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Africa and climate change

Projecting vulnerability and adaptive capacity

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Human activities have warmed the climate 1 °C above pre-industrial levels, triggering fundamental changes in the earth's physical and social landscapes. Africa has contributed little to climate change, but is home to some of the world's harshest climates and most vulnerable populations. To navigate the risks climate change poses to Africans over the coming decades, governments must prioritise human development and harmonise economic development with climate change adaptation strategies.

Key findings

- Human activity, primarily CO_2 emissions, has already warmed the climate 1 °C above pre-industrial levels and further warming is inevitable, at least through the mid-century. 1.5 °C of warming will be reached by 2050 and is likely to be reached as early as 2030.
- As the climate warms human security will continue to be undermined by hotter mean temperatures, sea level rise and acidification, increasingly erratic rainfall patterns and more intense climate hazards.
- No society is immune to climate change, but people living at low levels of development are disproportionately vulnerable to the adverse impacts of climate change.
- Africa is home to half of the world's population of people who are extremely poor. Extremely poor populations are increasing in all of Africa's regions, but are the largest and growing the fastest in Eastern and Western Africa.
- These populations are extremely vulnerable to droughts, floods and other climate hazards, in addition to heightened food insecurity and water scarcity.
- Climate change adaptation strategies often complement development efforts and can boost resilience in the short and long term.

Recommendations

- Over the short term, African governing institutions at all levels need to prioritise adapting to the unavoidable impacts of climate change. Climate change adaptation strategies must be included in all development agendas.
- Protecting communities that are both extremely vulnerable and exposed to climate change hazards is the immediate priority. Governments at local and national levels must strengthen implementation of the Sendai Framework for Disaster Risk Reduction or risk further needless loss of life to natural disasters.
- Over the medium to long term, national governments need to integrate climate adaptation into all development strategies in order to foster resilience to climate change.
- Over the long term, Africa's national and regional governments need to balance equitable economic growth with smart environmental management.
- Local communities and their knowledge of the climate are indispensable resources as Africa confronts harsher and increasingly erratic climates.
- Adaptation and mitigation strategies must be locally or regionally specific given constant variations in communities' vulnerability and exposure to the impacts of climate change.

Introduction

In March 2018 United Nations (UN) Secretary-General António Guterres labelled climate change 'the most systemic threat to humankind.'[1] Human activity has already warmed the earth-atmosphere system 1 °C above pre-industrial levels, and is in turn destroying the climatic conditions necessary for survival. The current concentration of atmospheric carbon dioxide (CO_2), the primary greenhouse gas responsible for the warming of the climate, is unprecedented in the past few million years[2] and humans are releasing CO_2 '14 000 times faster than nature has over the past 600 000 years.'[3]

In response, the earth's physical and social landscapes are undergoing fundamental changes – many irreversible.[4] The past three decades have seen successively hotter temperatures than any other decade since 1850.[5] The atmosphere and oceans are warming, snow and ice sheets are melting and the sea is rising and more acidic than it has been for the last 300 million years.[6] Normalcy in climate behaviour is vanishing.

The impacts of climate change are already being felt around the world and natural disasters have taken centre stage. Rising surface temperatures have contributed to their increased frequency and intensity.[7] The number of natural disasters has quadrupled since 1970 to around 400 per year.[8] Storms, droughts and floods have displaced an estimated 21.5 million people per year since 2008[9] and displace three to ten times more people than conflict.[10] Natural disasters from 1998 to 2017 caused reported directed losses of US$2.9 trillion – roughly two and half times more than from 1978 to 1997 (US$1.3 billion). Africa reported losses from just 13% of disasters on the continent over this period.[11]

And further climate change is inevitable.[12] Regardless of actions taken now to cut emissions, warming will continue and climate change impacts will intensify over the next few decades owing to past emissions and inertia in the climate system.[13] The magnitude of these impacts beyond 2050, however, depends on the extent to which world leaders reduce emissions in the short term.

