPRED, 2015, p. 2 (translated into English). Reproduced with permission of CENEPRED.

Right: WFP and CENEPRED, 2015, p. 3 (translated into English). Reproduced with permission of CENEPRED.

Notes: These maps are for illustration purposes only. The boundaries and names shown and the designations used on these maps do not imply official endorsement or acceptance by the authors, the International Organization for Migration or the Potsdam Institute for Climate Impact Research.

Figures show vulnerability at the regional (left), district (centre) and town level (right). The methodology to measure and map the probability of the population suffering from food insecurity due to the impact of a threat of recurrence of natural phenomena, expressed via an index of vulnerability, was developed by WFP.

3.5. CLIMATE RISKS: A SUMMARY

Peru's exposure to overlapping hazards is vast and rising. At present, half of the national territory and one third of the population occupy and use exposed space (SINAGERD et al., 2014), with exposure rising due to population growth, unplanned urbanization and growing informal settlements. Many migrants have no choice but to settle in areas already exposed to multiple risks, such as riverbeds, water-stressed hills in the outskirts of cities, or floodplains. Others live in or move into areas that will be exposed more in the future, or that will be exposed for the first time, for example, through sea-level rise.

As much as 61 per cent of the population is in conditions of vulnerability (SINAGERD et al., 2014). People deprived of assets, skills, voice and access to services are particularly vulnerable to climate impacts. Those most at risk include people who rely on ecosystems, such as the 80 per cent of farmers who practice subsistence farming (USAID, 2017), but also the poor, land-poor families and undiversified households with skills not easily transferable to new settings. While millions of people have moved out of poverty in Peru, still every second rural dweller lives below the national poverty line and over one third of urban residents in slums (World Bank, 2019). Inequalities have improved but do persist: the poorest 20 per cent of the population holds less than 5 per cent of all income. Gender and ethnic inequalities continue across all human development dimensions. A major concern is that climate change threatens to undue much of Peru's recent progress and push numerous people into new vulnerabilities. Above the poverty line, 4 out of 10 Peruvians remain at risk of falling into poverty if hit by a negative shock (World Bank, 2017). Many of these vulnerable people are susceptible to experiencing damage and some will try to move out of harm's way. However, migration and displacement can also reinforce precarious conditions.

Climate change has already had important effects across the country and will be a significant threat multiplier. Peru has already experienced a countrywide rise in temperatures with an increase in temperature extremes as well. This trend will continue throughout the twenty-first century. Related deglaciation has been rapid and may be close to complete by the end of the century in high-emissions scenarios, driving water scarcity that can result in migration and displacement. Heatwave intensity has also already increased and is set to rise further. Floods have already intensified and are likely to increase displacement risk. In most areas of Peru, rainfall events will likely become more intense (resulting in displacement risks) and dry spells longer (possibly inducing migration). Sea-level change in a high-emissions pathway could reach 1 m over the next 100 years in Peru, and synergetic effects of rising sea levels and more frequent strong eastern Pacific El Niño events can result in more extreme rainfall and related displacements. The need for planned relocation may rise, too. Climate impacts on agriculture are of particular concern, as millions of people in Peru depend on income and food from the sector. Both direct and indirect risks for crops, livestock and fisheries threaten food security and livelihoods. Already, one in five Peruvians today live in districts highly or very highly vulnerable to food insecurity in the face of recurring hazards (WFP and CENEPRED, 2015). These risks could lead to more people using migration as a coping or adaptation strategy, but livelihood erosion can also displace people. Concurrently, decreasing resources can also pose barriers for people to leave increasingly marginal places.

Congress Palace of the Republic of Peru.
© Shutterstock/Elzbieta SEKOWSKA

4. POLICY ANALYSIS

The previous chapters have shown that climate-related human mobility can already be observed in Peru and will likely rise in a future with rising climate risks absent adequate adaptation measures. Therefore, policymaking and programming must start addressing the issue in an integrated manner and with a long-term view. This chapter analyses to what extent existing legal instruments and policies already address the climate–migration nexus. Central questions include:

(a) In which pertinent frameworks are mobility and climate change integrated and to what extent? Where are they missing?

(b) How do frameworks relevant to climate change incorporate mobility, and how is climate change incorporated in those relevant to mobility? How are the topics framed and contextualized?

Figure 45 (on p. 150) provides an overview of identified laws and policies relevant to the climate change–mobility nexus in Peru at different levels of governance and from different fields.

4.1. CONSTITUTIONAL PROVISIONS

The Political Constitution of Peru of 1993 contains several norms that protect people on the move.[31] The first chapter is on fundamental rights of "all persons" (Article 2), independent of mobility status. Protecting these rights and the dignity of all human beings are the "supreme goal of society and State" in Peru (Article 1). They include the right to life, identity, physical and psychological integrity, free development and well-being, alongside a range of other civil, political, social and economic rights. The Constitution also explicitly spells out the right to freedom of movement (Article 2), excluding only exceptional circumstances. The human rights provisions in the Constitution must be interpreted in accordance with the Universal Declaration of Human Rights and other international human rights instruments. The Constitution gives all international treaties ratified by Peru, including human rights instruments, legal force in domestic law (Article 55). It also establishes the primary duty of the State to protect the population from threats to their security and to promote general welfare (Article 44). It is the State's duty to guarantee the security of the nation from internal and external threats through

31 The Political Constitution of Peru was enacted by the Congress of the Republic on 29 December 1993. An official English translation is available at www.congreso.gob.pe/Docs/files/CONSTITUTION_27_11_2012_ENG.pdf.

Figure 45. Laws and policies relevant to the climate change–human mobility nexus in Peru

Source: Conceptualized by Jonas Bergmann and produced by webreform GmbH.

Note: NAP – National Action Plan; UNCCD – United Nations Convention to Combat Desertification; UNFCCC – United Nations Framework Convention on Climate Change; WIM – Warsaw International Mechanism for Loss and Damage.

the National Defence System (Articles 163 and 164). This provision builds the foundation for the Civil Defence System to respond to disasters, as established by laws discussed further in the succeeding sections.[32]

4.2. FRAMEWORKS ON MIGRATION AND DISPLACEMENT

4.2.1. Across borders

Two main institutions in Peru govern international migration. The Ministry of External Relations oversees consular and cultural connections to diasporas. The Ministry of the Interior formulates policies on migration and administers, coordinates and controls cross-border migration of nationals and foreigners. Further public entities play a role, such as the Ministry of Labour and Employment Promotion (whose Labour Migration Directorate oversees national and sectoral policies and standards on labour migration), as well as the Ombudsman's Office (which is the independent constitutional body responsible for protecting rights of all persons, including migrants). Since 2011, Peru also has a permanent Intersectoral Work Table for Migration Management (MTIGM)[33] for sectoral coordination in the formulation and implementation of migration policies.

While Peru has a range of relevant norms, the National Human Rights Plan 2018–2021 (and previous plans) also mentions many challenges (MINJUSDH, 2018). These challenges include the lack of knowledge of migration procedures; deficiencies in migration control coordination; the lack of observance of norms and principles on attention to migrants and refugees; and the lack of adequate policies to meet special needs, as in the case of unaccompanied minors or trafficked persons. It proposes specific measures to protect all of these at-risk groups to "guarantee knowledge and access to rights under conditions of equality to ensure the development, integration and well-being of people in a situation of mobility" (MINJUSDH, 2018, p. 137). It also names climate change as a central challenge. The plan also calls for the protection of foreigners living in Peru, as well as of Peruvians abroad or returning.

32 However, these constitutional provisions have been described as "insufficient to deal efficiently with natural phenomena" because they focus mostly on emergency rules for public order and security, not on ensuring the safety and well-being of people (Landa, 2017, para. 9).

33 MTIGM was formalized by Supreme Decree 067-2011-PCM, 2011.

Regular migration categories

International immigration and emigration in Peru are governed by national, regional and international frameworks, all of which include human rights obligations.[34] Two recent (although non-binding) supranational commitments with importance for the climate–migration nexus are the Global Compact for Safe, Orderly and Regular Migration, which Peru adopted in 2018 (United Nations, 2018) and the Global Compact on Refugees. Member States agreed to enhance collaboration on all aspects of migration. The Global Compact for Migration acknowledges the importance of climatic and environmental drivers, the multi-causality of migration, and the impacts of migration on the environment. Objective 2 addresses the "adverse drivers and structural factors that compel people to leave their country of origin", and Objective 5 calls for enhanced "availability and flexibility of pathways for regular migration". Countries can report on progress achieved in the follow-up mechanisms designed for the Global Compact for Migration. Also launched from the New York Declaration of 2017, the Global Compact on Refugees mentions the interaction of climate, environmental degradation and disasters with the drivers of refugee movements. It calls for prevention efforts and for the protection of persons displaced by disasters. While the Global Compact for Refugees is also non-binding, the associated Global Refugee Forum presents opportunities for follow-up and sharing of good practices.

At the national level, in 2017, Peru adopted a Law on Migration and a Regulation on Migration,[35] **as well as a national policy on cross-border migration.** The National Migration Policy 2017–2025 includes provisions on disasters, for example, humanitarian visas for those "migrating because of natural and environmental disasters", which are discussed in more detail in the next paragraph. The National Migration Policy also emphasizes the inclusion of foreign citizens in preparedness and emergency responses to hazards. Despite recent policy efforts and the variety of available instruments, the Ombudsman's Office of Peru has noted weaknesses in the migration norms for both Peruvian emigrants and immigrants in Peru, including the lack of sectoral integration (Peru, Office of the Ombudsman, 2009, 2011, 2015 and 2018).

34 For an overview of agreements, see: Sánchez Aguilar, 2012, Annex 1.
35 The law refers to Supreme Decree No. 015-2017-RE approving the National Migration Policy (PNM), 2017–2025; Legislative Decree 1350 (Migration Law); Supreme Decree 007-2017-In (Regulation of the Legislative Decree on Migration); and Regulations of the Legislative Decree on Migration.

Temporary, regular-entry mechanisms can help people fleeing from the immediate consequences of climate-related hazards, especially in areas close to borders. Short stay options abroad are available for Peruvians wanting to leave, as well as for foreigners wanting to enter Peru: Peruvians do not need visas for short stays of at least 60 days in most other South American States.[36] To enter Peru for short stays, citizens from other South American States do not require visas (Rodriguez-Serna, 2015), while citizens from several Central American States do (Cantor, 2018). However, due to the limited time of stay, rights and possibility to identify the needs of the displaced persons, these short-stay entry possibilities may not adequately respond to the situations of people displaced by disasters over the longer term (Rodriguez-Serna, 2015).

Several regional frameworks uphold a relatively high freedom to move within the region and can provide mechanisms for people to move between States in cases of disasters. South America as a region converges towards a discourse of freedom of movement (Llamas, 2017; Cernadas, 2013; Acosta, 2018; Cerrutti, 2017). The region has a wide range of solid protection mechanisms that have been effectively applied for disaster displacement in the past (Rodriguez-Serna, 2015).

First, the Southern Common Market (MERCOSUR (Mercado Común del Sur)) is the most important regional framework (Margheritis, 2015), with provisions on freedom of movement applicable to persons displaced by disasters across borders. Most South American States are either full or associated members of this trade bloc.[37] Peru became an associated State in 2003. All member States admit their citizens based on national identification documents and clean criminal records. The MERCOSUR Residence Agreement was approved in 2002 but only ratified in 2009, and, in some countries, a long time passed between legislation and de-facto implementation (Cernadas, 2013; Cerrutti, 2017). Peru ratified the agreement in 2011.[38] The Residence Agreement guarantees rights for regular migrants between member States and the Plurinational State of Bolivia, Chile, Colombia, Ecuador and Peru. They can enter and apply for temporary residence in other MERCOSUR countries for up to two years. Temporary residence grants the same social and economic rights as nationals (International Labour Organization, n.d.), such as the right to access social security, the right to family reunion and the right to work. Nearing two years, temporary residents can apply for permanent residence if they can prove means of subsistence (IOM, 2018b). At least 2 million residencies have been warranted under this agreement (Ramírez et al., 2017; IOM, 2018b). The legal status and access to rights of migrants

36 Only few South American countries require visas for short stays of other South American citizens. Often, national identification cards are enough, for example, to enter as tourists. Peruvians require a visa only for French Guiana and Suriname.
37 Except for French Guiana, Guyana and Suriname.
38 As noted in MERCOSUR Decision No. 20/2012, Decision No. 21/2011 and Decision No. 04/2011.

has improved (Acosta, 2018; IOM, 2018b). The Residence Agreement has been implemented with hurdles but can provide a tangible pathway for mobility in the context of climate change (Cantor, 2018). People displaced by disasters could use this option to stay for a substantial period, and potentially for good, if other durable solutions are unavailable (Steeman, 2015). The Nansen Initiative Protection Agenda for People Displaced Across Borders in the Context of Disasters and Climate Change (2015) and its follow-up, the Platform on Disaster Displacement, consider the agreement to be one of the promising medium- to long-term protection alternatives for South Americans displaced across borders (Cantor, 2018). Converting temporary into permanent residence, which requires a certification of the ability to gain a living (in some countries only considered as regular and registered jobs), may be challenging for people affected and displaced by disasters.

Within MERCOSUR, the idea of free circulation is gaining traction, and community citizenship has developed as the preferred tool to reach this objective (Cerrutti, 2017). In 2010, MERCOSUR adopted a Plan of Action for MERCOSUR Citizenship that members aim to fully implement by 2021.[39] The plan of action does not yet mention associate member States of MERCOSUR such as Peru, but as Peru and other members of the Andean Community of Nations (CAN) have given up their plans for an Andean Citizenship Statute for now (discussed in the next section), the MERCOSUR avenue might also be of potential relevance for Peru (Rodriguez-Serna, 2015; Acosta, 2018). The Plan of Action for MERCOSUR Citizenship holds potential to expand freedom of movement in a rights-based manner but must pay attention not to exclude "some types of migrants" (Cernadas, 2013, p. 2), for example, extraregional migrants (Acosta and Freier, 2018). Gaps also persist between statements of intent and actual implementation, and some recent restrictive turns in immigration policies, as well as political difficulties in important member States, could jeopardize the plan (Acosta and Freier, 2018; Aguerre and Sampaio, 2016). Three main difficulties remain: the risk of inconsistency between instruments of various regional organizations; improper national implementation; and the lack of supranational adjudication of the implementation. (Acosta, 2018; Acosta and Freier, 2018)

39 MERCOSUR/CMC Decision No. 64/10 (MERCOSUR Statute of Citizenship: Action Plan (2010)). Article 2 states that the citizenship would grant the following objectives: "Implementation of a policy of free circulation of people in the region; equal civil, social, cultural and economic rights and liberties for the nationals of all MERCOSUR states parties; equal of conditions of accessing work, health, and education."

Second, the Andean Community of Nations (CAN) has also adopted several regulations on migration management and facilitation inside, as well as migrant protection outside the community space.[40] The community is a customs union between the Plurinational State of Bolivia, Colombia, Ecuador and Peru. One of its institutions relevant to migration is the Andean Committee of Migration Authorities.[41] Citizens of CAN member States can move between the countries without visa requirements. The Andean Instrument for Labour Migration is progressively working towards free labour circulation and stay of Andean nationals in the subregion.[42] Two instruments to safeguard social security, safety and health at work accompany the instrument.[43] In 2015, the CAN Parliament adopted the Statute on Human Mobility, which contains rights to migration, non-discrimination and unity of family, among others.[44] To gain legislative power, it would still need to be adopted by the CAN council of foreign ministers (Acosta, 2018). The Statute includes regional migrants, as Andean citizens, as well as foreigners with regular residence in an Andean State. Under its provisions, migrants can first enter and stay in Peru for two years and eventually apply for permanent residence. CAN has also debated an Andean Citizenship Statute since 2008, but due to dead ends, all CAN members progressively ratified the MERCOSUR Residence Agreement instead (Acosta and Freier, 2018). MERCOSUR now includes all CAN States; if it further develops its instruments, it is unlikely that CAN will duplicate these efforts (Rodriguez-Serna, 2015; Acosta, 2018). CAN legislation comes with the advantage that it is directly applicable at the national level and supreme to national law; the Andean Court of Justice, a supranational tribunal, has adjudicated cases on free movement in the past (Acosta and Freier, 2018). Although only accessible for those with job offers or work contracts, the regional instrument could be an interesting avenue for people from Peru affected by climate change who are seeking alternative livelihoods as labour migrants or have become displaced, and, vice versa, for citizens from other member States coming to Peru.

40 Andean Cooperation Mechanism on Consular Assistance and Protection and Migratory Issues (Andean Community Decision 548 and Resolution 1546 – Regulation of Decision 548).
41 Established through Andean Community Decision 471.
42 As in Andean Community Decision 545, Article 1.
43 As in Andean Community Decisions 583 and 584.
44 As in Andean Parliament, Decision No. 1343 of 24 April 2015, Article 3.

Third, the South American Conference on Migration (CSM (Conferencia Suramericana sobre Migraciones)) is a non-binding regional consultative process on migration with dedicated action on the climate–migration nexus. Established in 2000, Peru and 11 other South American States are members.[45] Since 2010, the CSM has addressed the issue of hazard-related human mobility in its meetings and annual declarations (Cantor, 2018; CSM, 2018).[46] The Conference has recently recommended its member States to implement its Regional Guidelines on Protection and Assistance to Displaced Persons Across Borders and Migrants in Countries Affected by Natural Disasters (CSM, 2018). The Regional Guidelines detail best practices on contingency measures to reduce and avoid the risk of displacement in the country of origin. They integrate potential measures for the protection of displaced persons arriving from countries affected by disasters and of migrants in countries affected by disasters. The Regional Guidelines are not binding for CSM countries, but they offer options for countries to enhance their systems and mechanisms. The Platform on Disaster Displacement is working on piloting a stronger integration of the provisions of the Guidelines in national frameworks.

Special migration categories, refugee protection, complementary protection and mass influx situations

Refugee protection – although not the primary pathway to protect people displaced from disasters – offers some options in and for Peru. Peru is party to several supranational instruments that guarantee the right to asylum.[47] Environmental reasons, however, do not qualify as persecution. Still, some South American States have started to accept certain consequences of disasters – such as civil unrest – as reasons for granting refugee protection. Such interpretations are developed in light of the wider refugee definition given by the South American 1984 Cartagena Declaration. Here, threats arising from situations of generalized violence and others that seriously affect public order are recognized as reasons for asylum. On this basis, Peru warranted asylum requests by some Haitians after the 2010 earthquake because they had experienced grave losses and suffered from insecurity and instability due to a lack of State presence (Cantor, 2015). The Brazil Declaration of 2014 and the associated Plan of Action 2014 recognize the "new challenges posed by climate change and natural disasters" and associated displacements and calls on States to adopt appropriate action.

45 As of 2019, Member States are Argentina, the Plurinational State of Bolivia, Brazil, Chile, Colombia, Ecuador, Guiana, Paraguay, Peru, Suriname, Uruguay and the Bolivarian Republic of Venezuela. Mexico is an observer State.
46 For example: CSM, Declaration of 8, 9 and 10 September 2015, Santiago.
47 Namely, the 1951 Convention on the Status of Refugees, its Protocol, the American Declaration on the Rights and Duties of Man, and the American Convention on Human Rights.

Complementary or temporary protection schemes can be open to individuals who do not qualify for asylum, but still cannot return to their homes because their rights could be violated there (McAdam, 2011). Peru offers temporary protection status for three months. It can be extended and warrants family reunification, as well as assistance to meet basic needs.[48] The Law and Regulation on Migration (cross-border),[49] as well as the national policy that Peru adopted in 2017, authorizes the entry and residence in Peru of foreigners who do not qualify for refugee protection but need humanitarian protection, including for those "who have migrated due to natural and environmental disasters". Peru grants humanitarian protection, for as long as the conditions of vulnerability persist. People under humanitarian protection are allowed to work. The provision also applies to "people who are outside the national territory in exceptional situations of internationally recognized humanitarian crisis, who request to come to Peru and obtain protection."[50]

Finally, people displaced across borders require durable solutions to their displacement. Most people displaced across borders are only given temporary status (Rodriguez-Serna, 2015), and receiving countries expect their return to their previous homes or another site in their home country. However, because many disasters are recurrent and whole areas may become uninhabitable, other durable solutions, such as integration in the new country or integration in a third country, will become increasingly important.

4.2.2. Within the country

Internal migration

There is no cohesive internal migration policy in Peru and the topic is mainly governed by population planning. The central instrument is the Law on National Population Policy in its modified 1995 version,[51] implemented through various national programmes and plans. The latest available version of this planning instrument is the National Population Plan 2010–2014 (Ministry of Development and Social inclusion (MIMDES), 2011). The plan labels internal migration as the "main factor in the rapid urbanization" and in the shift of populations towards the coast (MIMDES, 2011, p. 24). Internal migration, and by consequence a "rapid and disorderly" urban "explosion", are seen as a challenge to be addressed because they result in the "aggravation of environmental problems and sanitation, housing and transportation, employment and security" (MIMDES, 2011, p. 24f). Migrants themselves and rural source areas only figure indirectly in the strategy. The plan

48 As in Law 27.981 (2002), Article 35s and 36 and Regulation of the Refugee Law (2002), Chapter VII.
49 As in "Law and regulation of migration", Legislative Decree No. 1350, Supreme Decree 007-2017-IN.
50 As in Law Article 29.2.k and Regulation Article 91.
51 As in Law No. 346 (1985) and modification of Chapter VI approved with Law No. 26530 (1995).

describes rural areas as dispersed and envisages policies and programmes to improve their living conditions.

The National Population Plan does not consider climatic changes and their potential effects on population patterns. The environment is only described as a good to be protected from in-migration – especially in "cities located in ecologically fragile areas of the Amazon or located in arid areas of the mountains and coast" (MIMDES, 2011, p. 37). While the plan casts internal migration mainly as a problem – either boosting urbanization or destroying the environment – it simultaneously emphasizes people's right to movement: People have a right to exercise their "demographic behaviour" in a "free, responsible and informed way", including the right to "to change and set their residence anywhere in the national territory" (MIMDES, 2011, p. 47). The plan does not address the environmental drivers of internal migration.

Internal displacement

The Ministry of Women and Vulnerable Populations (MIMP) oversees internal displacement originating from conflict, disasters and development projects. It is in charge of protection policies, action and research, reparation, and the National Registry of Displaced Persons. It is also responsible for the national population policy, including forced and voluntary instances of internal migration (MIMP and IOM, 2015). INDECI oversees immediate assistance to displaced populations after emergencies, together with other relevant regional and subregional actors,[52] and MIMP is responsible for their longer-term protection and durable solutions.

Peru must adhere to international and regional laws and principles that protect internally displaced persons. The State is obliged to protect, respect and remedy all international human rights independently of people's situation, including disaster displacement. The Guiding Principles on Internal Displacement synthesize these binding international human rights principles throughout all stages of displacement (OCHA, 1998). At the regional level, the Inter-American human rights instruments are applicable to all persons, including those displaced internally by disasters (Inter-American Commission on Human Rights (IACHR), 2016).[53] Since 2004, the General Assembly of the Organization of American States (OAS) has also repeatedly underscored State obligations to provide protection to internally displaced persons[54] and encouraged action on the subject.

52 As in Law of SINAGERD, Article 13, section c.
53 As in the American Declaration of the Rights and Duties of Man (1948), the American Convention on Human Rights (1969) and several other conventions and protocols.
54 For example: AG/RES. 2667 (XLI-O/11) and AG/RES. 2928 (XLVIII-O/18).

Internal displacement has long been a major issue in Peru, but respective norms have been developed only recently and have remained skewed towards conflict displacement. Internal displacement became a salient issue in Peru due to internal armed conflicts in the 1980s. Yet it was only in 2004, through the Law on Internal Displacement,[55] that internally displaced persons (IDPs) was defined and emphasized that they hold the same rights as other citizens, with special State obligations established for their protection and assistance. The definition in the law places emphasis on conflict-induced displacement "in particular" (Article 2) but does not rule out other causes of displacement such as disasters. Only the regulation that put the law into action in 2005[56] explicitly incorporated "natural disasters" (Article 4) as a potential cause of displacement.[57]

So far, the implementation of the law and regulation in concrete disaster situations has been inadequate (MIMP and IOM, 2015). Even after the law passed, knowledge about the law is still frail and especially disaster-displaced people have remained invisible (MIMP and IOM, 2015, p. 71). The National Human Rights Plan notes a lack of observance of norms on attention to displaced persons and the lack of adequate policies to meet their special needs. The plan proposes measures to protect them and to "guarantee knowledge and access to rights under conditions of equality to ensure [their] development, integration and well-being" (MINJUSDH, 2018, p. 137). It also calls to guarantee the right to humanitarian assistance and protection of all IDPs. According to MIMP and IOM (2015), major challenges in multisectoral and multilevel coordination continue; preemptive and holistic planning is scarce; attention is too often focused on the short term; and, finally, political, budgetary, regulatory and competence constraints compound the situation. In some areas with limited State presence, affected populations also distrust or resist interventions by the Government. Paternalism, inefficiency, unsustainability and lack of coordination of State responses at different levels persist (MIMP and IOM, 2015). The National Human Rights Plan notes concern on humane living conditions and participation for the reintegration – return or resettlement – of IDPs (MINJUSDH, 2018). The plan also criticizes the lack of baseline data, names MIMP as the responsible entity, and calls for sustainable reintegration of people in protracted displacement.

55 As in Law No. 28223 (Internal Displacement Law).
56 Referring to Supreme Decree No. 004-2005-MIMDES (Regulation of the Internal Displacement Law).
57 Author's translation of Article 41: "[Internal displacement] is the process by which a person or a group of people are compelled or forced to leave their home or place of habitual residence, as a result or to avoid the effects … natural or man-made disasters that have not resulted in the crossing of an internationally recognized State border..."
The regulation also moved from considering "displaced" persons (as a characteristic of an individual) to considering people in "displacement" (as a situation and process).

MIMP also ought to guarantee the rights of all displaced persons by registering them in a National Registry for Displaced Persons.[58] Once registered in this system, IDPs are to receive an accreditation as "internally displaced" to facilitate access to assistance. The database should contain information about how the displacement affected the rights of displaced households, and their communities of origin and reception, thus providing the baseline data for State action. However, to date, the public registry does not contain any instances of disaster, but only conflict displacements.[59] The first few thousand people – those in protracted displacement after the El Niño Costero 2017 – have only recently been surveyed. The thousands of people displaced by disasters before (as shown in Figure 19), remain invisible in the public registry. Even though INDECI has statistics of individuals who lost their homes due to disasters (INDECI, 2018), displaced persons must be registered and surveyed so their rights can be guaranteed. The National Human Rights Plan (MINJUSDH, 2018) emphasizes the need to identify and register all IDPs. It criticizes the lack of baseline data and calls on MIMP to develop an instrument to measure the assistance provided, aiming to reach 100 per cent of IDPs by 2021.

4.3. FRAMEWORKS ON DISASTER RISK MANAGEMENT AND PLANNED RELOCATION

Besides the special legislation on disaster displaced people, Peru also has many institutions and frameworks addressing disasters more generally. The analysis in this chapter will move from international frameworks to regional and national ones. It also discusses planned relocation within the disaster risk management approach.

4.3.1. International

At the international level, Peru has been active in frameworks for disaster risk reduction (DRR) and management (DRM) that have an increasingly broad view of mobility. Peru adopted the Sendai Framework for Disaster Risk Reduction 2015–2030 in 2015. The Sendai Framework points out the primary responsibility of the State for DRR, the need to protect persons, their assets and all their human rights, and address underlying vulnerabilities and the goal to build back better to reduce disaster risk. Where prior efforts viewed mobility only as the result or a driver of risk, the Sendai Framework also considers its resilience potential (Guadagno, 2016). The framework aims to empower local authorities to work and coordinate with various stakeholders, including migrants, in disaster risk management at the local level. It describes migrants as stakeholders that "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" (UNISDR, 2015, p. 23). It also calls on States to formulate public policies to prevent or relocate human settlements in disaster risk-prone zones. States are to develop "policies and programmes addressing disaster-induced human mobility to strengthen the resilience of affected people and that of host communities" (UNISDR, 2015, p. 20). The framework represents demographic change as a compounding factor of risk. States should ensure "rapid and effective response to disasters and related displacement, including access to safe shelter, essential food and non-food relief supplies, as appropriate to local needs" (UNISDR, 2015, p. 21). Governments should also improve evacuation capacities. Although some facets of mobility are still missing and some States opposed more ambitious language on displacement, the Framework does constitute progress.

At the regional level, some South American States have also pointed to the mobility dimensions of disasters (Cantor, 2015). For example, the Andean Community CAN (Plurinational State of Bolivia, Colombia, Ecuador and Peru) has developed an Andean Strategy for Disaster Risk Management. The latest version constitutes supranational law and is aligned with the Sendai Framework (CAN, 2017). Focused on prevention, it provides a road map for DRR, mainly through institutional capacity-building and the establishment of regional approaches to reduce vulnerability. It mentions rural-urban migration as a factor that has increased exposure to hazards, especially in poorer areas with new human settlements, so-called "invasions". The document describes relocation as one strategy of remedial risk management, while the need for prospective interventions to prevent construction in risk zones is emphasized. The strategy also envisions a strengthening of governance of disaster risk through cross-border cooperation in shared border areas, to increase resilience and reduce disaster risk, including the risk of epidemics and displacement. Peru also has bilateral accords with Ecuador for cooperation during emergencies in border areas, for example, guaranteeing the passage of aid teams and materials (Cantor, 2018).

58 Established through Article 36: Regulations on Displaced Persons.
59 The online registry is available at www.mimp.gob.pe/direcciones/dgpdv/contenidos/articulos-ddcp.php?codigo=21.

4.3.2. National

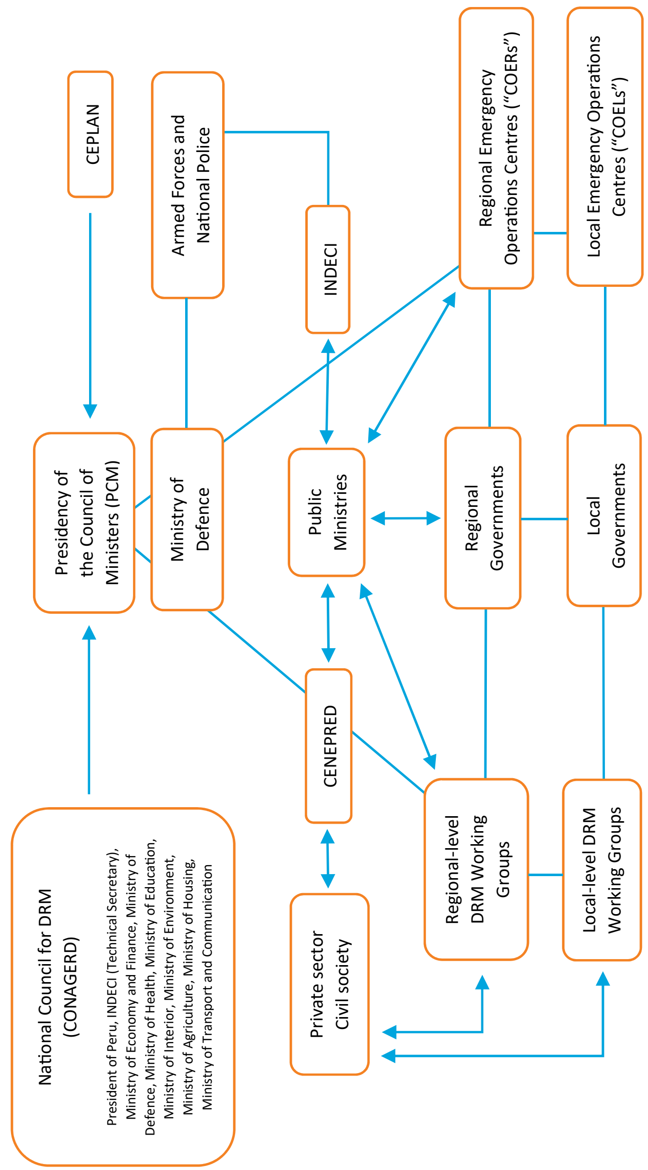
Disaster risk reduction and disaster risk management

At the national level, Peru's long history of severe disasters has resulted in great attention to the issue. Nonetheless, a transition from ex-post emergency response towards more integrated disaster risk management has started only one decade ago (French and Mechler, 2017). In 2004, Peru established a National Disaster Prevention and Management Plan,[60] which identifies migration mostly as a problem that increases exposure, puts stress on cities and results in deforestation, similar to the abovementioned National Population Plan. The first National Disaster Risk Management Plan (PLANAGERD) for Peru was approved in 2014[61] (SINAGERD et al., 2014). It stipulates a DRM strategy for the period of 2014 to 2021 and describes the organizational setup. The plan foresees investments to reduce risks and to strengthen institutions and information and is accompanied by several laws and policies.

Yet the governance system for disaster risks in Peru remains complex. Historically, the Civil Defence System, led by the National Institute of Civil Defence (INDECI), had been responsible for disaster risk reduction (MIMP and IOM, 2015). INDECI was established more than forty years ago and "reflect[s] the country's longstanding focus on reactive disaster response" (French and Mechler, 2017, p. 18). Only in 2011, the National System for Disaster Risk Management (SINAGERD) emerged.[62] SINAGERD integrates prospective, corrective and reactive DRM efforts. It includes a complex web of actors at different government levels alongside non-State stakeholders, as depicted in Figure 46.[63] Although SINAGERD is highly centralized, according to the subsidiarity principle, decision-making and implementation should be made as close to the disaster and at the lowest administrative level possible. Local entities respond first; only if their resources are exceeded, response responsibility rises to the regional and then the national levels (French and Mechler, 2017).

60 Through Supreme Decree No. 001-A-2004-DE/SG.
61 Through Supreme Decree No. 034-2014-PCM.
62 Through National Agreement No. 32 (2010) and Law No. 29664 (2011).
The law that creates the National Disaster Risk Management System (SINAGERD) (Law No. 29664 (2011)) and the supreme decree that approves the Regulations of Law No. 29664, which creates the National Disaster Risk Management System - SINAGERD (Supreme Decree No. 048-2011-PCM (2011)).
63 Enumerated in Law No. 29664, Articles 11 and 12, and Articles 3 and 5 of the Regulation.

Figure 46. Institutional relationships in Peru's National System for Disaster Risk Management

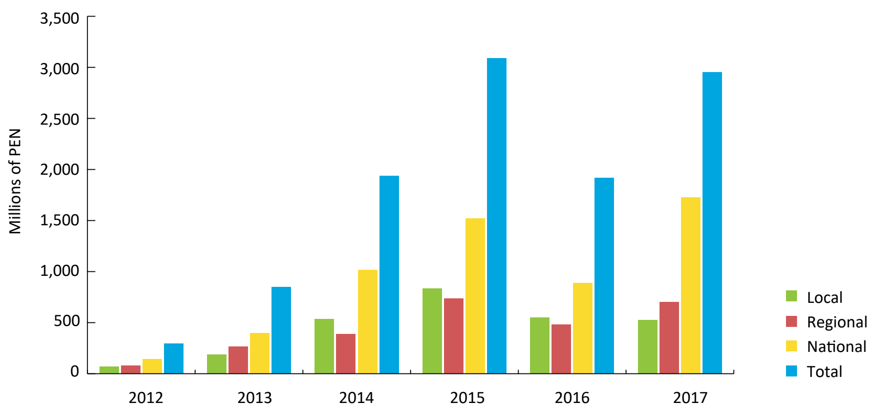


Source: Reproduced by Frederic Grobler, based on French and Mechler (2017, p.18).

Note: The Presidency of the Council of Ministers (PCM) is responsible for steering national disaster risk reduction. The National Council for Disaster Risk Management (CONAGERD) holds political decision authority in emergencies. INDECI and the National Centre for Disaster Risk Estimation, Prevention and Reduction (CENEPRED) oversee the technical implementation of the National Policy and the National Disaster Risk Management Plan. Since 2017, both pertain to the Ministry of Defence. INDECI and its regional offices oversee disaster preparation, response and rehabilitation. CENEPRED, in turn, has overseen prospective and corrective disaster risk management only since 2011.

The legal and policy context has developed positively, yet major governance challenges for the DRM system in Peru persist. The discrepancies between the well-designed formal frameworks for DRM and the actual practices are still large, especially at regional and local levels (United Nations, 2014): "achieving coordination in the day-to-day activities of these large siloed bureaucracies remains complex and incomplete" (French and Mechler, 2017, p. 19). Historical responsibilities assumed for DRM by ministries prior to the National System have often stayed with them, adding their own complex bureaucracies and governance structures to the governance system as a whole. Compared to the two years before the National DRM Plan, funding has increased across all government levels and provides resources to transition into more integrated and prospective DRM, as Figure 47 shows. However, widespread lack of political will and the weak absorption capacity of subnational institutions remain major challenges for the uptake, alongside corruption and inefficient spending, especially under lowered controls during emergencies (French and Mechler, 2017).

Figure 47. Funding for disaster risk management measures in Peru



Source: French and Mechler, 2017, p. 21.

Note: The data shows funding for different levels of government under the flagship budget programme for DRM (PP0068), in millions of Peruvian *soles* (PEN), with preliminary amounts for 2017.

Land use planning and planned relocation

Land-use planning is key because climate change will expose many zones in Peru to rising hazards. Until recently, Peru had no national-level norms on settlements in high-risk zones (MINAM, 2016c; Ministry of Agriculture and Irrigation (MINAGRI), 2012). In the new SINAGERD system emerging since 2011, policies for landscape-scale planning and zoning processes figure prominently (French and Mechler, 2017). They aim to reduce exposure to disasters by precluding or decreasing human activity in risk areas. The Ministries of Housing (in urban settings) and the Environment (nationwide) share responsibility for "territorial ordering". The National Water Authority (ANA) establishes buffer zones around waterways. However, zoning has not been enforced effectively and human activity in hazardous areas continues to undermine disaster risk management (French and Mechler, 2017). The only mention of migration in the national DRM plan is also in this context: Migration into hazardous areas is depicted as one factor that increases vulnerability to disaster risks (SINAGERD et al., 2014, p. 32). The plan mentions it alongside non-compliance with zoning norms, weak institutional systems and systemic poverty.

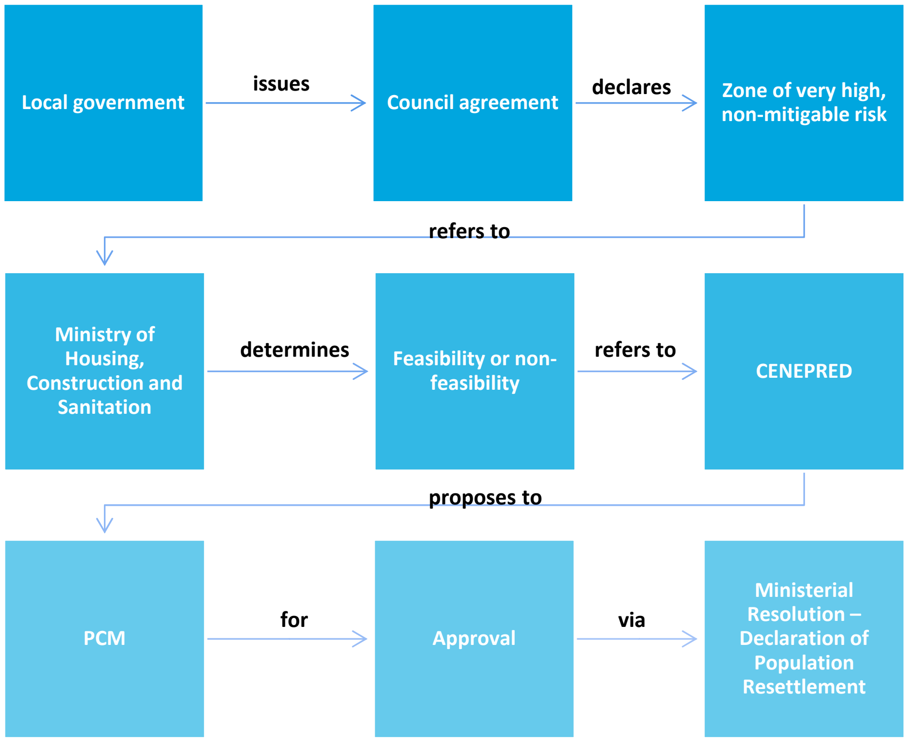
Many people in Peru live in areas exposed to high risk and over the last years, planned relocation has been "framed as the solution to this risk" in areas where risk is considered "unmitigable" (Venkateswaran et al., 2017, p. iii). In 2012, Peru adopted the Law on Population Relocation for Areas with Very High, Unmitigable Risk, its 2017 modification and its Regulation.[64] The legislation created a process to identify such risk areas and relocate populations from them – voluntarily or involuntarily (Articles 7 and 8). The idea of risks that cannot be mitigated refers to areas likely to suffer continuously damages where the burden of protection infrastructure would be disproportionate or impossible.[65] The 2017 Modification of the law added "zones of recurrent risk for landslides, *huaicos* and river overflows" as such areas.[66] However, the "line between what can be mitigated and what can't is fluid" in reality and there is a "need to explore the trade-offs between adaptation, mitigation and resettlement" (Venkateswaran et al., 2017, pp. 50 and 52); according to analysts, the dichotomy of mitigable and unmitigable does not consider "contextual "softer" solutions" such as early-warning systems that "promote 'living with [hazards]".

64 Specifically, Law No. 29869, Population Resettlement Law for Areas of Very High Unmitigable Risk, 2012; Law No. 30645 Law Modifying Law 29869, 2017; Supreme Decree No. 115-2013-PCM (Regulation of Law No. 29869).

65 Areas with very high, immitigable risks are those with "a probability that the population or their livelihoods will suffer damages or losses as a result of the impact of a hazard, and where the implementation of mitigation measures are more costly and complex than carrying out the relocation of households and infrastructure" (Article 4).

66 These "recurring risk zone" as areas where "the population or their livelihood will likely suffer damages on a recurring basis, as a result of constant landslides, floods and overflows of rivers, among others. Although this zone is mitigable in the short term, due to the recurrence of the natural disaster, it is of greater cost and complexity than carrying out only the relocation of the respective houses and urban equipment…" (Law No. 30645).

Figure 48. The process of approving planned relocation in Peru



Source: Reproduced by Jonas Bergmann from Poma (n.d.).

The law establishes a formal process to plan and implement planned relocation that comes with some hurdles. Figure 48 depicts this process. One possibly conflictive rule excludes inhabitants having lived less than 10 years in the village from the relocation (Article 33 Regulation). Once declared as uninhabitable, areas cannot receive public service investments anymore (Article 21).[67] If the time span between this declaration and actual relocation is long, this inability to receive investments can result in increased vulnerability. Another challenge in relocation concerns land. The law determines that the reception area must be identified and its security evaluated (Article 18); if owned by the State, relocation has priority over other uses. Otherwise, the new location must be owned or acquired by the district municipality. In justified cases, the State can expropriate private owners (Article 22.1 Regulation).

67 If an imminent danger is determined in a zone of "very high, immitigable risk", INDECI declares a state of emergency and contribute to a temporal relocation (Articles 5.5 and 9.2 Regulation).

Financing is another key challenge in relocation. The regional governments oversee funding initiatives (Article 5.2. Regulation), but local governments must finance the public investment projects linked to relocation. They are to use resources they receive from charges and overcharges linked to rents from natural resource exploitation, as well as mining royalties (Article 24). However, not all regions and local governments dispose of the same funds from these sources. The subsidiarity principle applies. If local governments have insufficient funding, the competent regional government grants resources from the same sources (Articles 5.2 and Regulation 24). If costs exceed both local and regional resources, then the national Government may provide resources "according to the budgetary availability of the sector in charge" (Article 24).

Throughout the process, relocated persons are entitled to benefits and rights. The relocation must aim to protect life and public welfare, as well as guarantee the rights and interests of the population to be relocated and their goods (Article 2). MIMP is to coordinate with all entities involved in the protection and humanitarian assistance of the affected people (Article 5.9 Regulation). Article 5 stipulates the following central principles: legality, sustainability (dignified lives, livelihoods and services), equality, information, subsidiarity and graduality (attention according to urgency). Article 6 stipulates and guarantees, among other things, the exhaustion of other mitigation options; actions to prevent adverse effects; participation of persons to be relocated; and assistance by the local government to transfer to the new area. Citizens have a right to active participation with the "necessary availability" (Article 17). The regional government manages the physical sanitation and required legal steps. Relocated families receive standard housing lots, established and regulated by the Ministry of Housing, Construction and Sanitation (Article 34 Regulation). The lots are to reflect the spatial distribution of the community of origin as much as possible. Relocated persons are to count with access to public services in the same or better condition than at origin. New housing must include basic services and provide better security against disasters (Article 20). The three levels of government must consider the award of social housing according to budget availability (Article 24).

The assessment of the relatively new law is mixed. Relocation is a highly complex and challenging process (Brookings Institution, Georgetown University and UNHCR, 2015; Georgetown University, UNHCR and IOM, 2017; Sherbinin et al., 2011; Wilmsen and Webber, 2015). The law constitutes progress but has been insufficiently implemented (French and Mechler, 2017). As discussed, the definition of "unmitigable risk" remains ambiguous. Monitoring and Evaluation are still insufficiently implemented. Planned relocation issues have also been contentious in the country: The "conditions of relocation and the politics surrounding them are also complex and conflicted" (French and Mechler, 2017, p. 21). So far, the approach has often been top-down, but resistance by populations is frequent (Venkateswaran et al., 2017). Sometimes people have been relocated back to at-risk lands, as after the 1997–1998 El Niño. The implementation of the law also overemphasizes physical infrastructure at the expense of long-term "social recovery", that is, livelihood restitution, health and education (Venkateswaran et al., 2017, p. 48). The authors caution that since many thousands of Peruvians already live in high-risk zones, relocation may not be sensible or feasible for all of them.

4.4. FRAMEWORKS ON CLIMATE CHANGE

Many institutions deal specifically with climate change in Peru (Pramova et al., 2015). After ratifying the United Nations Framework Convention on Climate Change (UNFCCC) in 1993, Peru established the National Climate Change Commission[68] to oversee the UNFCCC implementation, as well as the integration of climate goals in the plans and budgets of all authorities.[69] The High-Level Climate Change Commission was established in 2018. The National Environmental Council (CONAM) was funded in 1994 and provided the basis for the subsequent establishment of the Ministry of Environment (MINAM) in 2008, with several public agencies such as the attached meteorological service. The Ministry is home to the Directorate General of Climate Change, Desertification and Water Resources, the national authority overseeing Peru's commitments under the UNFCCC, the fight against climate change, as well as action on desertification and drought. Responsibilities on environmental issues are distributed across government levels. Relevant frameworks exist at the international, national and subnational levels.

68 Spanish: *Comisión Nacional sobre el Cambio Climático.*
69 Created in 1993 and modified in 2013 by the Supreme Decree No. 015-2013-MINAM.

4.4.1. Commitments to international processes

Peru has mentioned the climate-migration nexus in different arenas related to the UNFCCC. So far, Peru has submitted three so-called "National Communications" to report on the implementation of the UNFCCC. The First and Second Communications included a brief analysis of (general) historical migration flows (CNCC, 2001; MINAM, 2010b). The communications also describe a future where population would continue to move from the highlands to the coast and rainforest. The First Communication also mentions how migration for agricultural land leads to deforestation in the rainforest. In both sections on glacier retreat and El Niño-related disasters, it points to the need for territorial zoning and relocation from risk zones. The Second Communication names agricultural losses and food insecurity as main climate change threats (MINAM, 2010b). Resulting economic instability can trigger overexploitation of natural resources in some cases – and migration in others. Migration is described as "abandonment of eroded lands that induces processes of greater degradation, all of which increase the vulnerability of the population". While the Second National Communication mentions the possibilities of such migrations, it does not discuss this dynamic in detail and omits displacement or relocation. The Third Communication does not mention migration related to food insecurity anymore (MINAM, 2016d), but rather mostly in the context of deforestation linked to migration for agricultural land in the rainforest. It alludes, however, for the first time to "displacement of populations by degradation of the environment", but only briefly to the indirect health impacts of climate change. The communication also points out that planned relocation is considered as lines of prioritized action in 2 of the 16 Regional Strategies on Climate Change approved by fall of 2015 (Cusco and Junín). Although still limited, the discussion of migration in the national communications provides a useful baseline for integration of the topic into the national adaptation plan and future strategies (Rodriguez-Serna, 2015).

Peru's Nationally Determined Contributions (NDCs), submitted under the Paris Climate Agreement,[70] establish adaptation goals to reduce vulnerability to climate change hazards in five priority thematic areas: water, agriculture, fishery, forestry and health. Table 3 presents the objectives for these sectors, which all have importance for migration dimensions. A specific focus is on vulnerable populations, such as rural small and subsistence farmers or those with weak market linkages; artisanal fishermen; native communities; small forest producers; and, from a health perspective, infants, women and the elderly (Government of Peru, 2015). The priority sectors are complemented by cross-cutting approaches to disaster risk management, resilient public infrastructure, poverty and vulnerable populations, gender, intergenerationality and -culturality,

70 Ratified and entered into force in 2016.

and promotion of private investment. Thanks to the Framework Law on Climate Change, the different instruments of integrated management of climate change such as the NDCs are binding (GTM-NDC, 2018).