Should they fail and emissions continue unmitigated, warming of 4 °C above pre-industrial levels will occur by 2100.[14] In a 4 °C world, 'the limits for human adaptation are likely to be exceeded in many parts of the world, while the limits for adaptation for natural systems would largely be exceeded throughout the world.'[15] In October 2018 the Intergovernmental Panel on Climate Change (IPCC) released a landmark report warning that warming of 1.5 °C above pre-industrial levels may be reached as early as 2030. This degree of warming will cause unprecedented heatwaves, widespread food shortages and more intense storms that will intensify dramatically at 2 °C.[16] Limiting warming to 1.5 °C rather than 2 °C is possible but would require world leaders to lead a rapid transformation of the global economy as envisaged by the Paris Agreement and without historical precedent. Achieving this would require an almost unimaginable level of coordination, but human survival depends on it.

> The magnitude of climate change impacts beyond 2050 depends on world leaders

No society is immune to the impacts of climate change, but communities living at low levels of development are disproportionately affected. Africa, the hottest continent on the planet and home to over half of the world's extremely poor, is particularly vulnerable. Well aware of the threat of climate change to development, African leaders stressed the importance of climate adaptation and mitigation in Agenda 2063, the long-term vision for Africa adopted by the African Union (AU) in 2013.

African governing institutions at all levels have an important role to play in this story. Although it is the continent least responsible for climate change, Africa is home to some of the world's harshest climates and most vulnerable populations. And the forecasts presented in this report suggest that these populations will continue growing well into the future. How – or whether – African policymakers and civil society respond to the realities of climate change will have tremendous implications for the capacity of societies across the continent to adapt.

Purpose and scope

This report reviews the observed and projected impacts of climate change on Africa. It explores Africa's current development trajectory (Current Path) to 2063 and what it means for vulnerability and adaptive capacity on the continent. The Current Path is then compared to an alternative scenario, the first Shared Socioeconomic Pathway (SSP 1), titled 'Sustainability – Taking the

Green Road' (Green Road). In this scenario, Africa (and the rest of the world) undertakes rapid, sustainable economic growth, resulting in low barriers to adapting to and mitigating climate change. It concludes with recommendations for how Africa can progress more quickly towards Agenda 2063's climate change aspirations by addressing immediate vulnerabilities to climate change and increasing adaptive capacity over the long term.

Because further warming and increasingly severe climate events are unavoidable for at least the next few decades, this report focusses on Africa's vulnerability to climate change, its capacity to adapt and how this will change to 2063. To do this, it projects three proxies for vulnerability and levels of development: extreme poverty, government revenue as a per cent of gross domestic product (GDP) and access to improved water. Climate change mitigation is also reviewed given its importance for African and global futures and the mutually beneficial nature of adaptation, mitigation and development strategies.

The International Futures modelling platform

This report uses the International Futures (IFs) modelling platform. IFs is an integrated assessment model that helps us to better understand how the world around us is unfolding and allows us to identify potential points of intervention to shape future development. IFs is a highly integrated quantitative tool that projects hundreds of interacting variables across human, social, and natural systems for 186 countries to the year 2100. As a hybrid system, IFs draws from many traditional modelling techniques to form a series of algorithms that endogenize relationships in key global systems. IFs is developed and housed at the Frederick S Pardee Center for International Futures at the Josef Korbel School of International Studies at the University of Denver. The IFs tool is open source and can be found at www.pardee.du.edu.

The model uses historical data from 1960 (where available) to identify and measure trends and produce "Current Path" forecasts from 2015 (the current base year) to 2100. The Current Path is a scenario that represents a continuation of current policy choices and technological advances and that assumes no major shocks or catastrophes.[17] However, it moves beyond a linear extrapolation of past and current trends by leveraging our available knowledge about how systems interact to produce a dynamic forecast.[18]

This report draws heavily from the scientific literature on climate change. In addition to allowing for the creation of customised alternative scenarios, IFs contains a packaged set of alternative scenarios drawn from other forecasting models. Included in this set are the five Shared Socioeconomic Pathways (SSPs) – global scenarios of societal development over the 21st century (See Box 1).[19] Applying the SSPs in IFs has enabled research on how they impact the large set of variables contained in IFs and highlights the value of an interdisciplinary approach to climate research.

Africa's climates

Arid lands cover two-thirds of the African continent and the majority of the continent experiences extreme heat during much of the year. While arid lands 'are extremely diverse in terms of their land forms, soils, fauna, flora, water balances and human activities', they are characterised by inadequate and variable precipitation and excessive heat.[20]

The hyper-arid climates of the world's largest hot desert, the Sahara, cover nearly all of Northern Africa, though the coasts of Tunisia, Algeria and Morocco have Mediterranean climates.[21] The Sahel, the semi-arid transitional ecoregion extending from Senegal to Eritrea, separates the Sahara from the diverse climates of sub-Saharan Africa.

> Further warming and increasingly severe climate events are unavoidable for the next few decades

Central Africa is blanketed by the rainforests of the Congo Basin, which stretch from Equatorial Guinea, Gabon and Cameroon across the Democratic Republic of Congo to overlap with the African Great Lakes Region.

The rainforest also extends into Western Africa, the African region with the most climatic diversity. The rainforest's humid and moist-humid climates stretch westward from coastal Nigeria to Guinea-Bissau and Côte d'Ivoire. Moving northward, the rainforests transform into the semi-arid, arid and hyper-arid climates of the savannah, the Sahel and the Sahara in Mali, Burkina Faso, northern Nigeria and Niger.

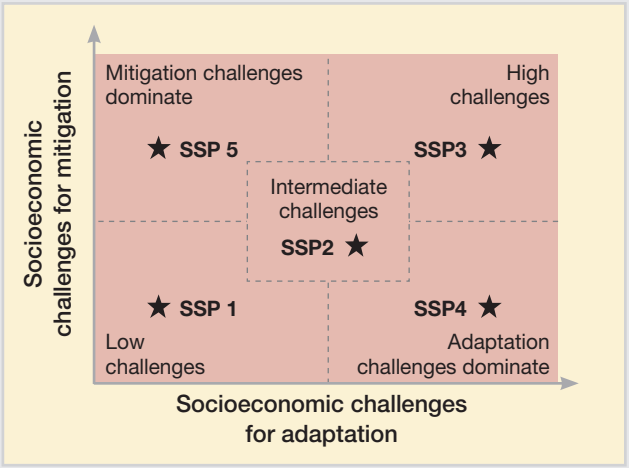
The arid climates of the savannah and deserts predominate in Eastern and Southern Africa. The Namib

Box 1: The scenario framework for climate change research

Recognising the importance of long-term scenarios in researching climate change, the modelling community developed a scenario framework for integrating socioeconomic, climate and policy futures. The framework comprises the SSPs and the Representative Concentration Pathways (RCPs), in addition the Shared Policy Assumptions, which are not reviewed in this report.

The SSPs are pathways of global socioeconomic development.[22] Each SSP is defined by whether it presents high or low challenges to climate mitigation and adaptation.[23] As such, the SSPs help 'characterize the range of uncertainty in mitigation … [and] adaptation efforts that could be undertaken to prepare for and respond to the climate changes and impacts associated with those pathways.'[24] SSPs 1, 2 and 3 are scenarios in which challenges to mitigation and adaptation co-vary, with SSP 1 representing low challenges; SSP 2 representing a 'middle-of-the-road' scenario; and SSP 3 representing high challenges. In SSP 4, challenges to adaptation are high while those to mitigation are low. The inverse applies to SSP 5.

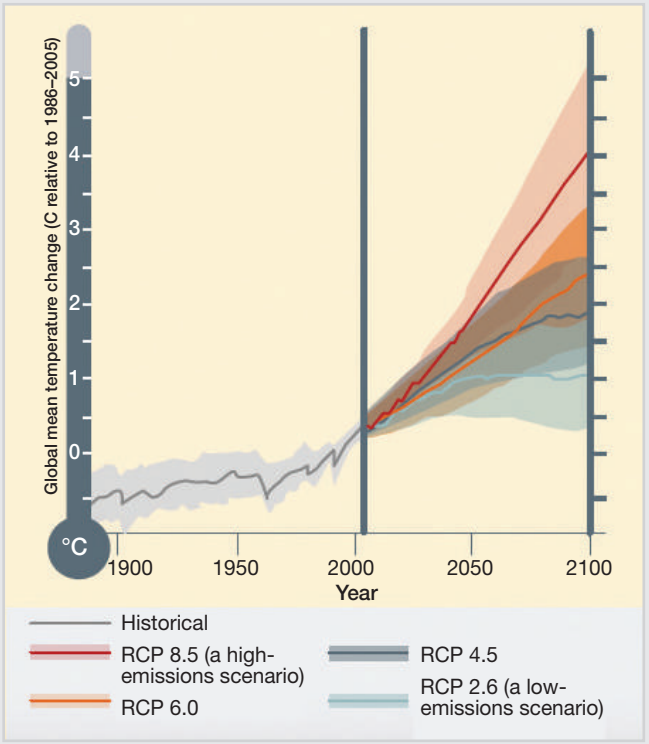
Figure 1: The 'challenge' space for the SSPs[25]