Table 3. Scope and objectives of NDC adaptation priority sectors

Sector	Water	Agriculture	Fishery	Forestry	Health
Scope	Includes supply and demand, direct human consumption, agriculture and livestock, energy, mining and industry; and physical and ecosystemic infrastructure.	Considers protecting the sector and its contribution to the economy and attending to the most vulnerable groups (e.g. small and subsistence farmers).	Considers protecting the sector and its contribution to the economy and includes attending to the most vulnerable groups (e.g. artisanal fishermen).	Considers protecting ecosystem services that forests provide and attending to the most vulnerable groups (e.g. indigenous communities and small forest producers).	Considers increasing the adaptive capacity of health services to face climate change and the resilience of vulnerable populations to its effects.
Intermediate objectives	Encourage and promote actions and projects that **increase the availability of water** in the context of climate change.	**Reduce the negative impact of climate change on agrarian activities** (agriculture, livestock and forestry).	**Reduce the vulnerability of the fishery and aquaculture sector** to climate change.	Promote comprehensive land management with a landscape approach, oriented towards **increasing forests' resilience** to climate change and **reducing the vulnerability of local populations.**	Reduce vulnerability and increase **population resilience to the health effects of climate change.**

Source: Government of Peru, 2015, p. 10 (abridged translation).

The first implementation period of the NDC will be 2020–2030 and the Government is currently finalizing the associated strategy. A multisectoral working group of temporary nature, with the involvement of 13 ministries, generated a final technical guidance to support the implementation of the NDC (GTM-NDC, 2018) (GTM-NDC, 2018). For the five priority adaptation areas,[71] the report spells out goals and measures to adapt to climate change in the short (to 2021), medium (to 2025) and long term (to 2030). It also details the actors in charge, funding, indicators, as well as monitoring and evaluation. The document of almost 1,000 pages scarcely mentions migration, displacement, planned relocation and non-mobility. In agricultural adaptation, it presents male outmigration from the highlands as a contextual variable that results in changing female roles and participation in agriculture, but it does not describe climate change as a potential driver of movements. The forest adaptation section again refers to migration as a driver of deforestation. The health adaptation section only the notes the need for safe shelter for people displaced by emergencies. The document does not discuss relocation and non-mobility. No attention is given to how mitigation projects (such as building of hydroelectric dams or biofuel production) may influence mobility patterns.

Besides the NDCs, National Adaptation Plans (NAPs) are another central instrument in international climate action with potential to address mobility dimensions, even as the current process to elaborate the Peruvian NAP does not yet seem to integrate these dimensions adequately. NAPs were created under the UNFCCC Cancun Adaptation Framework to identify national medium- and long-term adaptation needs and their implementing strategies (UNFCCC, 2010). Analysts have pointed to NAPs as potent tools to address human mobility related to climate change and the associated opportunities and challenges for adaptation effectively. NAPs could help to design local adaptation to avert mobility pressure where viable, but also to facilitate migration as an adaptation strategy where it will be necessary. IOM recommends incorporating migration into NAPs based on assessed evidence of climate–mobility and into every step of the NAP process (Warner et al., 2015; Warner et al., 2014). Most South American countries make limited reference to mobility in their policies and frame migration mostly as a failure to adapt (Warn, 2013). The Peruvian National Adaptation Plan (NAP) is still a work in progress. Led by MINAM, in 2016 a guiding instrument was proposed for the formulation of the NAP with input and recommendations consulted with the sectors of the priority areas and the cross-cutting areas of the NDC.[72] The adaptation section in Peru's NDC for adaptation to climate change will establish the operational

71 It also details the mitigation strategy, but the focus here is on adaptation.
72 More information is available at www.minam.gob.pe/notas-de-prensa/peru-sienta-las-bases-para-su-plan-nacional-de-adaptacion-al-cambio-climatico.

phase of the NAP (GTM-NDC, 2018, p. 452f.). However, as explained above, the current version of the Peruvian NDC implementation strategy so far does not include substantial attention to climate–mobility dimensions.[73] Besides, the NAP will also draw on Peru's National Strategy on Climate Change discussed in the succeeding section.

4.4.2. National climate change policies

Since 2000, Peru has set several milestone frameworks on climate change, yet attention to mobility has remained scarce. The 2002 Organic Law of Regional Governance decentralized environmental regulations and demanded subnational strategies for the formulation and implementation of national climate change policies from all regions.[74] MINAM issued guidelines to develop the regional strategies that mention displacement and migration alongside conflicts over resources, but not planned relocation or non-mobility. Migration and displacement are described as potential "amplifiers of vulnerabilities", because, for example, "the effects of environmental risks and climatic variations contribute to migration to the city" (MINAM, 2009a, p. 22). Of the 26 regional entities in the country,[75] by early 2019, all but Callao, San Martín and Tumbes had adopted such a strategy. In 2003, Peru adopted its first National Strategy on Climate Change.[76] The framework identified vulnerability to climate change and strategies for mitigation and adaptation, without any reference to mobility. Peru's 2010 Climate Change Adaptation and Mitigation Action Plan (MINAM, 2010a) details priority actions on climate change and key vulnerabilities. The action plan proposes to incorporate disaster risk management and adaptation measures in planning processes at the regional level. It neither references migration as an adaptation option nor mentions displacement or relocation.

73 There may be still a chance that these dimensions come in later: In 2016, the ministry stated that the future NAP would include strategic guidelines for the priority sectors of the Nationally Determined Contributions, but also for sectors that are not part of the NDCs, visit www.minam.gob.pe/notas-de-prensa/peru-sienta-las-bases-para-su-plan-nacional-de-adaptacion-al-cambio-climatico.

74 Law No. 27867 (2002): Organic Law of Regional Governance.

75 Since 2003, Peru has 26 entities at the regional level: 24 departments and two provinces with special regimes (the Constitutional Province of Callao, with its own regional government, and the province of Lima, independent of Lima Region).

76 Supreme Decree No. 086-2003-PCM (2003): National Strategy on Climate Change.

Attention to mobility increased mostly in the 2010s: The revised National Strategy on Climate Change of 2014 references migration for the first time. It presents "forced migration" as one of the problems resulting from climate change (MINAM, 2015c, p. 10f). Because climate change and disasters deteriorate the "habitability conditions of the settlements … forced migration and the loss or displacement of the family and social capital" can result (MINAM, 2015c, p. 15). Relocation is not mentioned. One of the main objectives is to develop adaptive capacities to confront climate change, yet the strategy does not mention mobility more specifically in these adaptive capacities – neither as a dynamic to be prevented by improving adaptive local capacities where viable, nor as a dynamic with adaptive potentials when local adaption to climate impacts is impossible.

In 2016, Peru adopted its National Strategy for the Fight against Desertification and Drought (MINAM, 2016a). The strategy draws on the United Nations Convention to Combat Desertification.[77] In the very beginning of the problem description, a study is cited that emphasizes how desertification can gradually overwhelm adaptation thresholds and possibly lead to large migration (MINAM, 2016a, p. 14). The strategy also quotes other studies that point to land degradation as a key factor in migration. It explains that one benefit of preventing land degradation is the avoidance of forced migration and the stability of the communities that invest in land protection. Within Peru, according to information provided by 13 regional governments, the consequences of desertification and drought include increased migration, abandonment of agricultural land and social conflict, alongside many others. The strategy emphasizes the lack of baseline data on affected areas that hinders the design of specific projects. It does not mention displacement or relocation.

In 2018, Peru unanimously adopted its Climate Change Framework Law, which establishes the legal basis to combat climate change. The law makes previous instruments binding, such as the National Strategy on Climate Change and the Nationally Determined Contributions. It also integrates new mitigation and adaptation measures and requires annual progress reports. The newly established High-Level Climate Change Commission[78] will oversee these measures.

77 Full name: United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa (UNCCD).

78 The High-level Commission on Climate Change co-exists with the National Commission on Climate Change (CNCC) from 1993, which has only limited powers.

A major step forward, the Climate Change Framework Law includes a final, non-binding provision on forced migration due to climate change impacts. Already in 2005, two national councils had noted climate change-related migration as one research priority (National Council for Science, Technology and Technological Innovation (CONCYTEC) and National Council for the Environment (CONAM), 2005). However, previous attempts to include the subject into climate change policies failed. The 2018 framework law required the "executive branch to issue an action plan to avert and address forced migration and displacement due to the effects of climate change". The glossary in the law even defines the term "environmental migrant". The definition is the same as the one suggested by IOM (2011, p. 33), with two small exceptions. While IOM states that the reasons for moving ought to be "predominantly" related to environmental changes, the glossary does not contain this qualification, but adds that these environmental changes ought to be "unavoidable". The law describes the first goal of such an action plan as avoiding negative consequences of movements for receiving areas, namely, infrastructure pressure and social conflict. The second stated goal is to avert negative consequences for the socioeconomic well-being of migrants.[79] The disposition does not allude to any potential positive consequences of (even forced) migration for neither the destination nor the origin areas or the migrants themselves. Overall, the framing exhibits a sedentary bias. It also remains silent on other forms of human mobility: the law does not explicitly mention neither planned relocation nor facilitated migration as measures of last resort, although the wide definition of environmental migration in the glossary of the law could be interpreted to include these forms of mobility. The issue of non-mobility is not discussed either. To implement the Climate Change Framework Law, a regulation has been consulted between the government and civil society. Recently approved, it requires MINAM in coordination with MIMP to issue the action plan (MINAM, 2019, twentieth final complementary disposition), which constitutes an important avenue to integrate the subject into the national planning systems, within 180 business days.

79 The called-for action plan intends to focus only on "forced" instances of migration; however, the migration definition given in the glossary stipulates that movements can be voluntary or forced. Whereas the title of the disposition and the definition in the glossary refer to "environmental migrants" – potentially including reasons beyond climate change impacts – the disposition itself only singles out migration due to the "effects of climate change".

4.5. OTHER SECTORAL AND CROSS-CUTTING FRAMEWORKS

By now, climate change has pierced through many Peruvian policies, strategies, plans and programmes in other key sectors, whereas the integration of mobility issues continues to be weak. This section exemplarily examines some frameworks for the sectors of agriculture, development, environment, forests, gender and health.

4.5.1. Agriculture and food security

The National Agricultural Policy, steered by the National Ministry for Agriculture and Irrigation, addresses climate vulnerabilities multiple times, but only refers to the deforestation threats linked to migratory agriculture (MINAGRI, 2016). One of the main objectives of Peru's Plan for Food Security and Nutrition for 2015–2021 (MINAGRI, 2015)[80] is stability in the face of climate change through adaptation. However, the plan does not take into consideration the linkages between food security and human mobility – neither on the driver side, nor on the side of consequences of movements. The Climate Change Adaptation and Risk Management Plan for the Agrarian Sector 2012–2021 entered its implementation phase in 2015. "Strategic Axis 2" (preparation and response to emergencies due to weather events) includes relevant provisions, such as action to reduce rural population's vulnerabilities in the face of extreme weather events and improved capacities to manage and adapt to risks in agriculture. However, it does not contain any specific mention of human mobility.[81] Agriculture is also one of the key adaptation sectors of Peru's NDCs.

80 Complemented by the National Food and Nutrition Security Strategy 2013–2021 (ENSAN), approved by Supreme Decree No. 021-2013-MINAGRI.

81 Further instruments include the following: National "Inclusion for Growth" Strategy, approved by Supreme Decree No. 008-2013-MIDIS; Family Farming Strategy 2015-2021 (ENAF), Supreme Decree No. 009-2015-MINAGRI; National Policy and Strategy of Water Resources, Supreme Decree No. 006-2015-MINAGRI; National Strategic Export Plan (PENX) to 2025, Supreme Decree No. 002-2003-MINCETUR.

4.5.2. Development

"Bicentennial Plan: Peru by 2021" spells out the strategic development vision for the current decade (CEPLAN, 2011). The Bicentennial Plan describes the growth of megacities and climate change effects on water availability as some of the megatrends affecting Peru. It represents internal migration mostly as a challenge and a driver of urbanization, which enables growth but also stresses infrastructure and triggers crime. The plan also points to internal migration as a driver of deforestation, as well as of informality and underemployment, resulting in people in need of social services and waste in the cities. It does not mention displacement. Although the plan does not an explicit link or prioritize action and populations accordingly, it contains relevant efforts for addressing underlying vulnerabilities to climate change and the situation of migrants in destinations.[82] For example, "Strategic Axis 1" includes efforts to address human development and poverty. "Strategic Axis 2" spells out opportunities and access to services in education, health, food security, public services, housing and security, among others. The plan also locates climate change adaptation as among the five principle goals under "Strategic Axis 6". It describes how climate change will decrease agricultural competitiveness, affect water availability in densely populated and agricultural areas, as well as result in erosion and a range of hazards. Goals include adaptation to climate change, as well as disaster risk and vulnerability reduction. Under "Strategic Axis 5", one objective is the "grouping of the rural population in intermediate cities established on the basis of planned population centres" (CEPLAN, 2011, p. 222). Strategic actions include the development of new planned urban intermediate centres to "attract and concentrate those who live in population centres of less than 500 inhabitants", as well as to "create incentives for the inhabitants of dispersed population centres of the rural areas to move and concentrate in the planned urban centres". The objective also includes the "relocation of human settlements located in areas of unmitigable risk", developing a similar approach as the law on planned relocation (CEPLAN, 2011, p. 222).

82 One national objective on "equality of opportunity and universal access to basic services" specifically mentions migrants as a group requiring special attention for interventions against illiteracy.

4.5.3. Environment

Peru's wide array of environmental frameworks offers some norms relevant to the climate change–mobility nexus. The General Law of the Environment of 2005 and related norms and regulations[83] establish the need for protection measures to ensure adequate habitability conditions for settlements (Article 64). They also highlight the need to provide protection against disasters in development plans (Article 68). The National Environmental Policy of 2009 (MINAM, 2009b) incorporates objectives on climate change adaptation, as well as mitigation measures. Among other things, it mentions better early warning and response to disasters. Another reference concerns land-use regulations that would prevent settlement of populations and socioeconomic activities in areas with high risks, similar to the Bicentennial Plan and the Law on Relocation. The National Environmental Agenda 2015–2016 (MINAM, 2015a) includes a focus on climate change adaptation and mitigation, but nothing on mobility. The latest National Environment Action Plan 2010–2021 (MINAM, 2011) is a long-term national planning instrument developed upon the National Environmental Policy, containing priority environmental goals for one decade. Some of the strategic actions are relevant to the climate–migration nexus, including the goals on reducing soil degradation and drought effects; strengthening of early-warning and prediction systems; and improvement of DRM. The National Environment Action Plan points out the high exposure and the vulnerability of ecosystem-based livelihoods of large shares of the population. However, it is silent on linkages between the environment and human mobility.[84]

83 General Environmental Law Law No. 28611 (2005); Framework Law of the National Environmental Management System Law No. 28245 (2004); Regulation of the Framework Law of the National Environmental Management System, Supreme Decree No. 008-2005-PCM (2005).

84 The only mention of migration concerns the adverse effects of immigration on forest areas.

4.5.4. Forests

Peru, home to the second largest portion of the Amazon rainforest, has several frameworks on forests that emphasize the risk of migratory agriculture. The country has embedded its national plan on Reducing Emissions from Deforestation and Forest Degradation, and the Role of Conservation, Sustainable Management of Forests and Enhancement of Forest Carbon Stocks in Developing Countries (REDD+) in the 2016 National Forest and Climate Change Strategy, which also contains sections on climate adaptation (MINAM, 2016b). The strategy underlines the socioeconomic and environmental impacts of population growth, migration and unplanned land occupation for agriculture, especially through deforestation and forest degradation. It does not consider climate impacts on forest resources and people's livelihoods. It also does not take into consideration a possible dieback of the Amazon rainforest on livelihoods in the region. Forests are also one of the key adaptation sectors of Peru's NDCs. Peru's National Forestry and Wildlife Policy (MINAGRI, 2013) contains no reference to mobility at all.

4.5.5. Gender

In 2016, Peru approved an Action Plan on Gender and Climate Change that points to some gender dimensions of migration. However, it connects migration mostly to deforestation due to migratory agriculture into the rainforest. As another example, it notes that male (not necessarily climate-related) migration to the cities can mean that women take over their traditional roles. As one explicit example of gender dimensions within the climate–migration nexus, the plan notes the increased vulnerability of women to disasters. The plan also portrays women as usually not migrating after disasters and, therefore, having to assume more responsibilities within the household. Finally, the action plan calls for research on the health effects of climate change, naming as one example disaggregated risks to health and security of populations after forced displacement as a consequence of climate change. The plan does not discuss relocation or non-mobility. Gender is one of cross-sectional concerns in Peru's NDCs.

4.5.6. Health

In 2014, Peru created a Sector Commission on Climate Change and its Impact on Health and started to develop a Comprehensive Mitigation and Adaptation Plan for the Effects of Climate Change on Public Health.[85] The plan has an orientation towards adaptation, with five objectives: sectoral policy guidelines, generation of evidence, risk scenarios, community participation and comprehensive health care. The proposal so far does not mention any mobility dimensions. Health is one of the key adaptation pillars of Peru's NDCs.

4.6. POLICY ANALYSIS: A SUMMARY

Overall, Peru disposes of a wide range of legal instruments and policies at different levels of government that are relevant to the nexus between climate change and human mobility. While there are good entry points to address the issue, gaps are still salient and an integrated, longer-term vision on the topic is needed.

On the positive side, Peru has laws that govern migration, displacement and planned relocation. Several human rights norms provide a solid foundation for a rights-based approach to the issue. More integrated frameworks for disaster risk management and reduction have also come into being to deal with emergencies and humanitarian responses. Some regional frameworks provide promising avenues to work on the topic, including processes by MERCOSUR, as well as progress around the Cartagena Declaration and the Brazil Declaration and Plan ot Action. The recent Climate Change Framework Law also provides an excellent step forward with its call for an action plan to avert and address forced migration and displacement due to the effects of climate change, which is still a work in progress.

Across Peru's national policies, climate change is increasingly present, yet the integration of mobility concerns in these climate change policies, strategies and other cross-cutting frameworks, such as on gender and health, is still insufficient. These frameworks still do not explicitly aim to prevent forced migration; to support migration as adaptation where local measures are not viable or desired; to govern the destination side of migration, mostly urban areas; to assist migrants and displaced people; and to search for durable solutions. Gaps also persist between statements of intent and actual implementation. The following chapter includes some recommendations on refining laws and policies.

85 As in Ministerial Resolution No. 246-2014-MINSA.

Lockdown amid the COVID-19 pandemic in Lima, Peru. © Shutterstock 2020/Adrian DASCAL

5. RECOMMENDATIONS

Based on the previous chapters, this section provides recommendations for better integration of the climate–migration nexus into relevant laws and policies, points to research gaps and underlines data needs.

5.1. REFINING LAWS AND POLICIES

Based on the analysis in the previous chapter, laws and policies in Peru could profit from the following recommendations.

Migration instruments

(a) Enhance the protection of all migrants in Peru addressing each stage of the migration cycle (before, during and after moving), in light of human rights instruments and with specific attention to situations of climatic vulnerability.

(b) In the National Population Plan, make clearer reference to challenges of displacement and planned relocation.

(c) Link programmes for return migration and diasporas with support for adaptation and resilience-building in the country.

(d) Integrate climate change considerations into norms on human mobility in regional tools and enhance coherence between them. For example, in the MERCOSUR Residence Agreement, allow the processing of residence applications in consular sections in home countries during disasters and reduce requirements for permanent residence applications for people affected by disasters. Join efforts around the MERCOSUR citizenship as an associate member and expand the range of rights warranted to all migrants in MERCOSUR, including persons displaced across borders by disasters. Consider Andean citizenship as a backup if MERCOSUR plans should fail and bolster CAN norms; for example, simplify and reduce entry requirements under the Andean Instrument for Labour Migration, so people affected by climate change can more easily migrate to diversify incomes.

Displacement instruments

(a) Enhance discussions around the situation of people displaced by disasters under the definition in the Cartagena Declaration and continue to consider granting refugee status for people displaced by disasters when disasters also seriously disturb public order.

(b) Fortify complementary, temporary and humanitarian protection schemes and apply them more often to foreigners affected by sudden- and slow-onset hazards, while linking temporary protection status to routes to citizenship and permanent residence, such as the MERCOSUR residence.

(c) Guarantee the registry of all internally displaced persons in the national registry after disasters, the updating of the database, and the collection of both baseline and follow-up data from displaced persons to understand and address vulnerable situations and their evolutions over time more adequately.

(d) Work with, consult and have displaced populations participate in finding durable solutions that fit their needs, with special attention to unaccompanied minors and gender.

Disaster risk reduction/management instruments

(a) Intensify the shift towards building long-term resilience, prospective DRM and no-regret measures instead of after-the-fact emergency responses.

(b) Mobilize resources for DRM and target global climate funds specifically for areas with high displacement risks to prevent forced movements where possible, and provide for displaced populations where their displacement cannot be avoided.

(c) Bolster intersectoral and multilevel institutional coordination for integrated DRM and climate change adaptation and streamline responsibilities within the complex system.

(d) Raise subnational capacities for both DRM and the absorption of funding so the subsidiarity principle can be fulfilled adequately in terms of decision-making and implementation.

Planned relocation instruments

(a) Ensure the exhaustion of other options for risk reduction and climate change adaptation before attempting planned relocation and large-scale "re-grouping" of rural populations.

(b) Strengthen the consultative process, which should preside before the decision to move communities, especially given the ambiguities on the exact thresholds of what constitutes "very high, unmitigable risks".

(c) Alleviate the public investment gap between the declaration of the uninhabitability of a settlement and its eventual relocation, and work to reduce people's vulnerabilities in the meantime.

(d) Integrate a due focus on social recovery, the long-term building of sustainable livelihood options and dignified living conditions in terms of basic services, social cohesion and social networks.

(e) Ensure stronger and more consistent monitoring and evaluation of relocation processes with adequate baseline and follow-up data.

Climate change instruments

(a) Develop the action plan on climate change and migration envisaged in the regulation of the Climate Change Framework Law to incorporate the issue systematically into national sectoral policies.

(b) The plan should consider the full life cycles of movement – before, during and after – as well as the full range of human mobility – migration, displacement, planned relocation and non-mobility – in an integrated manner. Alongside preventing and addressing forced instances of climate-related mobility, also develop strategies to tap into its adaptive and positive potentials.

(c) As two other entry points, integrate human mobility in the upcoming update of the National Strategy on Climate Change by 2021 and the current development of the National Adaptation Plan (NAP).

Other sectoral and cross-cutting instruments

(a) In instruments on agriculture, duly consider climate change-related food (in)security and their linkages with human mobility. Also, include strategies to address food security of displaced people and at-risk groups. Integrate these considerations in the current update of all agricultural policies.

(b) In instruments on development, design strategies to improve migration conditions – on both sending and receiving sides – so that migrants can tap into their potentials, while avoiding forced instances of movement. Also, channel resources in existing development strategies into programmes that reduce the vulnerability and exposure of populations in high-risk areas.

(c) In environmental instruments, incorporate the effects of human mobility on local environments more comprehensively. Consider environmental challenges for migrants in urban destination areas more thoroughly and improve the habitability of settlements in cities.

(d) In instruments on forests, prepare for likely severe future climate impacts on the health of rainforest populations, as well as on forest resources, related stress on livelihoods and, by extension, possible mobility patterns. Provide pre-migration skill formation programmes to aspiring migrants suffering from climate impacts so they can engage in more sustainable livelihoods than deforestation-based agriculture when arriving in the rainforest.

(e) In all instruments and data, integrate gender alongside other intersecting social lines of difference that qualify options to move or stay, as well as their outcomes. Invest in addressing discrimination and unequal status that hinder people to choose their most desirable option in the first place.

(f) In instruments on health, devise strategies to address the health impacts of climate change that may induce migration or displacement, such as new diseases or increased disease prevalence among human beings and animals. Bolster infrastructure to address the possible health impacts of rising migration, displacement and planned relocation, as well as non-mobility, including trauma, altered patterns of disease spread and health impacts of outmigration on left-behind family members, especially children and older adults.

Plaza de Armas, Cusco, Peru.
© Unsplash/Adrian DASCAL

5.2. FILLING RESEARCH GAPS

The review has identified the following main research gaps that require further investigation.