The five RCPs are global climate scenarios over the 21st century that show the results of different levels of greenhouse gas emissions. RCP 1.9 is the lowest emissions scenario in which warming is limited to 1.5 °C, the Paris Agreement goal. RCP 8.5 is the highest emissions scenario.[26]

Figure 2 shows observed warming and projected warming under each of the RCPs. In all of the scenarios there will be a higher concentration of CO_2 in the atmosphere by 2100 than there is today. In addition, warming will be more or less the same in all of the scenarios over the next few decades.

Figure 2: Observed warming and projected warming under the RCPs



Source: ODI and CDKN, The IPCC's Fifth Assessment Report: what's in it for Africa?, 2014, https:// cdkn.org/resource/highlights-africa-ar5/?loclang=en_gb.

Table 1 shows how likely each RCP scenario is under each of the SSPs. SSP 2 has a 68% chance of being associated with RCP 6.0, while SSP 3 is most likely (50%) to be associated with RCP 6.0. SSP 4 is also most likely to associate with RCP 6.0 (56%), while SSP 5 is the only scenario associated with RCP 8.5. SSP 1 has a 90% probability of being associated with either RCP 4.5 or 6.0.

Table 1: SSP and RCP probability matrix[27]

	RCP 2.6	RCP 4.5	RCP 6	RCP 8.5
SSP 1	9%	45%	45%	0%
SSP 2	0%	9%	68%	23%
SSP 3	0%	17%	50%	33%
SSP 4	0%	37%	56%	7%
SSP 5	0%	7%	37%	56%

On a business-as-usual path in which emissions continue unmitigated, the world is heading towards warming of 4 °C above pre-industrial levels by 2100. This would mean that we are on the path of the two highest emissions scenarios, RCP 6 and RCP 8.5.

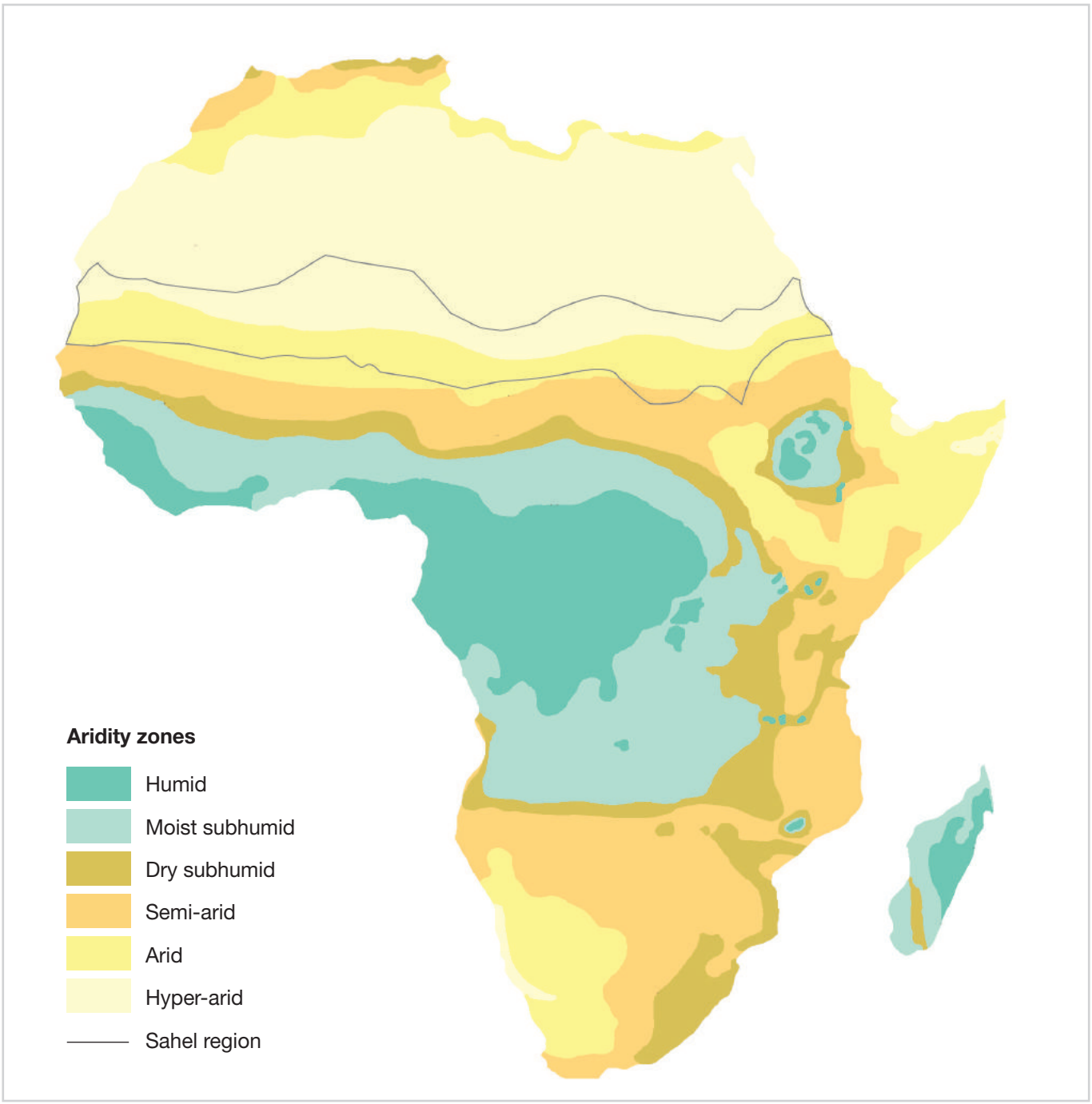
and Kalahari deserts span Namibia and Botswana, while the Danakil Desert extends from Ethiopia to Eritrea and Djibouti.

Climate change in Africa

Observed impacts

Accelerated warming of the earth and its climate have already harmed livelihoods and water and food security in Africa. Land surface temperatures across most of Africa's land mass have risen by 0.5 °C to 2 °C over the last 50 to 100 years.[28] In July 2018 the city of Ouargla in the Algerian Sahara Desert experienced the hottest temperature ever reliably recorded in Africa: 51.3 °C.[29] Although this record temperature cannot be directly attributed to climate change, it supports the overwhelming scientific consensus that the earth-atmosphere system is warming quickly due to human

Figure 3: Africa's climates[30]



activity.[31] Sea levels have risen, causing saltwater to infiltrate the freshwater systems people rely on for drinking water and agriculture. Saltwater intrusion has already impacted the Nile Delta, which produces food for 80 million Egyptians.[32]

These impacts have contributed to the increased frequency and intensity of natural disasters and magnified existing stress on water and food availability, especially in the arid lands that cover most of the continent.[33] Eastern Africa has experienced increased droughts and storms over the last 30 to 60 years, although whether this was caused by anthropogenic climate change or natural climatic variability is unclear.[34] Warmer mean temperatures in East Africa have contributed to the increased incidence of malaria in parts of the region.[35]

Climate change has also harmed wheat and maize production and the productivity of Great Lakes fisheries and fruit-bearing trees in the Sahel.[36] Ocean acidification and warming has damaged marine ecosystems in the Mozambique Channel and rivers and lakes in a large swathe of south-eastern Africa (across Mozambique, Tanzania, Malawi, Zambia and Zimbabwe), while atmospheric warming has affected the incidence and intensity of floods and droughts in the region.[37]

> Warmer temperatures have contributed to the increased incidence of malaria in East Africa