Livelihoods

Research focuses on people in Peru's primary sector who are reliant on a mix of crop and animal farming but ignores other important activities. Livelihood activities are one key variable for understanding how people must deal with climate hazards, but the extent and quality of discussions varies strongly in the studies. Off-farm income activities are scarcely mentioned, and sometimes because they do not represent an option in the study sites, sometimes because the studies, by design, only examine farming practices. Scarce research exists on how climate change impacts influences human mobility for people living close to the sea in Peru, although fishing has become a central part of the economy and provides food and jobs to large populations (FAO, 2010 and 2019) and Peru's fisheries are among the world's most vulnerable to climate change stressors (Allison et al., 2009; Magrin et al., 2007; Magrin et al., 2014). Studies also overlook the processing and distribution industry that revolves around ecosystem services and usually also employs many people (e.g. Kluger et al., 2018). Similarly, the agroindustry on the coast is scarcely studied, which provides jobs to thousands of people and important revenues in exports. Few studies examine urban lives and livelihoods, as well as their exposure to climate extremes. In an already highly urbanized country with water stress and more urban growth expected (UN DESA, 2015 and 2018b), partially due to migration, more research is needed on the secondary and tertiary sectors.

Drivers of mobility

Identified studies shed some light on the role of hazards in migration decisions, but important drivers and their interactions remain unexplored. The global debate has come to emphasize the multicausality of drivers (Castles, 2002; Jäger et al., 2009; Warner and Afifi, 2014). The only other review on Latin America takes the same stand (Kaenzig and Piguet, 2014). The review here confirms these findings but also unveils several gaps. Most studies on Peru look at how hazards affect *environmental drivers* of human mobility (such as food security and habitability), which the Foresight (2011) report described as the ones most likely affected. However, the report also emphasized that the influence of hazards on *economic drivers* is the most important for mobility. In Peru, some studies do look at income or job opportunities, but seldom at producer or consumer prices. Almost no studies provide solid assessments of the other macro drivers of movements, namely, *political drivers* (e.g. conflict insecurity) and, to a lesser extent, *demographic drivers* (e.g. disease prevalence).[86] Only three studies explicitly explored some conflict dimensions (Koubi et al., 2018; Magallanes, 2015; Hoffman and Grigera, 2013). Some studies emphasize the interplay of hazards with other structural processes, such as globalization and inequalities in land rights or power. However, at large, studies on Peru seldom investigate reasons for moving in adequate detail, especially indirect pathways and interactions. For example, when people indicate a lack of jobs or income as their motivations to move, few studies investigate whether hazards might have played a role in depriving people of these factors in the first place. The roles of skills, resources, knowledge and networks to move also require more attention.

Climate change dimensions

Future analysis of climate change dimensions should be improved. Few studies include robust discussions of observed and projected climate change. Some fail to account for multiple, overlapping hazards and the compounded effect of sudden and slow-onset processes. For example, coastal studies focus mostly on El Niño, but do not discuss changes in temperature and rainfall trends in detail. Hazards, trends and future projections in the high jungle, the Páramo, across the coast and the lower Amazon are understudied.

Consequences of moving

Little knowledge exists on the consequences of moving. Some identified studies look at different stages of human mobility, but comprehensive views on the full cycle of movement and from all relevant vantage points are scarce in the Peruvian context. Most studies do not examine any consequences, although key global studies call for assessments of the situation in destination areas and other impacts (Foresight, 2011). Almost no studies look at consequences for both those moving and those staying behind. Little attention is paid to how migrants fare in their new surroundings and how that influences their vulnerability to future hazards over longer periods. More attention is needed on how new destinations may increase or decrease the exposure to existing and future hazards, and how skills, resources, knowledge and networks affect consequences.

86 Social factors such as family relations or seeking education also drive migration, especially within countries, but Foresight (2011) finds limited evidence that environmental change can influence these social drivers.

Population characteristics

A further gap concerns how various population characteristics – such as age, education, ethnicity, gender and physical ability – affect strategies to deal with hazards, including mobility. These factors are also insufficiently discussed in explaining outcomes of coping and adaptation efforts, including the consequences of moving. For example, few studies duly account for gender dynamics, although other investigations have repeatedly pointed to the lack of attention to the important dimension of gender in this field of study overall (Gioli and Milan, 2018), in South America (Cerruti, 2009) and in Peru specifically (Milan, 2016).

Non-mobility

Non-mobility – people unable or unwilling to leave sites with climate risks – has received close to no attention in Peru, although major research has pointed to it as one of the possibly most salient dimensions of increasing climate hazards (Foresight, 2011; Adger et al., 2014). The limited existing research shows that even in areas affected by climate change, many people opt to stay, at least in the beginning of gradual changes (Koubi et al., 2016; Koubi et al., 2018). Even for some poor households, resource constraints seem to play a smaller role than commonly assumed (Adams, 2016; Adams and Adger, 2013). Conversely, instrumental and affective bonds can bind people to places and continue to be a strong link even when climate impacts make the places more marginal. However, thresholds of place satisfaction may be crossed ultimately. The loss of some key non-economic ecosystem services due to climate change could drastically decrease people's place attachment and thereby shape migration decision processes of more people than usually assumed (Adams, 2016; Adams and Adger, 2013). More research is needed to understand how people react to and anticipate hazards, which factors bind them to places, what makes them unwilling or unable to move, how much agency they retain, and how vulnerabilities of those staying behind develop over time.

Further recommendations include:

(a) **Investigate all types of mobility**. Few studies look at planned relocation or displacement and even fewer define the differences between displacement and migration. No studies exist on cross-border movements of people related to climate hazards in Peru, a clear gap in a country that has had significant net emigration (INEI, 2017; INEI et al., 2018). Historically, most emigrants have held jobs outside of agriculture. However, increasing climate risks may still result in cross-border movements of ecosystem-dependent people in the future, especially from border areas or from areas with established networks for international emigration.

(b) **Study the use of remittances**. Few studies discuss how remittances connect places of origin and destination, although internal and international remittances play a role in Peru. Social remittances – the exchange of social capital, ideas, habits, skills, practices, innovation and identities (Levitt, 1998; Levitt and Lamba-Nieves, 2011) – are hardly discussed at all. The omitted discussion of international remittances may relate to the fact that most reviewed studies do not look at urban areas, since few international remittances go to rural areas (INEI, 2016a and 2017). Conversely, internal remittances often go to rural areas and recipients in vulnerable situations, such as the elderly and economically inactive people staying behind (Sánchez Aguilar, 2015b). More research is needed on the use of internal remittances in rural areas and their potential to support adaptive capacities alongside potential threats for inequalities.

5.3. IMPROVING DATA

The review has also revealed several data gaps that constitute challenges to a comprehensive understanding of the issue. The report gives the following three key recommendations:

Better data on human mobility

Comprehensive and more diverse indicators on human mobility should be introduced in data collection. For all data, disaggregation by location, age, education, ethnicity, gender, physical ability and other intersectional lines of vulnerability is key, alongside more precise tracking of duration and distance of movements (IDMC, 2019a). The census and national household surveys would both profit from the inclusion of indicators that explore the importance of (perceived) climate-related hazards in people's decisions to move. Attempting to measure the direct and indirect influences of slow-onset hazards on drivers of movement would be especially beneficial. Existing data collection on migration in Peru, for example, the census and the National Household Survey on Living Conditions and Poverty (ENAHO), could also cover short-term and circular movement more adequately. Migration variables should be introduced into other key instruments such as the Demographic and Family Health Survey (ENDES), which provides valuable information on socioeconomic vulnerabilities. Data on internal displacements should be expanded, especially for protracted situations. Both baseline and follow-up data are needed. Displacement Tracking Matrix data by IOM could usefully complement national efforts. Data on planned relocation is not yet collected rigorously over time and still insufficiently harmonized, making it difficult to monitor, evaluate and learn from past examples, as well as to guarantee the rights of affected people. Migration variables also should be introduced or expanded in existing agricultural surveys such as the National Agricultural Survey and the National Agricultural Census, for example, to cover motivational and temporal dimensions of moving more adequately.

Longitudinal studies

To date, no study with longitudinal data exists for Peru. Cross-sectional studies provide useful but limited insights: they are like snapshot analyses that emphasize a certain moment in people's lives. Conversely, longitudinal data is particularly useful to understand the temporal evolution of people's exposure and vulnerability to hazards, their varied coping and adaptation strategies, including mobility responses and the consequences of these strategies over time. The research community has noted the lack of longitudinal studies previously (KNOMAD, 2015) but long-term data collection and analysis are still complicated and costly. Existing surveys, also from other fields, should be explored for usability.

More resources for weather, climate and agricultural data

Monitoring, forecasting and projections could benefit from more resources. First, there is a still lack of station data for monitoring, especially in the Amazon. In the production of the established observation data set PISCO, collaboration with neighbouring countries to include station data beyond the borders of Peru would also come as an advantage since, currently, problems with data arise especially in border areas. In addition, more quality control of the station data would be welcome. Second, as in most regions worldwide, seasonal forecasting and projections would benefit from more human and time resources. SENAMHI brings seasonal forecasts of global models to a regional level with a regional model, but more such models could raise the quality of these forecasts. A similar problem concerns projections, which still have considerable leeway to improve worldwide. Again, SENAMHI already operates downscaling with a regional model. Employing a multi-model ensemble been shown to provide superior results to individual

models. As the topography of Peru is very complex, it is a particularly challenging region for climate models. High-resolution, convection-permitting models could improve the simulations and, therefore, projections, of Peru's climate.

Further recommendations include:

(a) **Conduct more empirical studies and with enhanced methodologies**. Compared to other countries and regions, Peru is still under-researched (Piguet et al., 2018). More studies would be useful in the blind spot areas pointed out in the section above. For all of Peru's regions, at least some solid studies exist, yet the robustness of applied methods differs across identified studies. More attention to methodological rigor would be welcome. Few studies apply the same methods across Peru's regions and climates, which complicates the already difficult comparison of results across cases. New research should build on existing insights and data instead of duplicating efforts and re-thinking access to existing data would help to advance the field. Other methods, such as ecological inference, gravity models and time series could offer additional insights.

(b) **Improve theory and conceptualizations in future studies**. Few reviewed studies theorize or conceptually develop human mobility and other key variables. Many leave temporal, spatial and motivational dimensions unspecified. Studies use terms often loosely, making cross-case comparisons difficult. Other reviews have pointed to this difficulty of cross-comparison of results due to the large number of different approaches (van der Land et al., 2018) and conceptualizations of the environment, hazards, human mobility and other key variables (Borderon et al., 2018). One notable exception in Peru is the Where the Rain Falls project (Milan and Ho, 2014).

(c) **Run more cross-country comparisons**. Studies seldom collect comparative data on dynamics within Peru and in neighbouring countries, although they often share similar ecosystems, livelihoods and climate risks. This thinking within national boundaries limits the research community's ability to understand the climate–migration nexus within similar socioecological systems more comprehensively and to lift knowledge to a higher level of abstraction. Such comparisons would be especially useful for understanding the effects of different policy setups.

Aerial view from the Huascarán National Park in Peru.
© Unsplash/Willian Justen DE VASCONCELLOS

6. CONCLUSION

This first comprehensive report on climate change and human mobility in Peru renders several insights for further advancement in this field of study. In terms of research, studies on Peru reflect some of the key academic debates framing the climate–migration nexus. Discussions have focused on an assumed forced nature of movement ("environmental refugees") and possibly related security threats ("securitization") on the one side (Baldwin et al., 2014; Hartmann, 2010), and a focus on human security or on migration as adaptation on the other (McLeman, 2016). Some authors have also criticized the narrative of migration as adaptation – for example, as a neoliberal shift of responsibility for adaptation towards individuals (Bettini and Gioli, 2015). The UNFCCC has discussed human mobility under the loss and damage mechanism (Task Force on Displacement, 2018). In Peru, the identified studies usually do not frame human mobility as a security threat, although a few hint at possible conflict dimensions. Several studies emphasize the possibly forced nature of movements and describe moving as a last resort. However, several others also frame moving in more neutral terms, as one among many strategies to deal with hazards. However, other studies, especially the Where the Rain Falls project (Ho and Milan, 2012; Milan and Ho, 2014; Milan, 2016; Afifi et al., 2015), differentiate explicitly between diverse migration outcomes: depending on household profiles, migration can increase resilience, for example, when migrants from relatively better off households gain new skills, diversify livelihoods and improve health through temporal migration. It can also merely serve for survival, for example, to buy food during hunger season or even erode resilience when migrants struggle to earn enough to remit money back home and deprive households at home of labour supply. This narrative is in line with another large global review, which finds that human mobility occurring under positive circumstances can yield profits for home and host areas, whereas forced, unsafe and poorly managed instances can be detrimental (Wrathall et al., 2018). None of the studies criticizes human mobility as a possible adaptation strategy. However, some do worry that migration as adaptation may have tangible limits, for example, when non-economic losses, such as the spiritual value of places, drive movement (Adams, 2012 and 2016; Adams and Adger, 2013), as movement usually cannot compensate for these non-economic losses. This constitutes an important reminder for the UNFCCC loss-and-damage debates. Furthermore, the report also sheds light on the larger debates on drivers of migration and the importance of hazards among them, as discussed in the recommendations chapter.

The report also provides a baseline for evidence-based policymaking and programming and valuable lessons for other cases, especially neighbouring countries with similar ecosystems and climate zones. Historically, many people in Peru are migrants or live in multiple sites. Simultaneously, the climatologically diverse country is exposed to a variety of hazards that increasingly undermine people's livelihoods. The evidence shows that already nowadays, hazards play an important role in people's decisions to move or to stay. Such migration mainly takes place along existing migration corridors, from rural to urban areas and especially from the highlands to coastal cities and, to some extent, to the rainforest. These patterns may be amplified in the near future, as will displacement in flood zones by the coast and in the rainforest. Over the long run, many interactions between climate impacts and migration are possible. They depend on global emissions, climate sensitivity and action, human development, demographic change, democratic progress, regional stability and other factors. Through the synopsis of both climate and migration literature in Peru, this report concludes with two qualitative long-term scenarios: One in which the worst climate impacts are avoided through ambitious mitigation, yet global warming of up to 2°C by 2100 poses significant challenges; and one in which warming reaches 4°C and the climate crisis escalates further into a disaster.

Scenario 1:
Climate crisis "with brakes applied" (path to 2°C global warming by 2100)

Ambitious global mitigation would translate into an emissions pathway with significant climate impacts in the long term, but more time and space for maneuver of policymakers and societies to address them. Some more sustainable development gains could materialize in Peru and be invested in large-scale local adaptation that reduces people's vulnerabilities. Yet exposure to hazards would continue to be high, especially as populations still grow, often in exposed areas.

Because most rural areas could preserve their habitability, there would be more space for local adaptation, although impoverishment risks would persist. Still, even in this emissions pathway, extensive glacier retreat would translate into severe water stress and related questions of habitability. As hazards increase, the importance of internal migration for livelihood diversification would continue to rise gradually.

As the volume of migration could be lower and more gradual, the State would have more options to engineer incentives for migrants to settle in various destinations, while destination communities could integrate migrants better. City administrators would have more time to prepare relevant infrastructure, basic services and labour market integration opportunities, while managing their own disaster risks and climate impacts. Still, many migrants would face the risk of impoverishment in exposed neighbourhoods and require support. There would be more options left to manage rising disaster risks, for example, due to more frequent extreme El Niño events, but displacement pressures could rise nonetheless.

Scenario 2:
"Full speed" climate disaster (path to 4°C global warming by 2100)

In this high-emissions pathway, climate impacts and hazards would multiply in an unmanageable way. They would undo much of Peru's recent human development progress and lead to an escalation of compounding impacts. Populations would continue to grow in increasingly exposed areas, resulting in high climate risks across rural and urban settlements.

The adaptation option space would shrink extremely. Adaptation limits would be reached in many areas and survival migration would rise strongly. The question of habitability would become increasingly pressing due to parallel no-analog threats, namely, heat stress and Amazon dieback; near-complete deglaciation and related water stress; and more frequent extreme El Niño events on top of rising sea levels. Policymakers would have to confront the interactions and possible cumulative effects of these no-analog threats on human mobility across the country. The threats would raise the question of where to go if there are fewer and fewer low-risk areas left, as both rural areas and cities would suffer drastically across all of Peru's landscapes.

Migration could become predominantly forced as households would have less capacity to move in a safe and dignified manner, which would increase vulnerabilities and raise protection issues. Key destinations like Lima and regional capitals would risk getting overwhelmed, both in terms of immigration and their own drastic climate risks such as water scarcity.

In this scenario, unforeseen events with major effects could occur, such as a partial migration flow reversal at some future point. If coastal cities would become overwhelmed and poor people living in their margins suffered drastic water and food insecurities, they might start moving to some of the few remaining rural areas that still allow subsistence food production. These areas would, in turn, experience accelerated population growth and resultant pressure on available resources. Peru's long history shows that reversals of migration corridors can occur. In pre-Hispanic times, monsoon-driven changes in water availability, vegetation and agricultural potentials have prompted many responses, often including migration from the coast to the highlands, and vice versa, when changes overwhelmed local adaptive capacities (Fehren-Schmitz et al., 2010; Fehren-Schmitz et al., 2014; Reindel, 2009). The changes in this climate disaster scenario could be even more severe and would affect a more densely populated country. The future will hold a different range of adaptation options than in pre-Hispanic times, yet even when considering technological advancements, cities' capacities to ensure food security and provide basic services could be overstretched.

Overall, under such drastic changes, adaptation would become impossible for the great majority of people.

While this study cannot offer a conclusive answer to the question of future migration flows, taken together, **the findings present a valid evidence base for Peru to start addressing human mobility related to climate change in the near future, but with a long-term view.** Drastic global emissions reductions to avoid a "full speed climate crisis" scenario are pivotal. Local- and national-level action by policymakers and practitioners is equally important because growing pressures on people's livelihoods and more movements mean substantial challenges for the dignity and well-being of affected people in Peru.

Policymakers should advance the ongoing drafting of the "Action Plan to Avert and Address Forced Migration and Displacement due to the Effects of Climate Change" – envisaged in the regulation of the Climate Change Framework Law – to ramp up efforts. They could also resume the integration of the issue in the upcoming update of its National Strategy on Climate Change and in other relevant frameworks, such as the National Forest and Climate Change Strategy, the National Strategy for the Fight against Desertification and Drought, the National Plan for Food Security and Nutrition, and the Climate Change Adaptation and Risk Management Plan for the Agrarian Sector.

In parallel, Peruvian policymakers should initiate preparations now that would serve successful local adaptation and migration in the future. They should integrate migration considerations in the existing five NDC adaptation priority areas (water, agriculture, fishery, forestry and health), the related drafting of the NAP, as well as in the upcoming updates of various agricultural policies. Planning should be based on an optimistic baseline scenario with a path to global warming around 2°C by 2100. Dynamic adaptation planning should set the course for 2050, but with a longer-term view to 2100. A key recommendation for policymakers is to build adaptive capacities of communities and households to prevent forced migration, and invest more resources into a better understanding of which households are particularly prone to move, the mixed drivers and the decision-making process, their destinations, and how they could be supported in gaining the skills and resources that enable them to either stay or to move in a way that benefits themselves and others. Building systems, capacities and institutions for dealing with a changing landscape of migration in a future world with increasing climate risks should be a priority. Deterring migration without offering options and resources for local adaptation will not lead to positive human development outcomes.

Appropriate adaptation measures can include investing in subsistence farmers' ability to adapt to impacts locally, for example, in improved agricultural techniques and climate-resilient crops; developing capacities of local administrations to deal with impacts close to the source, for example, by funding training and personnel on agricultural resilience and water management capacity development; identifying areas that may degrade severely and will not be suitable for agriculture in the future, as well as supporting their inhabitants in acquiring skills to move early enough and to achieve an adequate standard of living afterwards; and preparing urban major areas and their margins, especially, for more habitants and addressing related local effects on infrastructure, services, markets and social cohesion.

Further research is required on the needs of migrants, displaced persons and host communities in main destinations such as Lima, in order to inform longer-term planning for inclusionary cities for migrants. In addition to protection strategies that centre on the human rights of those moving, these efforts should also include the needs of host communities. Cities and city administrators must also urgently address their own climate risk landscapes.

There must be a better understanding of how policymakers could provide incentives to migrants to settle across a larger number of destinations which are suitable to their needs. This would be important to avoid overwhelming single hubs such as Lima and key migrant communities. Ways of improving the attractiveness of secondary cities and other economic destinations with livelihood opportunities should be investigated, planned and developed.

Overall, actions taken in this decade will be critical in determining the magnitude of future climate impacts and their outcomes for migration in Peru. The opportunity for mitigating climate impacts in South America depends on the level of ambition and the pace of change in global emissions reduction. Local policy innovation to enable the achievement of the SDGs could help to overcome disparities between rural and urban populations and wider socioeconomic inequalities, which are defining variables in migration decision-making. Improved climate adaptation targeted particularly at vulnerable populations would bring multiple co-benefits, not least to increased resilience against health crises like the COVID-19 pandemic. As rising climate impacts may make out-migration necessary in more regions of the country, Peruvian policymakers, civil society and international actors will need to join forces to protect people's dignity and preserve their agency over their lives.

GLOSSARY

adaptation "In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects." (IPCC, 2018a, p. 542)

climate change "Climate change refers to a change in the state of the climate that can be identified (e.g. by 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. Climate change may be due to natural internal processes or external [forces,] such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use." (IPCC, 2018a, p. 544)

Note: The United Nations Framework Convention on Climate Change, in its Article 1, defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods."

coping "The use of available skills, resources, and opportunities to address, manage, and overcome adverse conditions, with the aim of achieving basic functioning of people, institutions, organizations, and systems in the short to medium term." (IPCC, 2014, p. 8)

costa, sierra and selva Spanish terms for the traditional grouping of Peru's three coarse topographical regions: the coast, the highlands and the rainforest ("Amazonia"), respectively.

deforestation "Conversion of forest to non-forest." (IPCC, 2014, p. 9)

disaster "Severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery." (IPCC, 2018a, p. 547)

disaster risk management (DRM) “Disaster risk management is the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses.” (United Nations, 2016, p. 15)

disaster risk reduction (DRR) “Policy objective to prevent new and reduce existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and, therefore, to the achievement of sustainable development.” (IOM, 2019, p. 50)

displacement “The movement of persons who have been forced or obliged to flee or to leave their homes or places of habitual residence, in particular as a result of or in order to avoid the effects of armed conflict, situations of generalized violence, violations of human rights or natural or human-made disasters.” (IOM, 2019, p. 53)

drought “A period of abnormally dry weather long enough to cause serious hydrological imbalance. … For example, shortage of precipitation during the growing season impinges on crop production or ecosystem function in general (due to soil moisture drought, also termed “agricultural drought”), and during the runoff and percolation season primarily affects water supplies (hydrological drought). Storage changes in soil moisture and groundwater are also affected by increases in actual evapotranspiration in addition to reductions in precipitation. A period with an abnormal precipitation deficit is defined as a meteorological drought.” (IPCC, 2018a, p. 547)

ecosystem An “ecosystem” refers to the systematic interaction between living organisms and their physical environment through nutrition and energy. (Chapin et al., 2012)

ecosystem service Ecosystem services are benefits received from ecosystems and can be categorized into: (a) supporting, (b) regulating, (c) provisioning and (d) cultural services. (Millennium Ecosystem Assessment, 2005)

El Niño–Southern Oscillation (ENSO) A climate phenomenon characterized by the “warming of the tropical Pacific Ocean east of the dateline. This oceanic event is associated with a fluctuation of a global-scale tropical and subtropical surface pressure pattern called the Southern Oscillation. This coupled atmosphere[ic]–ocean[ic] phenomenon … is known as the El Niño-Southern Oscillation (ENSO) … The cold phase of ENSO is called La Niña.” (IPCC, 2018a, p. 548)

exposure “The presence of people, livelihoods, species or ecosystems, environ¬mental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.” (IPCC, 2014, p. 123)

flood “The overflowing of the normal confines of a stream or [an] other body of water, or the accumulation of water over areas not normally submerged. Floods include river (fluvial) floods, flash floods, urban floods, pluvial floods, sewer floods, coastal floods, and glacial lake outburst floods.” (IPCC, 2014, p. 13)

food security “A state that prevails when people have secure access to sufficient amounts of safe and nutritious food for normal growth, development, and an active and healthy life.” (IPCC, 2014a, p. 13)

hazard “A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation.” (IOM, 2019, p. 87)

***huaico* (also, *huayco*)** Flash floods formed in the highlands through extreme rainfall that carry mud, rock, and debris flows through ravines and valleys (from Quechua wayqu, equivalent to Spanish *quebrada* (more precisely, *lloqlla*, for avalanche)).

human mobility “A generic term covering all the different forms of movements of persons.” (IOM, 2019, p. 91)

migrant “An umbrella term, not defined under international law, reflecting the common lay understanding of a person who moves away from his or her place of usual residence, whether within a country or across an international border, temporarily or permanently, and for a variety of reasons. The term includes a number of well-defined legal categories of people, such as migrant workers; persons whose particular types of movements are legally defined, such as smuggled migrants; as well as those whose status or means of movement are not specifically defined under international law, such as international students.” (IOM, 2019, p. 30)

Note: In this report, “displacement” is used when discussing instances of forced movement.

no-analog threat Threats related to climate change without current equivalents or modern precedents, for which we have no analog.

non-mobility The state of being unable or unwilling to move away from sites with climate risks.

planned relocation "In the context of disasters or environmental degradation, including when due to the effects of climate change, a planned process in which persons or groups of persons move or are assisted to move away from their homes or place of temporary residence, are settled in a new location, and provided with the conditions [necessary] for rebuilding their lives." (Brookings Institution, Georgetown University and UNHCR, 2015, p. 5)

risk Risk concerns the "the potential for consequences where something of value is at stake and where the outcome is uncertain." It is based on the "probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur." (Oppenheimer et al., 2014, p. 1048)

A high risk exists when adverse outcomes are highly probable, but also when they are less probable but entail highly adverse consequences (IPCC, 2014b). The risk framework in the latest IPCC assessment reports examines risk from climate impacts as a function of climate-related hazards, exposure and vulnerability.

vulnerability "The 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." (IPCC, 2014, p. 128).