West Africa in particular has suffered an increasing number of extreme rainfall events over the past 50 years, though whether climate change has caused this is unclear.[38] Historic floods in Nigeria in 2012 killed nearly 400 people and displaced another 2 million people.[39] Floods in Nigeria have since resulted in hundreds of deaths and displaced hundreds of thousands of people, with nearly 200 being killed by floods so far this year.[40]

Projected impacts

Climate change is projected to continue undermining livelihoods in Africa through the rest of the century and beyond. Average temperatures in Africa will rise faster than the global average.[41] Africa's climates will generally become more arid, which will compromise food and water security. However, Central and Eastern Africa will experience heavier rainfall, especially after mid-century, which will likely increase the incidence and spread of water- and vector-borne diseases.[46] Average sea-level rise is projected to reach approximately 30 cm by 2050 and between 30 cm and 1.8 m by 2100 (then rising an additional 30 cm or more each decade after).[47]

The IPCC has noted that the Sahel and tropical Western Africa are 'climate change hotspots.'[48] The two regions are projected to experience unprecedented climates around the late 2030s to early 2040s – earlier than anywhere else on earth.[49] In the Sahel, one of the most environmentally degraded areas on earth, average temperature increases are projected to be 50% higher than the global average.[50] The FAO estimates 6 million people are severely food insecure in the region and that 1.6 children are at risk for severe acute malnutrition.[51] Ongoing armed conflict is compounding these crises.

Northern Africa will experience extreme heatwaves, flooding owing to sea-level rise and food shortages over the next few decades. Northern Africa is already dependent on food imports to feed its population and most agriculture is rain-fed. Projected declines in precipitation and increases in average temperatures will

Box 2: Anthropogenic climate change versus natural climatic variability

The latest scientific evidence has found that human activities (primarily the burning of fossil fuels and subsequent release of CO_2) have caused all global warming since 1970.[42] However, there is natural variability in the climate system that is exacerbated by long-term global warming.

The El Niño–La Niña cycle is the most significant contributor to short-term, natural variations in climate.[43] El Niño is a climate event that causes the Equatorial Pacific to become hotter than usual, producing extreme weather events and oftentimes heat records around the world. Conversely, La Niña is an event in which there are colder-than-average temperatures in the Equatorial Pacific, also resulting in extreme weather events globally and temperatures below the global warming trend line.[44]

The climate has undergone major global changes in the past owing to external events such as changes in the earth's orbit and volcanic eruptions, but long before modern humans existed.[45]

reduce agricultural productivity and threaten livelihoods. Recent studies indicate that Tunisia, for example, can expect 10–50% reductions in wheat production at 2 °C of warming.[52]

Climate change will also exacerbate water shortages in Northern Africa, but population growth, increased reliance on irrigation and other land use changes are also expected to play a significant role.[53] Climate change is also projected to cause a decline in groundwater recharge in hyper-arid climates such as the Sahel, the Horn of Africa and parts of Southern Africa.[54]

Cities in Northern and Western Africa and along the Sahel, which are growing rapidly, will face extreme heat during summers, where there will be more than three consecutive months with average temperatures of 35° C.[55] Western Africa's cities in particular will have some of the largest urban populations of extremely poor people in the world.[56] Major informal settlements home to millions of people will continue to grow, largely without any forward planning or basic infrastructure, often on degraded land or close to coasts or rivers.

> The Sahel and tropical West Africa are projected to experience unprecedented climates earlier than anywhere else

Recent studies identified Egypt, Tunisia, Morocco and Libya as the African countries with the largest populations exposed to sea-level rise. In Morocco, for example, over 60% of the population live in coastal cities.[57] Alexandria, Benghazi and Algiers are especially vulnerable to sea-level rise of as little as 0.2 m, which is likely to happen by mid-century.[58]

In sub-Saharan Africa, heightened food insecurity is expected to be the most severe impact of climate change owing to increasing aridity and the limited adaptive capacity of small farmers. Warming of 1.5 °C is expected to cause farmers to lose between 40 and 80% of cropland for maize, millet and sorghum to drought and aridity by the 2030s and 2040s.[59] Warming of 4 °C or higher – a nearly apocalyptic scenario – is projected to cause a 30% decrease in annual precipitation and 50–70% decrease in groundwater recharge rates in Southern and Western Africa.[60]

The options: adaptation, development and the role of mitigation

In the face of these projected impacts of climate change, there are two broad, complementary paths of action that policymakers, societies and individuals can take: adapt and mitigate (See Box 3).[61] Both adaptation and mitigation are limited and are most effective when implemented together and no single strategy is appropriate across all social and environmental settings. Rather, the IPCC has stressed that responses to climate change must be locally specific and focus on building resilience at the community level. This involves supporting autonomous adaptation strategies, respecting human rights and cultural and ethical considerations and promoting the participation of youth, women and the poor in adaptation policy development and implementation.

Given that climate change will inevitably worsen until at least mid-century, adapting to climate change is the immediate task at hand for Africa. Fortunately, adaptation practices can complement development and are in fact essential to sustainable development.[62] Acknowledging the positive interlinkages between adaptation and development, African leaders expressed in Agenda 2063 the aspiration that 'Africa shall address the global challenge of climate change by prioritizing adaptation in all our actions ... for the survival of the most vulnerable populations ... and for sustainable development and shared prosperity.'[63]

There are low-regrets strategies (practices that would produce net social and economic benefits in all future climate change scenarios) African leaders may implement now to realise this aspiration, the most fundamental of which is strengthening human development, especially in sub-Saharan Africa. Improving access to education and healthcare and basic service delivery (i.e., of clean water and sanitation facilities) will build resilience to climate change in all future climate scenarios. Granting poor communities access to and control over land and other resources is also critical to alleviating poverty and supporting human development.[64]

Improving disaster risk management is also fundamental to reducing the vulnerability of communities who are exposed to climate change risks. Although the AU's 2004 Africa Regional Strategy for Disaster Risk Reduction demonstrated Africa's commitment to be a global leader in managing disasters, thousands of lives are lost

Box 3: What is adaptation and mitigation?

Climate change adaptation refers to actions to manage inevitable climate change impacts by addressing short-term vulnerabilities and risks.[65] For example, Tanzania in June completed 2 400 metres of sea walls in an effort to protect its vulnerable communities, infrastructure and resources from rising sea levels. This represents a 'hard' infrastructure adaptation strategy, which are usually very costly.

Climate change mitigation refers to actions to limit or reduce the magnitude or rate of anthropogenic climate change over the long term.[66] Most of the benefits of mitigative strategies taken now and in the near term will emerge during the second half of the century.[67] The Paris Agreement signified a global effort to mitigate the future impacts of climate change by reducing greenhouse gas emissions now. However, reforestation and the protection of peatlands, mangroves and other environments that capture and store atmospheric CO_2 also are mitigation strategies.[68]

needlessly to floods, droughts and other climate events each year on the continent. Improving implementation of this regional strategy and the Sendai Framework for Disaster Risk Reduction is the best way to prevent further loss of life. Local urban governments are critical to these efforts as Africa continues to urbanise rapidly.

In addition, the IPCC has highlighted natural resource management practices as a low-regrets strategy to adapt to climate change and promote development.[69] Natural resource management harmonises adaptation and development efforts and build resilience to climate change. Natural regeneration of local trees in the Sahel is an example of a natural resource management strategy to combat desertification: In Niger and Burkina Faso, herders and farmers have selected and protected small native trees to maturity, sustainably creating resilient and productive landscapes (and livelihoods) in previously extremely degraded environments. In Malawi and Zambia, an initiative for restoring degraded soil by combining nitrogen-fixing trees with mineral fertilisers has dramatically boosted yields, resulting in income generation and enhanced food security.[70] Key to the success of these initiatives was the integration of local stakeholders, specifically of rural and indigenous communities.[71] Indeed, local communities and their knowledge of the climate will be indispensable resources as Africa confronts harsher and increasingly erratic climates. Moreover, these strategies must be locally or regionally specific, given constant variations in vulnerability and exposure.[72]