BIBLIOGRAPHY

Acosta, D.
2018 *The National versus the Foreigner in South America: 200 Years of Migration and Citizenship Law.* Cambridge University Press, Cambridge, United Kingdom.

Acosta, D. and L.F. Freier
2018 Regional governance of migration in South America. In: *Handbook of Migration and Globalisation* (A. Triantaphyllidu, ed.). Edward Elgar Publishing, Cheltenham, United Kingdom and Northampton, Massachusetts, p. 69.

Adams, H.
2012 Migration decision-making under environmental change: Place utility, mobility and ecosystem services in highland Peru [PhD dissertation]. University of East Anglia, Norwich, United Kingdom.
2016 Why populations persist: Mobility, place attachment and climate change. *Population and Environment*, 37(4):429–448.

Adams, H. and W.N. Adger
2013 The contribution of ecosystem services to place utility as a determinant of migration decision-making. *Environmental Research Letters*, 8(1):15006.

Adams, S., V. Aich, T. Albrecht, F. Baarsch, A. Boit, N. Canales Trujillo, M. Cartsburg, D. Coumou, A. Eden, M. Fader, B. Hare, H. Hoff, G. Jobbins, L. Jones, O. Kit, L. Krummenauer, F. Langerwisch, V. Le Masson, E. Ludi, R. Marcus, M. Mengel, B. Mosello, J. Möhring, A. Norton, I.M. Otto, M. Perette, P. Pereznieto, A. Rammig, D. Reckien, J. Reinhardt, C. Reyer, A. Robinson, M. Rocha, B. Sakschewski, M. Schaeffer, S. Schaphoff, J. Schewe, C.-F. Schleussner, O. Serdeczny, J. Stagl, K. Thonicke and K. Waha
2014 *Turn Down the Heat: Confronting the New Climate Normal (Vol. 2): Main Report.* World Bank, Washington, D.C.

Adger, W.N., J.M. Pulhin, J.R. Barnett, G.D. Dabelko, G.K. Hovelsrud, M. Levy, U. Oswald Spring and C.H. Vogel
2014 Human security. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects* (C.B. Field, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea and L.L. White, eds.). Cambridge University Press, Cambridge, United Kingdom and New York, pp. 755–791.

Aguerre, M.J. and A.P. Sampaio
2016 *Estatuto de ciudadanía del Mercosur y plan estratégico de acción social : logros y desafíos pendientes* (Mercosur citizenship status and social action strategic plan: Achievements and pending challenges). Report. MERCOSUR, Montevideo.

Alata, E., B. Fuentealba and J. Recharte
2018 *El despoblamiento de la puna : efectos del cambio climático y otros factores* (Depopulation of the *puna*: Effects of climate change and other factors). *Revista Kawsaypacha*, 2:49–68.

Alkire, S. and S. Jahan
2018 The new Global MPI 2018: Aligning with the Sustainable Development Goals. Occasional paper. United Nations Development Programme, New York.

Allison, E.H., A.L. Perry, M.C. Badjeck, W. Neil Adger, K. Brown, D. Conway, A.S. Halls, G.M. Pilling, J.D. Reynolds and N.L. Andrew

2009 Vulnerability of national economies to the impacts of climate change on fisheries. *Fish and Fisheries*, 10(2):173–196.

Altamirano Girao, F.

2012 *Escenarios de migraciones (forzadas) ante el cambio climático global : el caso de la comunidad andina de Cruz de Mayo (Parón) y la Laguna Parón* (Scenarios of (forced) migration in the face of global climate change: The case of the Andean community of Cruz de Mayo (Parón) and the Parón Lake) [master's thesis]. International University of Andalucia, Andalucia, Spain.

Altamirano Rua, T.

2014 *Refugiados ambientales : cambio climatico y migracion forzada* (Environmental refugees: climate change and forced migration). Pontificia Universidad Católica del Perú, Lima.

Andean Community (Comunidad Andina (CAN))

2017 Decision 819 on the Andean Strategy for Disaster Risk Management (EAGRD) of 9 May 2017.

Andres, N., F. Vegas Galdos, W.S. Lavado Casimiro and M. Zappa

2014 Water resources and climate change impact modelling on a daily time scale in the Peruvian Andes. *Hydrological Sciences Journal*, 59(11):2043–2059.

Andrews, O., C. Le Quéré, T. Kjellstrom, B. Lemke and A. Haines

2018 Implications for workability and survivability in populations exposed to extreme heat under climate change: A modelling study. *The Lancet Planetary Health*, 2(12):e540–e547.

Anthoff, D., P. Nicholls, R.S. Tol and A. Vafeidis

2006 Global and regional exposure to large rises in sea-level: A sensitivity analysis. Working paper. Tyndall Centre for Climate Change Research – Oxford University, Oxford, United Kingdom, p.96.

Aragón, F.M., F. Oteiza and J.P. Rud

2018 Climate change and agriculture: Farmer adaptation to extreme heat. Working paper. Institute for Fiscal Studies, London.

Aybar, C., C. Fernández, A. Huerta, W. Lavado, F. Vega, and O. Felipe-Obando

2019 Construction of a high-resolution gridded rainfall dataset for Peru from 1981 to the present day. *Hydrological Sciences Journal*, 17(2):1–16. Available at https://doi.org/10.1080/02626667.2019.1649411.

Badjeck, M.C.

2008 Vulnerability of coastal fishing communities to climate variability and change: Implications for fisheries livelihoods and management in Peru [PhD dissertation]. Centre for Tropical Marine Ecology – University of Bremen, Bremen, Germany.

Badjeck, M.C., J. Mendo, M. Wolff and H. Lange

2009 Climate variability and the Peruvian scallop fishery: The role of formal institutions in resilience building. *Climatic Change*, 94(1):211–232.

Baldwin, A., C. Methmann and D. Rothe

2014 Securitizing 'climate refugees': the futurology of climate-induced migration. *Critical Studies on Security*, 2(2):121–130.

Baraer, M., B.G. Mark, J.M. McKenzie, T. Condom, J.T. Bury, K.I. Huh, C. Portocarrero, J. Gómez and S. Rathay

2012 Glacier recession and water resources in Peru's Cordillera Blanca. *Journal of Glaciology*, 58(207):134–150.

Barichivich, J., E. Gloor, P. Peylin, R.J.W. Brienen, J. Schöngart, J.C. Espinoza and K.C. Pattnayak

2018 Recent intensification of Amazon flooding extremes driven by strengthened Walker circulation. *Science Advances*, 4(9):eaat8785.

Barrón, M.

2008 Exclusion and discrimination as sources of inter-ethnic inequality in Peru. *Economía*, 61(31):51–80.

Bayer, A.M., H.E. Danysh, M. Garvich, G. Gonzálvez, W. Checkley, M. Álvarez and R.H. Gilman

2014 An unforgettable event: A qualitative study of the 1997–98 El Niño in northern Peru. *Disasters*, 38(2):351–374.

BBC News

2020 Coronavirus: Peru economy sinks 40% in April amid lockdown. BBC News, 16 June. Available at www.bbc.com/news/world-latin-america-53051157.

Blanchard, J.L., S. Jennings, R. Holmes, J. Harle, G. Merino, J.I. Allen, J. Holt, N.K. Dulvy and M. Barange

2012 Potential consequences of climate change for primary production and fish production in large marine ecosystems. *Philosophical Transactions of the Royal Society of London (Series B: Biological Sciences)*, 367(1605):2979–2989.

Bodmer, R., P. Mayor, M. Antunez, K. Chota, T. Fang, P. Puertas, M. Pittet, M. Kirkland, M. Walkey, C. Rios, P. Perez-Peña, P. Henderson, W. Bodmer, A. Bicerra, J. Zegarra and E. Docherty

2018 Major shifts in Amazon wildlife populations from recent intensification of floods and drought. *Conservation Biology: The Journal of the Society for Conservation Biology*, 32(2):333–344.

Boesten, J.

2007 Free choice or poverty alleviation? Population politics in Peru under Alberto Fujimori. *European Review of Latin American and Caribbean Studies Revista Europea de Estudios Latinoamericanos y del Caribe*, (82):3–20.

Borderon, M., P. Sakdapolrak, R. Muttarak, E. Kebede, R. Pagogna and E. Sporer

2018 A systematic review of empirical evidence on migration influenced by environmental change in Africa. International Institute for Applied Systems Analysis (IIASA). Working paper. Laxenburg, Austria.

Borma, L.S., C.A. Nobre and M.F. Cardoso

2013 Response of the Amazon tropical forests to deforestation, climate, and extremes, and the occurrence of drought and fire. In: *Climate Vulnerability: Understanding and Addressing Threats to Essential Resources (Volume 2: Vulnerability of Human Food Resources to Climate)* (R.A. Pielke, ed.). Academic Press, Cambridge, United Kingdom, pp. 153–163.

Brandt, H.-J.

2016 *Soziale konflikte* (Social conflict). In: Peru heute: *Politik, Wirtschaft, Kultur* (Peru Today: Politics, Economy, Culture) (I. Paap and F. Schmidt-Welle, eds.). Verlag Vervuert, Frankfurt, Germany, pp. 219–242.

Brookings Institution, Institute for the Study of International Migration – Georgetown University and the Office of the United Nations High Commissioner for Refugees (UNHCR)

2015 Guidance on protecting people from disasters and environmental change through planned relocation. Guidance document, 7 October. Brookings Institution, Washington, D.C., Georgetown University, Washington, D.C. and UNHCR, Geneva. Available at www.unhcr.org/protection/environment/562f798d9/planned-relocation-guidance-october-2015.html.

Bury, J.T.

2005 Mining mountains: Neoliberalism, land tenure, livelihoods, and the new Peruvian mining industry in Cajamarca. *Environment and Planning A*, 37(2):221–239.

Bury, J.T., B.G. Mark, J.M. McKenzie, A. French, M. Baraer, K.I. Huh, M.A. Zapata Luyo and R.J. Gómez López

2011 Glacier recession and human vulnerability in the Yanamarey watershed of the Cordillera Blanca, Peru. *Climatic Change*, 105(1-2):179–206.

Buytaert, W. and B. de Bièvre
2012 Water for cities: The impact of climate change and demographic growth in the tropical Andes. *Water Resources Research*, 48(8):897.

Buytaert, W., F. Cuesta-Camacho and C. Tobón
2011 Potential impacts of climate change on the environmental services of humid tropical alpine regions. *Global Ecology and Biogeography*, 20(1):19–33.

Buytaert, W., S. Moulds, L. Acosta, B. de Bièvre, C. Olmos, M. Villacis, C. Tovar and K.M.J. Verbist
2017 Glacial melt content of water use in the tropical Andes. *Environmental Research Letters*, 12(11):114014.

Cai, W., G. Wang, A. Santoso, M.J. McPhaden, L. Wu, F.-F. Jin, A. Timmermann, M. Collins, G. Vecchi and M. Lengaigne
2015 Increased frequency of extreme La Niña events under greenhouse warming. *Nature Climate Change*, 5(2):132–137.

Cai, W., A. Santoso, G. Wang, S.W. Yeh, S.I. An, K.M. Cobb, M. Collins, E. Guilyardi, F.F. Jin, J.S. Kug, M. Lengaigne, M.J. McPhaden, K. Takahashi, A. Timmermann, G. Vecchi, M. Watanabe and L. Wu
2015 ENSO and greenhouse warming. *Nature Climate Change*, 5:849–859.

Cai, W., G. Wang, B. Dewitte, L. Wu, A. Santoso, K. Takahashi, Y. Yang, A. Carréric and M.J. McPhaden
2018 Increased variability of eastern Pacific El Niño under greenhouse warming. *Nature*, 564(7735):201–206.

Calderón, J.C., J.R. Quispe, P. Lucci and A. Lenhardt
2015 On the path to progress: Improving living conditions in Peru's slum settlements. Case study. Overseas Development Institute, London. Available at www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/9666.pdf.

Canedo, C., R. Pillco Zolá and R. Berndtsson
2016 Role of hydrological studies for the development of the TDPS System. *Water*, 8(4):144.

Cantor, D.J.
2015 Law, policy and practice concerning the humanitarian protection of aliens on a temporary basis in the context of disasters. Background paper for the States of the Regional Conference on Migration and Others in the Americas, Regional Workshop on Temporary Protection Status and/or Humanitarian Visas in Situations of Disaster, San José, 10–11 February. Available at https://disasterdisplacement.org/wp-content/uploads/2015/07/150715_FINAL_BACKGROUND_PAPER_LATIN_AMERICA_screen.pdf.
2018 Cross-border displacement, climate change and disasters: Latin America and the Caribbean. Consultancy study prepared for the United Nations High Commissioner for Refugees (UNHCR) and the Platform on Disaster Displacement at request of governments participating in the 2014 Brazil Declaration and Plan of Action. UNHCR, Geneva.

Carey, M., C. Huggel, J.T. Bury, C. Portocarrero and W. Haeberli
2012 An integrated socio-environmental framework for glacier hazard management and climate change adaptation: Lessons from Lake 513, Cordillera Blanca, Peru. *Climatic Change*, 112(3-4):733–767.

Carranza, C.C.
2016 *Die peruanische Wirtschaft zu Beginn des 21. Jahrhunderts* (The Peruvian economy at the beginning of the 21st century). In: *Peru heute: Politik, Wirtschaft, Kultur* (Peru Today: Politics, Economy, Culture) (I. Paap and F. Schmidt-Welle, eds.). Verlag Vervuert, Frankfurt, Germany, pp. 93–116.

Carrivick, J.L. and F.S. Tweed
2016 A global assessment of the societal impacts of glacier outburst floods. *Global and Planetary Change*, 144:1–16.

Castles, S.
2002 Environmental change and forced migration: Making sense of the debate. New Issues in Refugee Research Series, research paper no. 70. UNHCR, Geneva. Available at www.unhcr.org/research/working/3de344fd9/environmental-change-forced-migration-making-sense-debate-stephen-castles.html.

Cavagnoud, R.T.F.
2018 *Vulnerabilidades medioambientales y migraciones juveniles desde las comunidades altoandinas cercanas al Lago Titicaca (Perú)* (Environmental vulnerabilities and youth migrations from the high Andean communities near Lake Titicaca (Peru)). *Revista Boliviana de Investigación/Bolivian Research Review*, 13(1):25–51.

Ceccherini, G., S. Russo, I. Ameztoy, C.P. Romero and C. Carmona-Moreno
2016 Magnitude and frequency of heat and cold waves in recent decades: The case of South America. *Natural Hazards and Earth System Science*, 16(3):821–831.

Cernadas, P.C.
2013 Migration, citizenship and free movement in South America: A rights-based analysis of regional initiatives. Draft paper prepared for the UNRISD Conference on Regional Governance of Migration and Sociopolitical Rights: Institutions, Actors and Processes, Geneva, 14–15 January.

Cerruti, M.
2009 Gender and intra-regional migration in South America. Human Development Research Series, paper no. 12. United Nations Development Programme (UNDP), New York.
2017 Mercosur and regional migration: A human rights approach. In: *Latin America since the Left Turn* (T.G. Falleti and E.A. Parrado, eds.). University of Pennsylvania Press, Philadelphia, pp. 88–110.

Cerrutti, M. and R. Bertoncello
2003 Urbanization and internal migration patterns in Latin America. Paper prepared for Conference on African Migration in Comparative Perspective, Johannesburg, 4–7 June.

Chapin, F.S., P.A. Matson and H.A. Mooney
2012 *Principles of Terrestrial Ecosystem Ecology*. Second edition. Springer, New York.

Charbonneau, M.
2008 From transhumance to nomadism: Movements in Andean pastoral societies. *Mappemonde*, 90.

Cheung, W., V. Lam, J. Sarmiento, K. Kearney, R. Watson, D. Zeller and D. Pauly
2010 Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change. *Global Change Biology*, 16:24–35.

Chevallier, P., B. Pouyaud, W. Suarez and T. Condom
2011 Climate change threats to environment in the tropical Andes: Glaciers and water resources. *Regional Environmental Change*, 11(S1):179–187.

Christensen, J.H., K.K. Kanikicharla, G. Marshall and J. Turner
2013 Climate phenomena and their relevance for future regional climate change. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (T.F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley, eds.). Cambridge University Press, Cambridge, United Kingdom and New York.

Church, J.A., P.U. Clark, A. Cazenave, J.M. Gregory, S. Jevrejeva, A. Levermann, M.A. Merrifield, G.A. Milne, R.S. Nerem, P.D. Nunn, A.J. Payne, W.T. Pfeffer, D. Stammer and A.S. Unnikrishnan
2013 Sea level change. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (T.F. Stocker, D. Qin, G.K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley, eds.). Cambridge University Press, Cambridge, United Kingdom and New York, pp. 1137–1216.

Climate Prediction Center
2020 ENSO: Recent Evolution, Current Status and Predictions [slide presentation], slide 4. Last updated 5 October. Available at www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf.

Cobb, K.M., N. Westphal, H.R. Sayani, J.T. Watson, E. Di Lorenzo, H. Cheng, R.L. Edwards and C.D. Charles
2013 Highly variable El Niño–Southern Oscillation throughout the Holocene. *Science*, 339(6115):67–70.

Collins, M., R. Knutti, J. Arblaster, J.L. Dufresne, T. Fichefet, P. Friedlingstein, X. Gao, W.J. Gutowski, T. Johns and G. Krinner
2013 Long-term climate change: Projections, commitments and irreversibility. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (T.F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley, eds.). Cambridge University Press, Cambridge, United Kingdom and New York, pp. 1029–1136.

Cometti, G.
2015a *Lorsque le Brouillard a Cessé de Nous Ecouter : Changement Climatique et Migrations Chez les Q'eros des Andes Péruviennes* (When the Fog Stops Listening to Us: Climate Change and Migration among the Qeros of the Peruvian Andes). First edition. Peter Lang AG, Internationaler Verlag der Wissenschaften, Bern, Germany.
2015b The necessity for an ethnographic approach in Peru. *Forced Migration Review*, 49:14.
2018 *Changement climatique et crise des relations de réciprocité dans les Andes péruviennes: Les Q'eros et l'Anthropocène* (Climate change and the crisis of reciprocal relationships in the Peruvian Andes: The Qeros and the Anthropocene). In: *Penser l'Anthropocène* (Thinking about the Anthropocene) (R. Beau and C. Larrère, eds.). Presses de Sciences Po, Paris, pp. 235–247.

Constant, C.
2016 Frauen und Frauenrechte (Women and women's rights). In: *Peru heute: Politik, Wirtschaft, Kultur* (Peru Today: Politics, Economy, Culture) (I. Paap and F. Schmidt-Welle, eds.). Verlag Vervuert, Frankfurt, Germany, pp. 243–261.

Cook, K.H. and E.K. Vizy
2008 Effects of twenty-first-century climate change on the Amazon rain forest. *Journal of Climate*, 21(3):542–560.

Coomes, O.T., Y. Takasaki, C. Abizaid and B. Barham
2010 Floodplain fisheries as natural insurance for the rural poor in tropical forest environments: Evidence from Amazonia. *Fisheries Management and Ecology*, 17(6):513–521.

Crespeigne, E., E. Olivera, R. Ccanto and M. Scurrah
2009 *Exploración de las estrategias y prácticas de una comunidad campesina de los Andes Centrales frente a los riesgos extremos asociados al cambio climático* (Exploring the strategies and practices of a Central Andes mountain community facing extreme risks associated with climate change). In: *Perú : el problema agrario en debate* (Peru: The Agrarian Problem in Debate) *: Seminario SEPIA XIII* (P. Ames and V. Caballero, eds.). Tarea Asociación Gráfica Educativa, Lima, pp. 260–290.

da Motta Paca, V.H., G.E. Espinoza-Dávalos, D.M. Moreira and G. Comair
2020 Variability of trends in Precipitation across the Amazon River Basin determined from the CHIRPS precipitation product and from station records. *Water*, 12(5):1244.

Damonte, G. and R. Boelens
2019 Hydrosocial territories, agro-export and water scarcity: Capitalist territorial transformations and water governance in Peru's coastal valleys. *Water International*, 44(2):206–223.

Dasgupta, S., B. Laplante, C. Meisner, D. Wheeler and J. Yan
2009 The impact of sea level rise on developing countries: A comparative analysis of impacts in developing countries. Policy research working paper 4901. World Bank, Washington, D.C.

Davies, T.M., R.N. Burr, J.P. Moore, J. Pulgar-Vidal and J.S. Kus
2018 Peru. *Britannica Online*. Available at www.britannica.com/place/Peru (accessed 14 February 2019).

Donat, M.G., L.V. Alexander, H. Yang, I. Durre, R. Vose, R.J.H. Dunn, K.M. Willett, E. Aguilar, M. Brunet, J. Caesar, B. Hewitson, C. Jack, A.M.G. Klein Tank, A.C. Kruger, J. Marengo, T.C. Peterson, M. Renom, C. Oria Rojas, M. Rusticucci, J. Salinger, A.S. Elrayah, S.S. Sekele, A.K. Srivastava, B. Trewin, C. Villarroel, L.A. Vincent, P. Zhai, X. Zhang and S. Kitching
2013 Updated analyses of temperature and precipitation extreme indices since the beginning of the twentieth century: The HadEX2 dataset. *Journal of Geophysical Research: Atmospheres*, 118(5):2098–2118.

Dunne, J.P., R.J. Stouffer and J.G. John
2013 Reductions in labour capacity from heat stress under climate warming. *Nature Climate Change*, 3:563–566.

Ecker, O. and C. Breisinger
2012 The Food Security System – A New Conceptual Framework. *International Food Policy Research Institute (FPRI) Discussion Papers*, 1166:1–14.

Emmer, A., V. Vilímek and M.L. Zapata
2016 Hazard mitigation of glacial lake outburst floods in the Cordillera Blanca (Peru): The effectiveness of remedial works. *Journal of Flood Risk Management*, 11:489–501.

Esipova, N., J. Ray and A. Pugliese
2017 Number of potential migrants worldwide tops 700 million. Gallup website, news article, 8 June. Available at https://news.gallup.com/poll/211883/number-potential-migrants-worldwide-tops-700-million.aspx.

Espinoza, J.C., P. Fraizy, J.L. Guyot, J.J. Ordoñez, R. Pombosa and J. Ronchail
2006 *La variabilité des débits du Rio Amazonas au Pérou* (The variability of flows from the Rio Amazonas in Peru). Climate Variability and Change – Hydrological Impacts: Proceedings of the Fifth FRIEND World Conference, November, Havana. *IAHS Publication*, 308:424–429.

Espinoza-Neyra, C., M. Jara-Pereda and C. Diaz-Vélez
2017 *Trastorno de estrés postraumático en una población afectada por inundaciones ocasionadas por el niño costero en Perú* (Post-traumatic stress disorder in a population affected by floods caused by the Costal El Niño in Peru). *Revista Peruana de Medicina Experimental y Salud Publica* (Peruvian Journal of Experimental Medicine and Public Health), 34(4):751–752.
2018 *Réplica: sobre la evaluación del trastorno por estrés postraumático a los afectados por el niño* (Reply: On the assessment of post-traumatic stress disorder to those affected by El Niño). *Revista peruana de medicina experimental y salud publica* (Peruvian Journal of Experimental Medicine and Public Health), 35(3):541.

Ewig, C.
2006 Hijacking global feminism: Feminists, the Catholic Church, and the family planning debacle in Peru. *Feminist Studies*, 32(3):633–659.

Fernández-Palomino, C.A. and W.S. Lavado-Casimiro
2016 Regional maximum rainfall analysis using L-moments at the Titicaca Lake drainage, Peru. *Theoretical and Applied Climatology* 129:1295–1307.

Feron, S., R.R. Cordero, A. Damiani, P.J. Llanillo, J. Jorquera, E. Sepulveda, V. Asencio, D. Laroze, F. Labbe, J. Carrasco and G. Torres
2019 Observations and Projections of Heat Waves in South America. *Scientific Reports*, 9(1):8173.

Ferradas, P.
2015 *La memoria es también porvenir. Historia mundial de los desastres* (Memory is Also the Future: World History of Disasters). Soluciones Prácticas, Lima.

Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea and L.L. White (eds.)
2014 *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects*. Cambridge University Press, Cambridge, United Kingdom and New York.

Food and Agriculture Organization (FAO)
1995 *Dimensions of Need: An Atlas of Food and Agriculture*. Rome.
2005 Livestock sector brief: Peru. Available at www.fao.org/ag/againfo/resources/en/publications/sector_briefs/lsb_PER.pdf.
2010 National fisheries sector overview: Peru. Available at www.fao.org/fishery/docs/DOCUMENT/fcp/en/FI_CP_PE.pdf.
2016 FAOSTAT – Food security. Data set. Available at www.fao.org/faostat/en/#data (accessed 19 February 2020)
2017 FAOSTAT Peru. Data set. Available at www.fao.org/faostat/en/#country/170 (accessed 19 February 2020).
2019 *Perfiles sobre la pesca y la acuicultura por países: La República Del Perú* (Profiles on fisheries and aquaculture by country: The Republic of Peru). Available at www.fao.org/fishery/facp/PER/es.

Foresight
2011 *Migration and Global Environmental Change: Future Challenges and Opportunities*. London. Available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/287717/11-1116-migration-and-global-environmental-change.pdf.

French, A. and R. Mechler
2017 *Managing El Niño Risks Under Uncertainty in Peru: Learning from the Past for a More Disaster-resilient Future*. International Institute for Applied Systems Analysis, Laxenburg.

French, A., R. Mechler, M. Arestegui, K. MacClune and A. Cisneros
2020 Root causes of recurrent catastrophe: The political ecology of El Niño-related disasters in Peru. *International Journal of Disaster Risk Reduction*, 47:101539. Available at https://doi.org/10.1016/j.ijdrr.2020.101539.

Frey, H., C. Huggel, Y. Bühler, D. Buis, M.D. Burga Hidalgo, W. Choquevilca, F. Fernandez, J. García Hernández, C. Giráldez, E. Loarte, P. Masias, C. Portocarrero, L. Vicuña and M. Walser
2016 A robust debris-flow and GLOF risk management strategy for a data-scarce catchment in Santa Teresa, Peru. *Landslides*, 13(6):1493–1507.

Frey, H., C. Huggel, R.E. Chisolm, P. Baer, B. McArdell, A. Cochachin and C. Portocarrero
2018 Multi-source glacial lake outburst flood hazard assessment and mapping for Huaraz, Cordillera Blanca, Peru. *Frontiers in Earth Science*, 6:1741.

Garreaud, R.D.
2018 A plausible atmospheric trigger for the 2017 coastal El Niño. *International Journal of Climatology*, 38(C7):e1296-e1302.

Georges, C.
2004 20th-century Glacier Fluctuations in the Tropical Cordillera Blanca, Perú. *Arctic, Antarctic, and Alpine Research*, 36(1):100–107.

Georgetown University, (Office of the) United Nations High Commissioner for Refugees (UNHCR) and International Organization for Migration (IOM)
2017 *A Toolbox: Planning Relocations to Protect People from Disasters and Environmental Change*. Georgetown University, Washington, D.C., UNHCR, Geneva and IOM, Geneva. Available at www.unhcr.org/protection/environment/596f1bb47/planned-relocation-toolbox.html.

Ginnetti, J., P.M. Kam, G. Aznar Siguan, J. Schewe and L. Milano
2019 Assessing the impacts of climate change on flood displacement risk. Methodological paper. Internal Displacement Monitoring Centre, Geneva. Available at www.internal-displacement.org/publications/assessing-the-impacts-of-climate-change-on-flood-displacement-risk.

Gioli, G. and A. Milan
2018 Gender, migration and (global) environmental change. In: *Routledge Handbook of Environmental Displacement and Migration* (R.A. McLeman and F. Gemenne, eds.). Routledge, London.

Giorgi, F., E. Coppola, F. Raffaele, G.T. Diro, R. Fuentes-Franco, G. Giuliani, A. Mamgain, M.P. Llopart, L. Mariotti and C. Torma
2014 Changes in extremes and hydroclimatic regimes in the CREMA ensemble projections. *Climatic Change*, 125(1):39–51.

Global Facility for Disaster Reduction and Recovery (GFDRR)
2019 Peru. Report, ThinkHazard website. Available at https://thinkhazard.org/en/report/195-peru (accessed 19 February 2020).

Gloor, M., R.J.W. Brienen, D. Galbraith, T.R. Feldpausch, J. Schöngart, J.-L. Guyot, J.C. Espinoza, J. Lloyd and O.L. Phillips
2013 Intensification of the Amazon hydrological cycle over the last two decades. *Geophysical Research Letters*, 40(9):1729–1733.

Gosling, S.N., R. Dunn, F. Carrol, N. Christidis, J. Fullwood, D.d. Gusmao, N. Golding, L. Good, T. Hall and L. Kendon
2011 Climate: Observations, projections and impacts: Peru. Report. Available at https://research.fit.edu/media/site-specific/researchfitedu/coast-climate-adaptation-library/europe/spain-amp-portugal/Met-Office.-Spanish-Climate-Observations,-Projections--Impacts.pdf.

Guadagno, L.
2016 Human Mobility in the Sendai Framework for Disaster Risk Reduction. *International Journal of Disaster Risk Science*, 7(1):30–40.

Haeberli, W., M. Buetler, C. Huggel, T. Lehmann Friedli, Y. Schaub and A. Schleiss
2016 New lakes in deglaciating high-mountain regions: opportunities and risks. *Climatic Change*, 139:201–214.

Hartmann, D.L., A.M.K. Tank, M. Rusticucci, L.V. Alexander, S. Brönnimann, Y.A.R. Charabi, F.J. Dentener, E.J. Dlugokencky, D.R. Easterling and A. Kaplan
2013 Observations: atmosphere and surface. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (T.F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley, eds.). Cambridge University Press, Cambridge, United Kingdom and New York, pp. 159–254.

Hastenrath, S. and A. Ames
1995 Recession of Yanamarey Glacier in Cordillera Blanca, Peru, during the 20th century. *Journal of Glaciology*, 41(137):191–196.

Haylock, M.R., T.C. Peterson, L.M. Alves, T. Ambrizzi, Y.M.T. Anunciação, J. Baez, V.R. Barros, M.A. Berlato, M. Bidegain, G. Coronel, V. Corradi, V.J. Garcia, A.M. Grimm, D. Karoly, J.A. Marengo, M.B. Marino, D.F. Moncunill, D. Nechet, J. Quintana, E. Rebello, M. Rusticucci, J.L. Santos, I. Trebejo and L.A. Vincent

2006 Trends in total and extreme South American rainfall in 1960–2000 and links with sea surface temperature. *Journal of Climate*, 19(8):1490–1512.

Heidinger, H., L. Carvalho, C. Jones, A. Posadas and R. Quiroz

2018 A new assessment in total and extreme rainfall trends over central and southern Peruvian Andes during 1965–2010. *International Journal of Climatology*, 38(S1):e998–e1015.

Heikkinen, A.

2017 Climate change in the Peruvian Andes: A case study on small-scale farmers' vulnerability in the Quillcay River Basin. *Iberoamericana – Nordic Journal of Latin American and Caribbean Studies*, 46(1):77–88.

Ho, R. and A. Milan

2012 Rainfall, food security, and human mobility – Case study: Peru. Report. United Nations University – Institute for Environment and Human Security, Bonn, Germany. Available at https://collections.unu.edu/eserv/UNU:1843/Reportno5Peru.pdf.

Hoffman, M. and A.I. Grigera

2013 *Cambio climático, migración y conflicto en la Amazonía y en los Andes : el aumento de tensiones y las opciones de políticas públicas en sudamérica* (Climate change, migration and conflict in the Amazon and in the Andes: Rising tensions and public policy options in South America). Report. Center for American Progress, Washington, D.C. Available at https://cdn.americanprogress.org/wp-content/uploads/2013/07/SPANISH_SouthAmericaClimateMigration.pdf.

Hofmeijer, I., J.D. Ford, L. Berrang-Ford, C. Zavaleta, C. Cárcamo, E. Llanos, C. Carhuaz, V. Edge, S. Lwasa and D. Namanya

2013 Community vulnerability to the health effects of climate change among indigenous populations in the Peruvian Amazon: a case study from Panaillo and Nuevo Progreso. *Mitigation and Adaptation Strategies for Global Change*, 18(7):957–978.

Hu, Z.-Z., B. Huang, J. Zhu, A. Kumar and M.J. McPhaden

2019 On the variety of coastal El Niño events. *Climate Dynamics*, 52(12):7537–7552.

Huerta, A. and W. Lavado-Casimiro

2020 Trends and variability of precipitation extremes in the Peruvian Altiplano (1971–2013). *International Journal of Climatology*. Available at https://doi.org/10.1002/joc.6635.

Huerta, A., C. Aybar and W. Lavado-Casimiro, W.

2018 *PISCO temperatura versión 1.1* (PISCO temperature version 1.1). National Service of Meteorology and Hydrology of Peru – Directorate of Hydrology, Lima.

Inter-American Commission on Human Rights (IACHR)

2016 Human rights of migrants, refugees, stateless persons, victims of human trafficking and internally displaced persons: Norms and standards of the Inter-American human rights system. Report. Washington, D.C.

Intergovernmental Panel on Climate Change (IPCC)

2014 Annex II: Glossary. In: *Climate Change 2014: Synthesis Report* (Core Writing Team, R.K. Pachauri and L.A. Meyer, eds.). Geneva, pp. 8, 9, 13, 117–130.

2018a Annex I: Glossary. In: *Global Warming of 1.5°C* (V. Masson-Delmotte, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor and T. Waterfield, eds.). Geneva.

2018b Summary for policymakers. In: *Global Warming of 1.5°C*. (V. Masson-Delmotte, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor and T. Waterfield, eds.). Geneva.

2019 Summary for policymakers. In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* (H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, M. Nicolai, A. Okem, J. Petzold, B. Rama and N. Weyer, eds.). Geneva.

Internal Displacement Monitoring Centre (IDMC)

2018 Global report on internal displacement: Peru conflict displacement figures analysis [slide presentation]. Available at www.ecoi.net/en/file/local/2008409/GRID+2018+-+Figure+Analysis+-+PERU.pdf.

2019a *Disaster Displacement: A Global Review 2008–2018*. Geneva.

2019b Peru country information (as of 31 December 2018). Data set. Available at www.internal-displacement.org/countries/peru (accessed 19 February 2020).

International Food Policy Research Institute (IFPRI)

2012 Food Security Portal – Peru. Available at www.foodsecurityportal.org/peru.

International Labour Organization (ILO)

n.d. Good practices database – Labour migration policies and programmes: MERCOSUR Residence Agreement. Available at www.ilo.org/dyn/migpractice/migmain.showPractice?p_lang=en&p_practice_id=187.

International Organization for Migration (IOM)

2011 *Glossary on Migration*. International Migration Law No. 25. Geneva.

2017a *DMT Ronda 3 : Monitoreo de flujo de migración venezolana en el Perú (Matriz de seguimiento de desplazamiento)* (DTM Round 3: Monitoring Venezuelan migration flows into Peru (Displacement Tracking Matrix)). Report. Lima. Available at https://reliefweb.int/report/peru/dtm-ronda-3-monitoreo-de-flujo-de-migraci-n-venezolana-en-el-matriz-de-seguimiento-del.

2017b Measuring global migration potential, 2010–2015. GMDAC Briefing Series No. 9. Berlin. Available at https://publications.iom.int/system/files/pdf/gmdac_data_briefing_series_issue_9.pdf.

2018a *DTM Ronda 4 : Matriz de monitoreo del desplazamiento – Perú: Fenómeno del niño costero 2017, evaluación final de sitios* (DTM Round 4: Displacement tracking matrix – Peru: Coastal El Niño Phenomenon 2017, final site assessment). Report. Lima. Available at https://reliefweb.int/report/peru/dtm-ronda-4-matriz-de-monitoreo-del-desplazamiento-fen-meno-del-ni-o-costero-2017.

2018b *Evaluación del Acuerdo de Residencia del MERCOSUR y su incidencia en el acceso a derechos de los migrantes* (Evaluation of the MERCOSUR Residence Agreement and its impact on access to rights of migrants). Cuadernos Migratorios Nº 9 (Migration Notebook No. 9). Available at https://publications.iom.int/books/estudio-sobre-la-evaluacion-y-el-impacto-del-acuerdo-de-residencia-del-mercosur.

2019 *Glossary on Migration*. International Migration Law No. 34. Available at www.iom.int/glossary-migration-2019.

Jäger, J., J. Frühmann, S. Grünberger and A. Vag

2009 *Environmental Change and Forced Migration Scenarios (EACH-FOR) Project Synthesis Report*. United Nations University – Institute for Environment and Human Security, Bonn, Germany.

Juen, I., G. Kaser and C. Georges

2007 Modelling observed and future runoff from a glacierized tropical catchment (Cordillera Blanca, Perú). *Global and Planetary Change*, 59(1-4):37–48.

Juřicová, A. and S. Fratianni
2018 Climate change and its relation to the fluctuation in glacier mass balance in the Cordillera Blanca, Peru: A review. *AUC Geographica*, 53(1):106–118.

Kaenzig, R. and E. Piguet
2014 Migration and climate change in Latin America and the Caribbean. In: *People on the Move in a Changing Climate* (E. Piguet and F. Laczko, eds.). Springer Netherlands, Dordrecht, pp. 155–176.

Kluger, L.C., S. Kochalski, A. Aguirre-Velarde, I. Vivar, M. Wolff and M. Handling
2018 Coping with abrupt environmental change: The impact of the coastal El Niño 2017 on artisanal fisheries and mariculture in North Peru. *ICES Journal of Marine Science*, 76(4):1122–1130.

KNOMAD
2015 Longitudinal research on environmental change and migration: A workshop on objectives, methods, and applicability to policy and practice, Washington, D.C., 19–20 March. Available at www.knomad.org/sites/default/files/2017-03/Agenda%20Longitudinal%20Research%20on%20Environmental%20Change%20and%20Migration%20v2.pdf.

Kochtitzky, W.H., B.R. Edwards, E.M. Enderlin, J. Marino and N. Marinque
2018 Improved estimates of glacier change rates at Nevado Coropuna Ice Cap, Peru. *Journal of Glaciology*, 64(244):175–184.

Koubi, V., T. Böhmelt, G. Spilker and L. Schaffer
2018 The determinants of environmental migrants' conflict perception. *International Organization*, 72(04):905–936.

Koubi, V., G. Spilker, L. Schaffer and T. Böhmelt
2016 The role of environmental perceptions in migration decision-making: Evidence from both migrants and non-migrants in five developing countries. *Population and Environment*, 38(2):134–163.

Kulp, S.A. and B.H. Strauss
2019 New elevation data triple estimates of global vulnerability to sea-level rise and coastal flooding. *Nature communications*, 10(1):4844.

Kuznar, L.A.
1991 Transhumant goat pastoralism in the high sierra of the south central Andes: Human responses to environmental and social uncertainty. *Nomadic Peoples*, 28:93–104.

Lajaunie, M.-L., S. Tillier, H.A. Serrano Navarro, C.L. Cordoba and S. Scheierling
2013 *El futuro del riego en el Peru : desafíos y recomendaciones* (The future of irrigation in Peru: challenges and recommendations). Report. World Bank, Washington, D.C.

Landa, C.
2017 *Constitución y desastres naturales* (Constitution and natural disasters). Blog post on *Enfoque Derecho: El Portal de Actualidad Jurídica de THEMIS* (Right Approach: The THEMIS Legal News Portal). Available at www.enfoquederecho.com/2017/03/20/constitucion-y-desastres-naturales.

Langerwisch, F., S. Rost, D. Gerten, B. Poulter, A. Rammig and W. Cramer
2013 Potential effects of climate change on inundation patterns in the Amazon Basin. *Hydrology and Earth System Sciences*, 17(6):2247–2262.

Langill, J.C.
2018 Differential experiences of climate change: Local knowledge and perspectives of severe flooding in the Peruvian Amazon [master's thesis]. Department of Geography and Planning, University of Toronto, Toronto, Canada.

Latinobarómetro
2018 *Informe Latinobarómetro 2018* (Latinobarómetro Report 2018). Santiago.

Lavado-Casimiro, W.S. and J.C. Espinoza
2014 *Impactos de El Niño y La Niña en las lluvias del Perú* (Impacts of El Niño and La Niña on Peruvian rains) (1965–2007). Revista Brasileira de Meteorologia, 29(2):171–182.

Lavado-Casimiro, W.S., D. Labat, J.L. Guyot and S. Ardoin-Bardin
2011 Assessment of climate change impacts on the hydrology of the Peruvian Amazon–Andes basin. *Hydrological Processes*, 25(24):3721–3734.

Lavado-Casimiro, W.S., D. Labat, J. Ronchail, J.C. Espinoza and J.L. Guyot
2013 Trends in rainfall and temperature in the Peruvian Amazon–Andes basin over the last 40 years (1965–2007). *Hydrological Processes*, 27(20):2944–2957.

Lavado-Casimiro, W.S., J. Ronchail, D. Labat, J.C. Espinoza and J.L. Guyot
2012 Basin-scale analysis of rainfall and runoff in Peru (1969–2004): Pacific, Titicaca and Amazonas drainages. *Hydrological Sciences Journal*, 57(4):625–642.

Lennox, E.
2015 Double exposure to climate change and globalization in a Peruvian highland community. *Society & Natural Resources*, 28(7):781–796.

Lennox, E. and J. Gowdy
2014 Ecosystem governance in a highland village in Peru: Facing the challenges of globalization and climate change. *Ecosystem Services*, 10:155–163.

Lenton, T.M., H. Held, E. Kriegler, J.W. Hall, W. Lucht, S. Rahmstorf and H.J. Schellnhuber
2008 Tipping elements in the Earth's climate system. *Proceedings of the National Academy of Sciences of the United States of America*, 105(6):1786–1793.

Levitt, P.
1998 Social remittances: Migration driven local-level forms of cultural diffusion. *International Migration Review*, 32(4):926–948.

Levitt, P. and D. Lamba-Nieves
2011 Social remittances revisited. *Journal of Ethnic and Migration Studies*, 37(1):1–22.

Liersch, S. and C. Gornott
2015 *Auswirkungen des Klimawandels auf eine nachhaltige Ernährungssicherung mit Fallstudien in Kenia, Pakistan und Peru* (Effects of climate change on sustainable food and nutrition security with case studies in Kenya, Pakistan and Peru). Report. Potsdam Institute for Climate Impact Research, Potsdam, Germany.

List, G.
2016 Agriculture and the risk of crop loss in the Amazon River floodplain of Peru [master's thesis]. McGill University, Montreal.

Llamas, V.
2017 Could Latin American citizenship be a fourth durable solution? *Forced Migration Review*, 56:67–68.

Lobell, D.B. and C.B. Field
2007 Global scale climate–crop yield relationships and the impacts of recent warming. *Environmental Research Letters*, 2(1):014002.

López-i-Gelats, F., Contreras Paco, J. L., R. Huilcas Huayra, Siguas Robles, O. D., Quispe Peña, E. C. and J. Bartolomé Filella
2015 Adaptation strategies of Andean pastoralist households to both climate and non-climate changes. *Human Ecology*, 43(2):267–282.

Lyra, A., P. Imbach, D. Rodriguez, S.C. Chou, S. Georgiou and L. Garofolo
2017 Projections of climate change impacts on central America tropical rainforest. *Climatic Change*, 141(1):93–105.

Mächtle, B.
2016 *Umwelt und Mensch im Naturraum* (Environment and people in nature). In: *Peru heute: Politik, Wirtschaft, Kultur* (Peru Today: Politics, Economy, Culture) (I. Paap and F. Schmidt-Welle, eds.). Verlag Vervuert, Frankfurt, pp. 17–38.

Macroconsult
2017 *Daños de El Niño* (Peruvian economic losses during El Niño 2017). Technical report. Macroconsult, Lima. Available at http://grupomacro.pe/2017/03/24/danos-de-el-nino-us3-124-millones-hasta-ahora-macroconsult.

Magallanes, J.M.
2015 Climate change and the potential for conflict and extreme migration in the Andes: A computational approach for interdisciplinary modeling and anticipatory policy-making [PhD dissertation]. George Mason University, Virginia.

Magrin, G., C. Gay García, D. Cruz Choque, J.C. Giménez, A.R. Moreno, G.J. Nagy, C. Nobre and A. Villamizar (eds.)
2007 *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Cambridge University Press, Cambridge, United Kingdom.

Magrin, G.O., J.A. Marengo, J.-P. Boulanger, M.S. Buckeridge, E. Castellanos, G. Poveda, F.R. Scarano and S. Vicuña
2014 Central and South America. In: *Climate Change 2014: Impacts, Adaptation and Vulnerability. Part B: Regional Aspects* (V.R. Barros, C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea and L.L. White, eds.). Cambridge University Press, Cambridge, United Kingdom and New York, pp. 1499–1566.

Malhi, Y., L.E.O.C. Aragão, D. Galbraith, C. Huntingford, R. Fisher, P. Zelazowski, S. Sitch, C. McSweeney and P. Meir
2009 Exploring the likelihood and mechanism of a climate-change-induced dieback of the Amazon rainforest. *Proceedings of the National Academy of Sciences of the United States of America*, 106(49):20610–20615.

Manzi, M.
2005 Peasant adaptation to environmental change in the Peruvian Amazon: Livelihood responses in an Amerindian and a non-Amerindian community [master's thesis]. McGill University, Montreal.

Marengo, J.A., L.S. Borma, D.A. Rodriguez, P. Pinho, W.R. Soares and L.M. Alves
2013 Recent extremes of drought and flooding in Amazonia: Vulnerabilities and human adaptation. *American Journal of Climate Change*, 2(2):87–96.

Marengo, J.A., R. Jones, L.M. Alves and M.C. Valverde
2009 Future change of temperature and precipitation extremes in South America as derived from the PRECIS regional climate modeling system. *International Journal of Climatology*, 29(15):2241–2255.

Marengo, J.A., J. Tomasella, L.M. Alves, W.r.R. Soares and D.A. Rodriguez
2011 The drought of 2010 in the context of historical droughts in the Amazon region. *Geophysical Research Letters*, 38(12):L12703.

Margheritis, A.
2015 MERCOSUR's post-neoliberal approach to migration: From workers' mobility to regional citizenship. In: *A Liberal Tide: Immigration and Asylum Law and Policy in Latin America* (D.J. Cantor, L.F. Freier and J.-P. Gauci, eds.). University of London – Institute of Latin American Studies, London, pp. 57–80.

Marzeion, B., A.H. Jarosch and M. Hofer
2012 Past and future sea-level change from the surface mass balance of glaciers. *The Cryosphere*, 6(6):1295–1322.

Masson-Delmotte, V., H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor and T. Waterfield (eds.)
2018 *Global Warming of 1.5°C*. Intergovernmental Panel on Climate Change, Geneva.

McAdam, J.
2011 Climate change displacement and international law: Complementary protection standards. Legal and Protection Policy Research Series. Office of the United Nations High Commissioner for Refugees, Geneva. Available at www.unhcr.org/protection/globalconsult/4dff16e99/19-climate-change-displacement-international-law-complementary-protection.html.

McGregor, S., A. Timmermann, M.H. England, O. Elison Timm and A.T. Wittenberg
2013 Inferred changes in El Niño–Southern Oscillation variance over the past six centuries. *Climate of the Past*, 9(5):2269–2284.

McPhaden, M.J., S.E. Zebiak and M.H. Glantz
2006 ENSO as an integrating concept in earth science. *Science*, 314(5806):1740–1745.

Milan, A.
2016 Rural livelihoods, location and vulnerable environments: Approaches to migration in mountain areas of Latin America [PhD dissertation]. Maastricht University, Maastricht, the Netherlands.

Milan, A. and R. Ho
2014 Livelihood and migration patterns at different altitudes in the Central Highlands of Peru. *Climate and Development*, 6.

Millennium Ecosystem Assessment
2005 Ecosystems and human well-being: Wetlands and water. Synthesis paper. World Resources Institute, Washington, D.C.

Millington, J.
2000 Migration and age: The effect of age on sensitivity to migration stimuli. *Regional Studies*, 34(6):521–533.

Moncada, M.A., G.G. Arias, R.G. Nitschke and C.H.R. Espinosa (eds.)
2018 *Vulnerabilidad social e impacto del desastre natural producido por el fenómeno del niño costero, en el cotidiano de las familias de las poblaciones rurales afectadas de lima* (Social vulnerability and impact of the natural disaster produced by the Coastal El Niño phenomenon, in the daily lives of the families of the affected rural populations of Lima). Paper presented at the *XVI Coloquio Panamericano de Investigación en Enfermería* (Sixteenth Pan-American Colloquium on Nursing Research), Havana, 5–9 November.

Mora, C., C.W.W. Counsell, C.R. Bielecki and L.V. Louis
2017a Twenty-seven ways a heat wave can kill you: Deadly heat in the era of climate change. *Circulation: Cardiovascular Quality and Outcomes*, 10(11):e004233.

Mora, C., B. Dousset, I.R. Caldwell, F.E. Powell, R.C. Geronimo, C.R. Bielecki, C.W.W. Counsell, B.S. Dietrich, E.T. Johnston, L.V. Louis, M.P. Lucas, M.M. McKenzie, A.G. Shea, H. Tseng, T.W. Giambelluca, L.R. Leon, E. Hawkins and C. Trauernicht
2017b Global risk of deadly heat. *Nature Climate Change*, 7:501–506.

Nicholls, R.J.
2011 Planning for the impacts of sea level rise. *Oceanography*, 24(2):144–157.

Nobre, C.A., G. Sampaio, L.S. Borma, J.C. Castilla-Rubio, J.S. Silva and M. Cardoso
2016 Land-use and climate change risks in the Amazon and the need of a novel sustainable development paradigm. *Proceedings of the National Academy of Sciences of the United States of America*, 113(39):10759–10768.

Notre Dame Global Adaptation Initiative (ND-GAIN)
2020 Peru. Profile. Available at https://gain-new.crc.nd.edu/country/peru.

O'Neill, B.C., E. Kriegler, K.L. Ebi, E. Kemp-Benedict, K. Riahi, D.S. Rothman, B.J. van Ruijven, D.P. van Vuuren, J. Birkmann, K. Kok, M. Levy and W. Solecki
2017 The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century. *Global Environmental Change*, 42:169–180.

Odell, S.D., A. Bebbington and K.E. Frey
2018 Mining and climate change: A review and framework for analysis. *The Extractive Industries and Society*, 5(1):201–214.

Oft, P.
2009 Can resilience be built through micro-finance tools? A case study of coping and adaptation strategies to climate-related shocks in Piura, Peru [PhD thesis], University of Bonn, Bonn, Germany.
2010 Micro-finance instruments can contribute to build resilience: A case study of coping and adaptation strategies to climate-related shocks in Piura, Peru [PhD thesis]. United Nations University – Institute of Environmental and Human Security, Bonn, Germany.

Oliver-Smith, A.
2014 Climate change adaptation and disaster risk reduction in highland Peru. In: *Adapting to Climate Change: Lessons from Natural Hazards Planning* (B.C. Glavovic and G.P. Smith, eds.). Springer, Dordrecht, Netherlands, pp. 77–100.

Olsson, T., M. Kämäräinen, D. Santos, T. Seitola, H. Tuomenvirta, R. Haavisto and W. Lavado-Casimiro
2017 Downscaling climate projections for the Peruvian coastal Chancay-Huaral Basin to support river discharge modeling with WEAP. *Journal of Hydrology: Regional Studies*, 13:26–42.

Oppenheimer, M., M. Campos, J. Birkmann, G. Luber, B. O'Neill, K. Takahashi, R. Warren, F. Berkhout, P. Dube and W. Foden
2014 Emergent risks and key vulnerabilities. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects* (C.B. Field, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea and L.L. White, eds.). Cambridge University Press, Cambridge, United Kingdom and New York, pp. 1039–1099.

Orlove, B.
2009 The past, the present and some possible futures of adaptation. In: *Adapting to Climate Change: Thresholds, Values, Governance* (W.N. Adger, I. Lorenzoni and K.L. O'Brien, eds.). Cambridge University Press, Cambridge and New York, pp. 131–163.

Ortiz, R.
2012 Climate change and agricultural production. Inter-American Development Bank Environmental Technical Notes No. IDB-TN-383. Available at www.climate-expert.org/fileadmin/user_upload/PDF/Costa_Rica/getdocument.pdf.

Paerregaard, K.
2013 Bare rocks and fallen angels: Environmental change, climate perceptions and ritual practice in the Peruvian Andes. *Religions*, 4(2):290–305.
2016 Making sense of climate change: Global impacts, local responses and anthropogenic dilemmas in the Peruvian Andes. In: *Anthropology and Climate Change: From Actions to Transformation* (S. Crate and M. Nuttall, eds.). Second edition, Routledge, New York.
2019 Liquid accountability: Water as a common, public and private good in the Peruvian Andes. *Water Alternatives*, 12(2):488–502.

Paerregaard, K. and A. Andersen
2019 Moving beyond the commons/commodity dichotomy: The socio-cultural complexity of Peru's water crisis. *Water Alternatives*, 12(2):459–469.

Pan-American Health Organization (PAHO)
2017 Health in the Americas: Peru. Available at www.paho.org/salud-en-las-americas-2017/?p=3232.

Pearson, A.
2009 The turning tides: Protection strategies for the Port of Callao for adapting to global sea level rise. Stanford University Engineering and Public Policy Framework Project: Climate Change and Its Impacts on the Built Environment in the Coastal Zone. Stanford University, Palo Alto, California.

Peng, Q., S.-P. Xie, D. Wang, X.-T. Zheng and H. Zhang
2019 Coupled ocean-atmosphere dynamics of the 2017 extreme coastal El Niño. *Nature Communications*, 10(1):298.

Perez, C., C. Nicklin, O. Dangles, S. Vanek, S.G. Sherwood, S. Halloy, K.A. Garrett and G.A. Forbes
2010 Climate Change in the High Andes: implications and adaptation strategies for small-scale farmers. *The International Journal of Environmental, Cultural, Economic and Social Sustainability*, 6:71–88.

(Government of) Peru
1993 Political Constitution of Peru. Available at www.constituteproject.org/constitution/Peru_2009.pdf?lang=en.
2015 Intended nationally determined contributions from the Republic of Peru. Government of Peru, Lima. Available at www4.unfccc.int/sites/submissions/indc/Submission%20Pages/submissions.aspx.

Peru, Congress of the Republic
1993 Political Constitution of Peru enacted on the 29th of December 1993. Available at www.congreso.gob.pe/Docs/files/CONSTITUTION_27_11_2012_ENG.pdf.

Peru, Mininistry of Agriculture and Irrigation (MINAGRI)
2012 *Plan de Gestión de Riesgos y Adaptación al Cambio Climático en el Sector Agrario 2012–2021*. (Risk Management Plan and Adaptation to Climate Change in the Agricultural Sector 2012–2021). Lima.
2013 *Política Nacional Forestal y de Fauna Silvestre* (National Forest and Wildlife Policy). Lima.
2015 *Plan Nacional de Seguridad Alimentaria y Nutricional 2015–2021* (National Plan for Food and Nutrition Security 2015–2021). Lima.
2016 *Politica Nacional Agraria* (National Agrarian Policy). Lima.

Peru, Ministry of Development and Social Inclusion (MIMDES)
2011 *Plan Nacional de Población 2010–2014* (National Population Plan 2010–2014). Lima.

Peru, Ministry of Environment (MINAM)
2009a *Guía para la Elaboración de la Estrategia Regional frente al Cambio Climático* (Guide to the Elaboration of the Regional Strategy against Climate Change). Lima.
2009b *Política Nacional del Ambiente en Perú* (National Environmental Policy in Peru). Lima.
2010a *Plan de Acción de Adaptación y Mitigación Frente al Cambio Climático* (Action Plan for Adaptation and Mitigation Against Climate Change). Lima.
2010b *Segunda Comunicación Nacional del Perú a la Convención Marco de las Naciones Unidas sobre Cambio Climático* (Second National Communication of Peru to the United Nations Framework Convention on Climate Change). Lima.
2011 *Plan Nacional de Acción Ambiental* (National Environmental Action Plan) (PLANAA Peru 2011–2021). Lima.
2015a *AgendAmbiente Perú 2015–2016: Agenda Nacional de Acción Ambiental* (AgendAmbiente Peru 2015–2016: National Agenda for Environmental Action). Lima.
2015b COP20 raised awareness on climate change and importance for Peru. Lima.
2015c *Estrategia Nacional ante el Cambio Climático* (National Strategy for Climate Change). Lima.
2016a *Estrategia Nacional contra la Desertificación y la Sequía 2016–2030* (National Strategy against Desertification and Drought 2016–2030). Lima.
2016b *Estrategia Nacional sobre Bosques y Cambio Climático* (National Strategy on Forests and Climate Change). Lima.

2016c *Ordenamiento territorial en el Perú (2011–2015)* (Land use planning in Peru (2011–2015)). Report. Lima.

2016d *El Perú y el Cambio Climático: Tercera Comunicación Nacional del Perú a la Convención Marco de las Naciones Unidas sobre Cambio Climático* (Third National Communication of Peru to the United Nations Framework Convention on Climate Change). *Capítulo 6 : Avances en la adaptación al cambio climático y el estado de la vulnerabilidad en el Perú* (Chapter 6: Advances in adaptation to climate change and the state of vulnerability in Peru). Lima.

2019 *Decreto Supremo que aprueba el Reglamento de la Ley Nº 30754, Ley Marco sobre Cambio Climático: Decreto Supremo Nº 013-2019-MINAM* (Supreme Decree that approves the Regulation of Law No. 30754, Framework Law on Climate Change: Supreme Decree No. 013-2019-MINAM). Lima.

Peru, Ministry of Justice and Human Rights (MINJUSDH)

2018 *Plan Nacional de Derechos Humanos 2018–2021* (National Human Rights Plan 2018–2021). Lima.

Peru, Ministry of Women and Vulnerable Populations (MIMP) and International Organization for Migration (IOM)

2015 *Desplazamientos internos en el Perú* (Internal displacement in Peru). Report. Lima

Peru, National Centre for Strategic Planning (CEPLAN)

2011 *Plan Bicentario: El Perú hacia 2021* (Bicentary Plan: Peru towards 2021). Lima.

2016 *Economía informal en Perú: Situación actual y perspectivas* (Informal economy in Peru: Current situation and perspectives). *Serie Avance de Investigación Nº 8* (Research Advancement Series No. 8). San Isidoro, Peru. Available at https://perureports.com/wp-content/uploads/2016/08/Economia-informal-en-Peru-situacion-actual-perspectivas-15-03-2016.pdf.

Peru, National Commission on Climate Change (CNCC)

2001 *Primera Comunicación Nacional del Perú a la Convención Marco de las Naciones Unidas sobre Cambio Climático*. (First National Communication of Peru to the United Nations Framework Convention on Climate Change). Lima.

Peru, National Council for Science, Technology and Technological Innovation (CONCYTEC) and National Council for the Environment (CONAM)

2005 *Agenda de Investigación Científica en Cambio Climático y Calidad del Aire* (Agenda for Scientific Research on Climate Change and Air Quality). CONCYTEC and CONAM. Lima.

Peru, National Institute for Research on Glaciers and Mountain Ecosystems (INAIGEM)

2018 Inventario Nacional de Glaciares: Las Cordilleras del Perú (National Glacier Inventory: The Cordilleras of Peru). Huaraz, Peru.

Peru, National Institute of Civil Defence (INDECI)

2016 *Compendio estadístico del INDECI en la preparación, respuesta y rehabilitación ante emergencias y desastres* (Statistical INDECI compendium on emergency and disaster preparedness, response and rehabilitation). Report. Lima. Available at http://bvpad.indeci.gob.pe/doc/pdf/esp/doc2641/doc2641.htm.

2017 *Séptimo boletín estadístico virtual del INDECI de al Gestión Reactiva* (Seventh virtual statistical bulletin of INDECI on reactive management). Report. Lima. Available at www.indeci.gob.pe/direccion-politicas-y-planes/boletin-estadistico-virtual-de-la-gestion-reactiva-del-indeci.

2018 *Compendio Estadístico 2018: Preparación, Respuesta, Rehabilitación* (Statistical Compendium 2018: Preparation, Response, Rehabilitation). Lima.

n.d. *Base de Datos de Emergencia y Daños* (Database of Emergencies and Damage), 2003–2017. Available at www.indeci.gob.pe/direccion-politicas-y-planes/base-de-datos-de-emergencia-y-danos/base-de-datos-de-emergencia-y-danos-2003-2017.

Peru, National Institute of Statistics and Informatics (INEI)

2007 *Perfil Sociodemográfico del Péru – Censos Nacionales : XI de Población y VI de Vivienda* (Sociodemographic Profile of Peru – National Census: XI of Population and VI of Housing). Report. Second edition, Lima. Available at www.inei.gob.pe/media/MenuRecursivo/publicaciones_digitales/Est/Lib1136/libro.pdf.

2009 *Perú: Estimaciones y proyecciones de población 1950–2050* (Population estimates and projections 1950–2050). Special Bulletin No. 17. Lima. Available at www.inei.gob.pe/media/principales_indicadores/libro_1.pdf.

2011 *Perú: Migración interna reciente y el sistema de ciudades 2002–2007* (Recent Internal Migration and the System of Cities 2002–2007). Report. Lima. Available at www.inei.gob.pe/media/MenuRecursivo/publicaciones_digitales/Est/Lib1025/libro.pdf.

2013 *IV Censo Nacional Agropecuario 2012 : Resultados Definitivos* (Fourth National Agricultural Census 2012 – Final results). Report. Lima. Available at https://sinia.minam.gob.pe/documentos/resultados-definitivos-iv-censo-nacional-agropecuario-2012-0.

2014 *Características Socioeconómicas del Productor Agropecuario en El Perú : IV Censo Nacional Agropecuario 2012* (Socioeconomic characteristics of the agricultural producer in Peru: Fourth National Agricultural Census 2012). Report. Available at www.inei.gob.pe/media/MenuRecursivo/publicaciones_digitales/Est/Lib1177/libro.pdf.

2016a *Censos 2017: Niveles y tendencias de la migración internacional peruana* (Census 2017: Levels and trends of Peruvian international migration) [slide presentation]. Lima. Available at www.inei.gob.pe/media/MenuRecursivo/boletines/presntacion_migraciones.pdf.

2016b *Evolución de la pobreza monetaria 2009–2015* (Evolution of monetary poverty 2009–2015). Technical report. Lima.

2017 *Emigración Internacional de Peruanos : Características de los Hogares de Origen y de los Receptores de Remesas, 2013 y 2015* (International emigration of Peruvians: Characteristics of the homes of origin and the recipients of remittances, 2013 and 2015). Report. Lima. Available at www.inei.gob.pe/media/MenuRecursivo/publicaciones_digitales/Est/Lib1473/libro.pdf.

2018 *Péru : Perfil Sociodemográfico : Informe Nacional – Censos Nacionales 2017 : XII de población, VII de vivienda y III de comunidades indígenas* (Peru: Sociodemographic Profile: National Report – National Census 2017: XII of population, VII of housing and III of indigenous communities). Lima. Available at www.inei.gob.pe/media/MenuRecursivo/publicaciones_digitales/Est/Lib1539/libro.pdf.

n.d. *Migración interna* (Internal migration). Data set. Available at http://m.inei.gob.pe/estadisticas/indice-tematico/internal-migration.

Peru, National Institute of Statistics and Informatics (INEI) and National Superintendency for Migration (SNM), Ministry of Foreign Affairs (RREE) and International Organization for Migration (IOM)

2018 *Estadísticas de la emigración internacional de Peruanos e inmigración de extranjeros, 1990–2017* (Statistics on international emigration of Peruvians and immigration of foreigners, 1990–2017). Report. Lima. Available at https://peru.iom.int/sites/default/files/Documentos/EST19902017.pdf (accessed 19 February 2020).

Peru, National Meteorological and Hydrological Service (SENAMHI)

2015 *Regionalización y caracterización de sequías en el Perú* (Regionalization and characterization of droughts in Peru). Report. Lima.

2019 *Caracterización espacio temporal de la sequía en el Perú a escala de departamentos altoandinos (1981–2018)* (Spatial–temporal characterization of droughts in Peru at the scale of high Andean departments (1981–2018)). Report. Lima.

n.d. *Clima : Heladas y Friajes*. (Climate: Frost and Coldwaves). Available at www.senamhi.gob.pe/?p=heladas-y-friajes-recursos.

Peru, National Office for the Evaluation of Natural Resources (ONERN)

1982 *Informe de Clasificación de Tierras del Perú* (Land Classification Report of Peru). Lima.

Peru, National Water Authority (ANA)
2013 *Plan nacional de recursos hídricos del Perú* (National Water Resources Plan of Peru). Lima.
2014 *Inventario de glaciares del Peru* – segunda actualizacion (Glacier Inventory of Peru) – second update. Huaraz, Peru.
2018 Compendio nacional de estadísticas de recursos hídricos 2017 [National Statistical Compendium of Water Resources 2017]. Lima.

Peru, Office of the Ombudsman (Defensoría del Pueblo)
2009 *Migraciones y Derechos Humanos. Supervisión de las políticas de protección de los derechos de los peruanos migrantes* (Migrations and human rights: Supervision of policies for the protection of the rights of migrant Peruvians). *Serie Informes Defensoriales Informe N° 146* (Defence Reports Series, report no. 146). Lima. Available at www.defensoria.gob.pe/wp-content/uploads/2018/05/informe-146.pdf.
2011 *Reporte de seguimiento de las Recomendaciones del Informe Defensorial Nº 146, "Migraciones y Derechos Humanos" 2010*. (Follow-up report on the Recommendations of the Ombudsman's Report No. 146, "Migrations and Human Rights"). *Serie Informes de Adjuntía Informe N° 003-2010-DP/ADHPD* (Attached Reports Series, Report No. 003-2010-DP/ADHPD). Lima. Available at www.defensoria.gob.pe/wp-content/uploads/2018/09/Informe-de-Adjuntia-N-003-2010DP-ADHPD.pdf.
2015 *Tratamiento de las personas extranjeras en el Perú. Casos conocidos por la Defensoría del Pueblo*. (Treatment of foreigners in Peru. Cases known to the Ombudsman's Office) *Serie de Informes de Adjuntía Informe N° 009-2014-DP/ADHPD* (Attached Reports Series, report no. 009-2014-DP/ADHPD). Lima. Available at www.defensoria.gob.pe/wp-content/uploads/2018/05/Informe-009-2014-DP-ADHPD.pdf.
2018 *Demandamos política integral migratoria que respete derechos humanos en el contexto de la migración internacional* (We demand a comprehensive migration policy that respects human rights in the context of international migration). *Pronunciamento N° 021DP/2018* (Statement No. 021DP/2018). Available at www.defensoria.gob.pe/wp-content/uploads/2018/08/Pronunciamiento-N°21-DP.pdf.

Peruvian Centre for Social Studies (CEPES)
2015 *Los suelos en el Perú* (Soils in Peru). La Revista Agraria (The Agrarian Review), 170(15):1–16.

Piguet, E., R. Kaenzig and J. Guélat
2018 The uneven geography of research on "environmental migration". *Population and Environment*, 30(2):225.

Plane, D.A.
1993 Demographic influences on migration. *Regional Studies*, 27(4):375–383.

Poma, E.C.
n.d. *Ley Nº 29869 : Ley de reasentamiento poblacional para zonas de muy alto riesgo no mitigable: Directora de Fortalecimiento y Asistencia Técnica* (Law No. 29869: Law of Population Resettlement for Areas with Very High Non-mitigable Risk). Director of Strengthening and Technical Assistance. Lima.

Pörtner, H.-O., D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, M. Nicolai, A. Okem, J. Petzold, B. Rama and N. Weyer (eds.)
2019 *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*. Geneva.

Pramova, E., M. Di Gregorio and B. Locatelli
2015 Integrating adaptation and mitigation in climate change and land-use policies in Peru. Working paper 184. Center for International Forestry Research, Bogor, Indonesia.

Rabatel, A., B. Francou, A. Soruco, J. Gomez, B. Cáceres, J.L. Ceballos, R. Basantes, M. Vuille, J.-E. Sicart, C. Huggel, M. Scheel, Y. Lejeune, Y. Arnaud, M. Collet, T. Condom, G. Consoli, V. Favier, V. Jomelli, R. Galarraga, P. Ginot, L. Maisincho, J. Mendoza, M. Ménégoz, E. Ramirez, P. Ribstein, W. Suarez, M. Villacis and P. Wagnon
2013 Current state of glaciers in the tropical Andes: A multi-century perspective on glacier evolution and climate change. *The Cryosphere*, 7(1):81–102.

Racoviteanu, A.E., Y. Arnaud, M.W. Williams, J. Ordoñez and O. Ordoñez
2008 Decadal changes in glacier parameters in the Cordillera Blanca, Peru, derived from remote sensing. *Journal of Glaciology*, 54(186):499–510.

Radić, V., A. Bliss, A.C. Beedlow, R. Hock, E. Miles and J.G. Cogley
2014 Regional and global projections of twenty-first century glacier mass changes in response to climate scenarios from global climate models. *Climate Dynamics*, 42(1-2):37–58.

Ramírez, J., C. Iréri, C. Soledad and R. Arteaga
2017 *"Ha, Usted viene por la visa Mercosur" : Migración, integracióny refugio en Ecuador* ("Hey, come for your Mercosur visa": Migration, integration and refuge in Ecuador. Latin American Geopolitical Strategic Center. Quito.

Rammig, A., T. Jupp, K. Thonicke, B. Tietjen, J. Heinke, S. Ostberg, W. Lucht, W. Cramer and P. Cox
2010 Estimating the risk of Amazonian forest dieback. *The New Phytologist*, 187(3):694–706.

Rau, P., L. Bourrel, D. Labat, P. Melo, B. Dewitte, F. Frappart, W. Lavado and O. Felipe
2017 Regionalization of rainfall over the Peruvian Pacific slope and coast. *International Journal of Climatology*, 37(1):143–158.

Rau, P., L. Bourrel, D. Labat, D. Ruelland, F. Frappart, W. Lavado, B. Dewitte and O. Felipe
2019 Assessing multidecadal runoff (1970–2010) using regional hydrological modelling under data and water scarcity conditions in Peruvian Pacific catchments. *Hydrological Processes*, 33(1):20–35.

Ray, D.K., N. Ramankutty, N.D. Mueller, P.C. West and J.A. Foley
2012 Recent patterns of crop yield growth and stagnation. *Nature Communications*, 3:1293–1297.

Reguero, B.G., I.J. Losada, P. Díaz-Simal, F.J. Méndez and M.W. Beck
2015 Effects of climate change on exposure to coastal flooding in Latin America and the Caribbean. *PLOS One*, 10(7):e0133409.

Riahi, K., D.P. van Vuuren, E. Kriegler, J. Edmonds, B.C. O'Neill, S. Fujimori, N. Bauer, K. Calvin, R. Dellink, O. Fricko, W. Lutz, A. Popp, J.C. Cuaresma, S. KC, M. Leimbach, L. Jiang, T. Kram, S. Rao, J. Emmerling, K. Ebi, T. Hasegawa, P. Havlik, F. Humpenöder, L.A. Da Silva, S. Smith, E. Stehfest, V. Bosetti, J. Eom, D. Gernaat, T. Masui, J. Rogelj, J. Strefler, L. Drouet, V. Krey, G. Luderer, M. Harmsen, K. Takahashi, L. Baumstark, J.C. Doelman, M. Kainuma, Z. Klimont, G. Marangoni, H. Lotze-Campen, M. Obersteiner, A. Tabeau and M. Tavoni
2017 The shared socioeconomic pathways and their energy, land use, and greenhouse gas emissions implications: An overview. *Global Environmental Change*, 42:153–168.

Rodriguez-Serna, N.
2015 Human mobility in the context of natural hazard-related disasters in South America. Background paper for the Nansen Initiative/Refugee Law Initiative South America Consultation, Quito, 15–16 July. Available at www.nanseninitiative.org/wp-content/uploads/2015/12/14122015_FINAL_BACKGROUND_PAPER_SOUTH_AMERICA_screen.pdf.

Rogers, A. and L.J. Castro
1981 Age patterns of migration: cause-specific profiles. Research Reports, RR-81-6:125–159.

Rojas-Medina, Y., J.A. Vargas Machuca and O.V. Trujillo
2008 *Trastorno de estrés agudo y episodio depresivo mayor en víctimas de una inundación en Tingo María : prevalencia y efectos de su desplazamiento a un alberg* (Acute stress disorder and major depressive episodes in victims of a flood in Tingo María: Prevalence and effects of their displacement to a shelter). *Revista Peruana de Medicina Experimental y Salud Pública*, 25(1):66–73.

Ros-Tonen, M.A.F. and J.H. van Boxel
1999 El Niño in Latin America: The case of Peruvian fishermen and north-east Brazilian peasants. *Revista Europea de Estudios Latinoamericanos y del Caribe/European Review of Latin American and Caribbean Studies*, 67:5–20.

Salem, J., Y. Amonkar, N. Maennling, U. Lall, L. Bonnafous and K. Thakkar
2018 An analysis of Peru: Is water driving mining conflicts? *Resources Policy*. DOI: 10.1016/j.resourpol.2018.09.010.

Salzmann, N., C. Huggel, M. Rohrer, W. Silverio, B.G. Mark, P. Burns and C. Portocarrero
2013 Glacier changes and climate trends derived from multiple sources in the data scarce Cordillera Vilcanota region, southern Peruvian Andes. *The Cryosphere*, 7(1):103–118.

Sanabria, J., L. Bourrel, B. Dewitte, F. Frappart, P. Rau, O. Solis and D. Labat
2018 Rainfall along the coast of Peru during strong El Niño events. *International Journal of Climatology*, 38(4):1737–1747.

Sánchez Aguilar, A.
2012 *Perfil Migratorio del Perú, 2012* (Migratory Profile of Peru 2012). International Organization for Migration, Lima.
2015a *La fuerza económica de las migraciones internas: Los novedosos polos del desarrollo peruano* (The Economic Force of Internal Migration: The Novel Poles of Peruvian Development). V&S Editores, Lima.
2015b *Migraciones internas en el Perú* (Internal Migration in Peru). International Organization for Migration, Lima. Available at https://peru.iom.int/sites/default/files/Documentos/Migraciones_Internas.pdf.

Schneider, D., C. Huggel, A. Cochachin, S. Guillén and J. García
2014 Mapping hazards from glacier lake outburst floods based on modelling of process cascades at Lake 513, Carhuaz, Peru. *Advances in Geosciences*, 35:145–155.

Seehaus, T., P. Malz, C. Sommer, S. Lippl, A. Cochachin and M. Braun
2019 Changes of the tropical glaciers throughout Peru between 2000 and 2016: Mass balance and area fluctuations. *The Cryosphere*, 13:2537–2556.

Segura, H., C. Junquas, J.C. Espinoza, M. Vuille, Y.R. Jauregui, A. Rabatel, T. Condom and T. Lebel
2019 New insights into the rainfall variability in the tropical Andes on seasonal and interannual time scales. *Climate Dynamics*, 53:405–426. Available at https://doi.org/10.1007/s00382-018-4590-8.

Serra, A.M.
2017 *Esterilizaciones (forzadas) en Perú: Poder y configuraciones narrativas* ((Forced) sterilizations in Peru: Power and narrative configurations). AIBR : Revista de Antropología Iberoamericana (AIBR: Latin American Anthropological Review), 12(1):31–52.

Settele, J., R. Scholes, R. Betts, S. Bunn, P. Leadley, D. Nepstad, J.T. Overpeck and M.A. Taboada
2014 Figure 4-8: Terrestrial and inland water systems. In: Climate Change 2014: *Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects* (Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)). Cambridge University Press, Cambridge, United Kingdom and New York.

Sherbinin, A. de and L. Bai
2018 Geospatial modelling and mapping. In: *Routledge Handbook of Environmental Displacement and Migration* (R.A. McLeman and F. Gemenne, eds.). Routledge, London.

Sherbinin, A. de, M. Castro, M.M. Cernea, P.M. Fearnside, G. Krieger, S. Lahmani, A. Oliver-Smith and A. Pankhurst
2011 Preparing for resettlement associated with climate change. *Science*, 334(6055):456–457.

Sherman, M., J. Ford, A. Llanos-Cuentas and M.J. Valdivia
2016 Food system vulnerability amidst the extreme 2010–2011 flooding in the Peruvian Amazon: A case study from the Ucayali region. *Food Security*, 8(3):551–570.

Sherman, M., J. Ford, A. Llanos-Cuentas, M.J. Valdivia and A. Bussalleu
2015 Vulnerability and adaptive capacity of community food systems in the Peruvian Amazon: A case study from Panaillo. *Natural Hazards*, 77(3):2049–2079.

Peru, National System for Disaster Risk Management (SINAGERD), Presidency of the Council of Ministers (PCM), Secretariat for Disaster Risk Management (SGRD), Peru, National Centre for Disaster Risk Estimation, Prevention and Reduction (CENEPRED), and Peru, National Institute of Civil Defence (INDECI)
2014 *Plan Nacional de Gestión del Riesgo de Desastres* (National Plan for Disaster Risk Management) (PLANAGERD) 2014–2021. Lima. Available at www.preventionweb.net/files/37923_39462planagerd201420215b15d1.pdf.

Skansi, M., M. Brunet, J. Sigró, E. Aguilar, J.A. Arevalo Groening, O.J. Bentancur, Y.R. Castellón Geier, R.L. Correa Amaya, H. Jácome, A. Malheiros Ramos, C. Oria Rojas, A.M. Pasten, S. Sallons Mitro, C. Villaroel Jiménez, R. Martínez, L.V. Alexander and P.D. Jones
2013 Warming and wetting signals emerging from analysis of changes in climate extreme indices over South America. *Global and Planetary Change*, 100:295–307.

Sörensson, A., C. Menéndez, R.C. Ruscica, P. Alexander, P. Samuelsson and U. Willén
2010 Projected precipitation changes in South America: A dynamical downscaling within CLARIS. *Meteorologische Zeitschrift* (Journal of Meteorology), 19(4):347–355.

South American Conference on Migration (Conferencia Sudamérica sobre Migraciones (CSM))
2018 Lineamientos regionales en materia de protección y asistencia a personas desplazadas a través de fronteras y migrantes en países afectados por desastres de origen natural (Regional guidelines on protection and assistance to cross-border displaced persons and migrants in countries affected by natural disasters.). South American Conference on Migration, Sucre, 22–23 November.

Sperling, F., C. Validivia, R. Quiroz, R. Valdivia, L. Angulo, A. Seimon and I. Noble
2008 Transitioning to climate resilient development: Perspectives from communities in Peru. Climate Change Series Environment Department Papers No. 115. World Bank, Washington, D.C.

Steeman, G.E.G.
2015 *Argentina y los migrantes por desastres naturales* (Argentina and migrants due to natural disasters). In: *Respuestas del derecho internacional a desastres y otras consecuencias de fenómenos naturales* (International law responses to disasters and other consequences of natural phenomena) (S.S.G. Napolitano, M.N. Mollar, P.M. Vernet, M.B. Gracia, I. Vázquez, G.E.G. Steeman, P. Bilbao, V.L. Elías, P.E. Cano and J.L. Revol, eds.). SGN Editora, Buenos Aires, pp. 189–200.

Stein, M. (ed.)
2017 Migration networks in Northern Peru: Linking social network and cognitive approaches to assess internal migration. Paper presented at the seventy-seventh Annual Meeting of the Society for Applied Anthropology, Santa Fe, New Mexico, 28 March to 1 April.
2018 Embeddedness, cultural consonance, and health in a dynamic migration network in Northern Peru [PhD thesis]. University of Alabama, Tuscaloosa, Alabama.

Stokes, B., R. Wike, J. Carle
2015 Global concern about climate change, broad support for limiting emissions. Report. Pew Research Center, Washington, D.C. Available at www.pewresearch.org/wp-content/uploads/sites/2/2015/11/Pew-Research-Center-Climate-Change-Report-FINAL-November-5-2015.pdf.

Strauss, B.H., S. Kulp and A. Levermann
2015 Carbon choices determine US cities committed to futures below sea level. *Proceedings of the National Academy of Sciences of the United States of America*, 112(44):13508–13513.

Suarez, W., N. Macedo, N. Montoya, S. Arias, S. Schauwecker, C. Huggel, M. Rohrer and T. Condom
2015 *Balance enérgetico neto (2012–2014) y evolución temporal del nevado Quisoquipina en la región de Cusco (1990–2010)* (Net energy balance (2012–2014) and temporal evolution of Quisoquipina Mountain in the Cusco Region (1990–2010)). *Revista Peruana Geo-Atmosferica* (Peruvian Geo-atmospheric Review), 4:80–92.

Takahashi, B. and A. Martinez
2018 Climate change communication in Peru. In: *The Oxford Encyclopedia of Climate Change Communication* (M. Nisbet, ed.). First edition, Oxford University Press, New York.

Takahashi, K. and A.G. Martínez
2019 The very strong coastal El Niño in 1925 in the far-eastern Pacific. *Climate Dynamics*, 52(12):7389–7415.

Takasaki, Y., B. Barham and O.T. Coomes
1999 Risk coping strategies in tropical forests: Floods, illnesses, and resource extraction. *Environment and Development Economics*, 9(2):203–224.
2010 Smoothing income against crop flood losses in Amazonia: Rain forest or rivers as a safety net? *Review of Development Economics*, 14(1):48–63.

Teves, N., G. Laos, S. Carrasco, C.S. Roman, L. Pizarro, G. Cardenas and A. Romero
1996 Sea-level rise along the Lima coastal zone, Perú, as a result of global warming: Environmental impacts and mitigation measures. In: *Adapting to Climate Change: An International Perspective* (J.B. Smith, N. Bhatti, G.V. Menzhulin, R. Benioff, M. Campos, B. Jallow, F. Rijsberman, M.I. Budyko and R.K. Dixon, eds.). Springer, New York, pp. 283–298.

Thiery, P.
2016 *Das politische System: Verfassung, Staat und Demokratie* (The political system: constitution, state, and democracy). In: *Peru heute: Politik, Wirtschaft, Kultur* (Peru Today: Politics, Economiy, Culture) (I. Paap and F. Schmidt-Welle, eds.). Verlag Vervuert, Frankfurt, Germany, pp. 143–178.

Timmermann, A., S.-I. An, J.-S. Kug, F.-F. Jin, W. Cai, A. Capotondi, K.M. Cobb, M. Lengaigne, M.J. McPhaden, M.F. Stuecker, K. Stein, A.T. Wittenberg, K.-S. Yun, T. Bayr, H.-C. Chen, Y. Chikamoto, B. Dewitte, D. Dommenget, P. Grothe, E. Guilyardi, Y.-G. Ham, M. Hayashi, S. Ineson, D. Kang, S. Kim, W. Kim, J.-Y. Lee, T. Li, J.-J. Luo, S. McGregor, Y. Planton, S. Power, H. Rashid, H.-L. Ren, A. Santoso, K. Takahashi, A. Todd, G. Wang, G. Wang, R. Xie, W.-H. Yang, S.-W. Yeh, J. Yoon, E. Zeller and X. Zhang
2018 El Niño-Southern Oscillation complexity. *Nature*, 559(7715):535–545.

Triscritti, F.
2013 Mining, development and corporate–community conflicts in Peru. *Community Development Journal*, 48(3):437–450.

United Nations
1992 United Nations General Assembly resolution 48/189 on the Framework Convention on Climate Change, adopted on 4 June (A/RES/48/189).
2014 *Análisis de la Implementacién de la Gestión de Riesgo de Desastres en el Peru* (Analysis of the Implementation of Disaster Risk Management in Peru). Lima.
2016 Report of the open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction (A/71/644). Note by the Secretary-General.
2018 United Nations General Assembly resolution 73/195 on the Global Compact on Safe, Orderly and Regular Migration, adopted on 19 December (A/RES/73/195).

United Nations Department of Economic and Social Affairs (UN DESA)
2015 *World Urbanization Prospects: The 2014 Revision*. New York.
2016 *The International Migration Report 2015*. New York.
2017a *Handbook on Measuring International Migration through Population Censuses*. New York.
2017b *World Population Prospects: The 2017 Revision – Key Findings & Advance Tables*. New York.
2018a International migrant stock: The 2017 revision. Data set. Available at www.un.org/en/development/desa/population/migration/data/estimates2/estimates17.asp (accessed 19 February 2019)
2018b *World Urbanization Prospects: The 2018 Revision*. New York.
2019 *World Population Prospects 2019, Volume II: Demographic Profiles*. New York. Available at https://population.un.org/wpp/Publications.

United Nations Development Programme (UNDP)
2018a Human development indices and indicators: 2018 statistical update. Briefing note for countries on the 2018 statistical update – Peru. New York.
2018b Multidimensional Poverty Index (MPI): developing countries. Data set. Available from hdr.undp.org/sites/default/files/table_6_2018_mpi.xlsx (accessed 18 February 2019).
2020a Covid-19 and external shock: Economic impacts and policy options in Peru. Report. New York. Available at www.latinamerica.undp.org/content/rblac/en/home/library/crisis_prevention_and_recovery/covid-19-y-el-schock-externo--impactos-economicos-y-opciones-de-.html.
2020b Early recovery responses to COVID-19 for migrants and host communities in Latin America and the Caribbean. Report. New York. Available at www.latinamerica.undp.org/content/rblac/en/home/library/democratic_governance/early-recovery-responses-for-migrants-and-host-communities-maxim.html.

United Nations Framework Convention on Climate Change (UNFCCC)
2010 Report of the Conference of the Parties on its sixteenth session, Cancun, Mexico, 29 November to 10 December (Decision 1/CP.16: The Cancun Agreements: Outcome of the work of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention).

(Office of the) United Nations High Commission for Refugees (UNHCR)
2018 Factsheet: Peru, November. Lima. Available at https://reliefweb.int/sites/reliefweb.int/files/resources/UNHCR%20Peru%20Factsheet%20-%20November%202018.pdf.

United Nations Office for Disaster Risk Reduction (UNDRR/UNISDR)
2015 Sendai Framework for Disaster Risk Reduction 2015–2030. Available at www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030.

United Nations Office for the Coordination of Humanitarian Affairs (OCHA)
1998 Guiding Principles on Internal Displacement. Geneva. Available at www.unocha.org/sites/dms/Documents/GuidingPrinciplesDispl.pdf.

United Nations Office of Drugs and Crime (UNODC)
2019 Intentional homicide victims. Data set. Available at https://dataunodc.un.org/crime/intentional-homicide-victims.

United States, Central Intelligence Agency (CIA)
n.d. Peru. In: *The World Factbook*. Available at www.cia.gov/library/publications/the-world-factbook/geos/pe.html (accessed 19 February 2020).

USAID
2011 Peru climate change vulnerability and adaptation desktop study. Report. Washington, D.C.
2014 Peru tropical forest and biodiversity assessment. Report. Washington, D.C.
2017 Climate Change Risk Profile: Peru. Available at www.climatelinks.org/resources/climate-change-risk-profile-peru.

van der Land, V., C. Romankiewicz and K. van der Geest
2018 Environmental change and migration: A review of West African case studies. In: *Routledge Handbook of Environmental Displacement and Migration* (R.A. McLeman and F. Gemenne, eds.). Routledge, London, pp. 163–177.

van Ittersum, M.K., K.G. Cassman, P. Grassini, J. Wolf, P. Tittonell and Z. Hochman
2013 Yield gap analysis with local to global relevance: A review. *Field Crops Research*, 143:4–17.

van Vuuren, D.P., J. Edmonds, M. Kainuma, K. Riahi, A. Thomson, K. Hibbard, G.C. Hurtt, T. Kram, V. Krey, J.-F. Lamarque, T. Masui, M. Meinshausen, N. Nakicenovic, S.J. Smith and S.K. Rose
2011 The representative concentration pathways: An overview. *Climatic Change*, 109(1):5.

Vargas, P.
2009 *El cambio climático y sus efectos en el Perú* (Climate change and its effects in Peru), 2009–2014. Report. *Banco Central de Reserva del Perú* (Central Reserve Bank of Peru), Lima.

Veettil, B.K.
2018 Glacier mapping in the Cordillera Blanca, Peru, tropical Andes, using Sentinel-2 and Landsat data. *Singapore Journal of Tropical Geography*, 39(3):351–363.

Veettil, B.K., S. Florêncio de Souza, J.C. Simões and S.F. Ruiz Pereira
2017 Decadal evolution of glaciers and glacial lakes in the Apolobamba–Carabaya region, tropical Andes (Bolivia–Peru). *Geografiska Annaler: Series A, Physical Geography*, 99(3):193–206.

Veettil, B.K. and U. Kamp
2019 Global disappearance of tropical mountain glaciers: Observations, causes, and challenges. *Geosciences*, 9(5):196.

Venkateswaran, K., K. MacClune and M.F. Enriquez
2017 Learning from El Niño costero 2017: Opportunities for building resilience in Peru. Report. Institute for Social and Environmental Transition (ISET) International, Boulder, Colorado, and the Zurich Flood Resilience Alliance, Zurich, Switzerland.

Vera, C., G. Silvestri, B. Liebmann and P. González
2006 Climate change scenarios for seasonal precipitation in South America from IPCC-AR4 models. *Geophysical Research Letters*, 33(13).

Vergara, W. and S.M. Scholz
2010 Assessment of the risk of Amazon dieback. Report. World Bank, Washington, D.C.

Vicente-Serrano, S.M., J.I. López-Moreno, K. Correa, G. Avalos, J. Bazo, C. Azorin-Molina, F. Domínguez-Castro, A.E. Kenawy, L. Gimeno and R. Nieto
2018 Recent changes in monthly surface air temperature over Peru, 1964–2014. *International Journal of Climatology*, 38(1):283–306.

Villa, M., J. Rodríguez and A.E. Lattes
2017 Population dynamics and urbanization in Latin America: Concepts and data limitations. In: *New Forms of Urbanization: Beyond the Urban–Rural Dichotomy* (G. Hugo, ed.). Routledge, London, pp. 89–111.

Vuille, M., M. Carey, C. Huggel, W. Buytaert, A. Rabatel, D. Jacobsen, A. Soruco, M. Villacis, C. Yarleque, O. Elison Timm, T. Condom, N. Salzmann and J.-E. Sicart
2018 Rapid decline of snow and ice in the tropical Andes – impacts, uncertainties and challenges ahead. *Earth-Science Reviews*, 176:195–213.

Vuille, M., B. Francou, P. Wagnon, I. Juen, G. Kaser, B.G. Mark and R.S. Bradley
2008 Climate change and tropical Andean glaciers: Past, present and future. *Earth-Science Reviews*, 89(3-4):79–96.

Warn, E.
2013 Adaptation, adaptation, adaptation: Migration, climate change and national adaptation plans in South America. IOM Web Blog, 13 November. Available at https://weblog.iom.int/adaptation-adaptation-adaptation-migration-climate-change-and-national-adaptation-plans-south.

Warner, K. and T. Afifi
2014 Where the rain falls: Evidence from 8 countries on how vulnerable households use migration to manage the risk of rainfall variability and food insecurity. *Climate and Development*, 6(1):1–17.

Warner, K., W. Kälin, S. Martin and Y. Nassef
2015 National adaptation plans and human mobility. *Forced Migration Review*, 49.

Warner, K., W. Kälin, S.F. Martin, Y. Nassef, S. Lee, S. Melde, H.E. Chapuisa, M. Franck and T. Afifi
2014 Integrating human mobility issues within national adaptation plans. Policy Brief Series No. 9. United Nations University – Institute for Environment and Human Security, Bonn, Germany.

World Food Programme (WFP)
2017 Peru Country Strategic Plan (2018–2022) (WFP/EB.2/2017/7-A/3/Rev.1). Available at https://documents.wfp.org/stellent/groups/public/documents/eb/wfp293157.pdf.

World Food Programme (WFP) and National Centre for Disaster Risk Estimation, Prevention and Reduction (CENEPRED)
2015 *Mapa de vulnerabilidad a la inseguridad alimentaria ante la recurrencia de fenómenos de origen natural 2015* (Vulnerability map to food insecurity due to the recurrence of phenomena of natural origin). Analytical report. Lima.

Wilmsen, B. and M. Webber
2015 What can we learn from the practice of development-forced displacement and resettlement for organised resettlements in response to climate change? *Geoforum*, 58:76–85.

World Meteorological (WMO)
2019 United in Science - High-level synthesis report of latest climate science information convened by the Science Advisory Group of the UN Climate Action Summit 2019. Synthesis report. Geneva. Available at https://ane4bf-datap1.s3-eu-west-1.amazonaws.com/wmocms/s3fs-public/ckeditor/files/United_in_Science_ReportFINAL_0.pdf?XqiG0yszsU_sx2vOehOWpCOkm9RdC_gN.

World Bank
2017 Peru: Systematic country diagnostic. Report, February. Washington, D.C.
2019 World Development Indicators. Data set. Available at https://openknowledge.worldbank.org/handle/10986/26376 (accessed 19 February 2020).

Wrathall, D.J., J.T. Bury, M. Carey, B. Mark, J. McKenzie, M. Baraer, A. French and C. Rampini
2014 Migration amidst climate rigidity traps: resource politics and social–ecological possibilism in Honduras and Peru. *Annals of the Association of American Geographers*, 104(2):292–304.

Wrathall, D.J., V. Mueller, P.U. Clark, A. BELL, M. Oppenheimer, M. Hauer, S. Kulp, E. Gilmore, H. Adams, R. Kopp, K. Abel, M. Call, J. Chen, A. deSherbinin, E. Fussell, C. Hay, B. Jones, N. Magliocca, E. Marino, A. Slangen and K. Warner
2019 Meeting the looming policy challenge of sea-level change and human migration. *Nature Climate Change*, 9(12):898–901.

Wrathall, D.J., J. van den Hoek, A. Walters and A. Devenish
2018 *Water stress and human migration: a global, georeferenced review of empirical research*. Land and Water Discussion Papers 11. Food and Agricultural Organization, Rome.

Yarleque, C., M. Vuille, D.R. Hardy, O.E. Timm, J. de La Cruz, H. Ramos and A. Rabatel
2018 Projections of the future disappearance of the Quelccaya ice cap in the Central Andes. *Scientific Reports*, 8(1):15564.

Zavaleta, C., L. Berrang-Ford, J. Ford, A. Llanos-Cuentas, C. Cárcamo, N.A. Ross, G. Lancha, M. Sherman and S.L. Harper
2018 Multiple non-climatic drivers of food insecurity reinforce climate change maladaptation trajectories among Peruvian Indigenous Shawi in the Amazon. *PLOS One*, 13(10):e0205714.

Zhao, C., B. Liu, S. Piao, X. Wang, D.B. Lobell, Y. Huang, M. Huang, Y. Yao, S. Bassu, P. Ciais, J.L. Durand, J. Elliott, F. Ewert, I.A. Janssens, T. Li, E. Lin, Q. Liu, P. Martre, C. Müller, S. Peng, J. Peñuelas, A.C. Ruane, D. Wallach, T. Wang, D. Wu, Z. Liu, Y. Zhu, Z. Zhu and S. Asseng
2017 Temperature increase reduces global yields of major crops in four independent estimates. *Proceedings of the National Academy of Sciences of the United States of America*, 114(35):9326–9331.

Zulkafli, Z., W. Buytaert, B. Manz, C.V. Rosas, P. Willems, W. Lavado-Casimiro, J.-L. Guyot and W. Santini
2016 Projected increases in the annual flood pulse of the Western Amazon. *Environmental Research Letters*, 11(1):1.

ASSESSING THE EVIDENCE:

CLIMATE CHANGE AND MIGRATION IN PERU

POTSDAM INSTITUTE FOR CLIMATE IMPACT RESEARCH

PIK

IOM
UN MIGRATION

EPICC
EAST AFRICA PERU INDIA CLIMATE CAPACITIES

cooperación alemana
DEUTSCHE ZUSAMMENARBEIT

Supported by:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

based on a decision of the German Bundestag

INTERNATIONAL CLIMATE INITIATIVE (IKI)