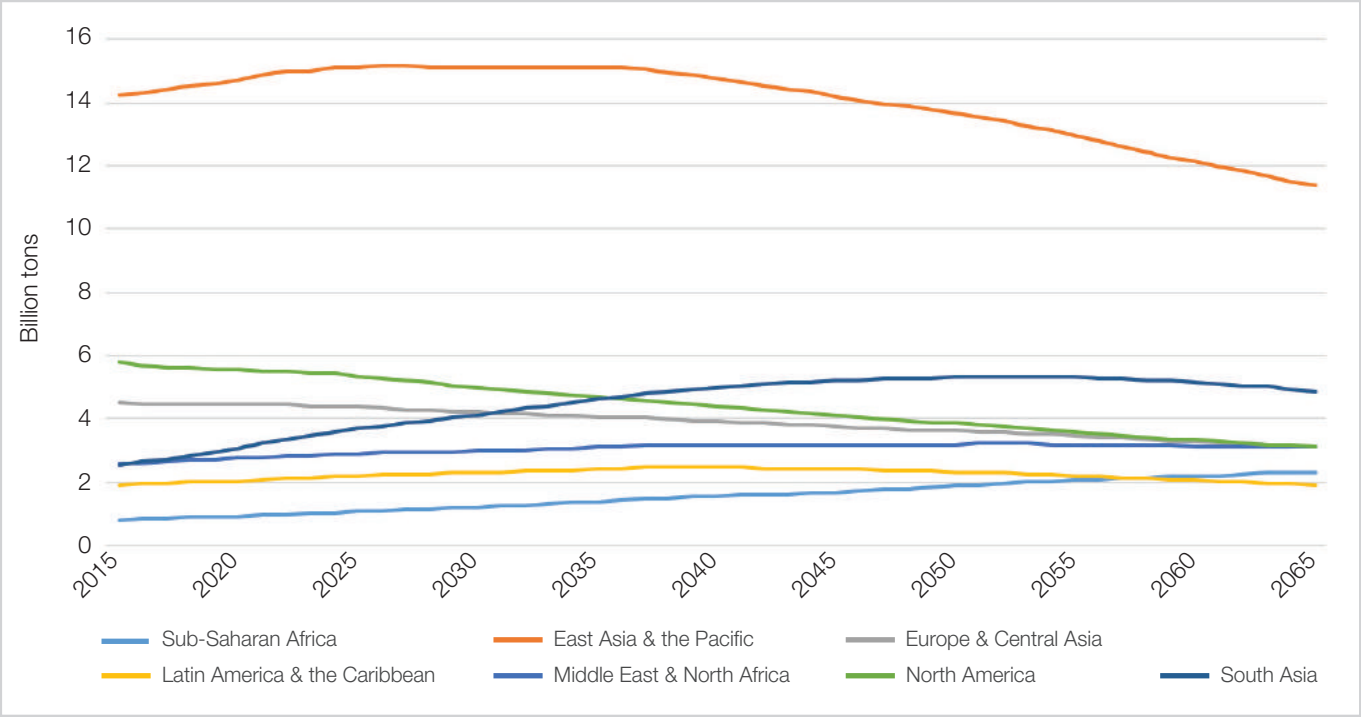
As well as recognising the importance of adapting to climate change, the AU articulates their commitment to mitigating climate change in Agenda 2063: 'Africa will participate in global efforts for climate change mitigation that support and broaden the policy space for sustainable development on the continent.'[73] Indeed, over the long term, it is in Africa's best interest to move towards sustainable development paths that address Africans' current needs without compromising future generations' ability to meet their own needs.[74] This involves taking advantage of Africa's vast renewable energy opportunities and pursuing land-based mitigation strategies such as reforestation.

Natural resource management practices harmonise adaptation and development efforts to build resilience

Africa accounts for a small share of global CO_2 emissions (4%) and has among the lowest per capita emissions rates in the world (See Figures 4 and 5). Africa's per capita energy demand is equivalent to three barrels of oil – one fifteenth of North America's average of over 45 barrels. (If we exclude South Africa, sub-Saharan Africa's average energy demand is a mere 1.7 barrels of oil per capita). However, Africa's emissions will grow in line with population growth, increases in income and urbanisation trends. While dwarfed by regions like East Asia & the Pacific and North America, this projected increase in emissions will contribute to further warming and worsen the future impacts of climate change. By 2060, sub-Saharan Africa is projected to release more CO_2 into the atmosphere per year than Latin America and the Caribbean (See Figure 4).

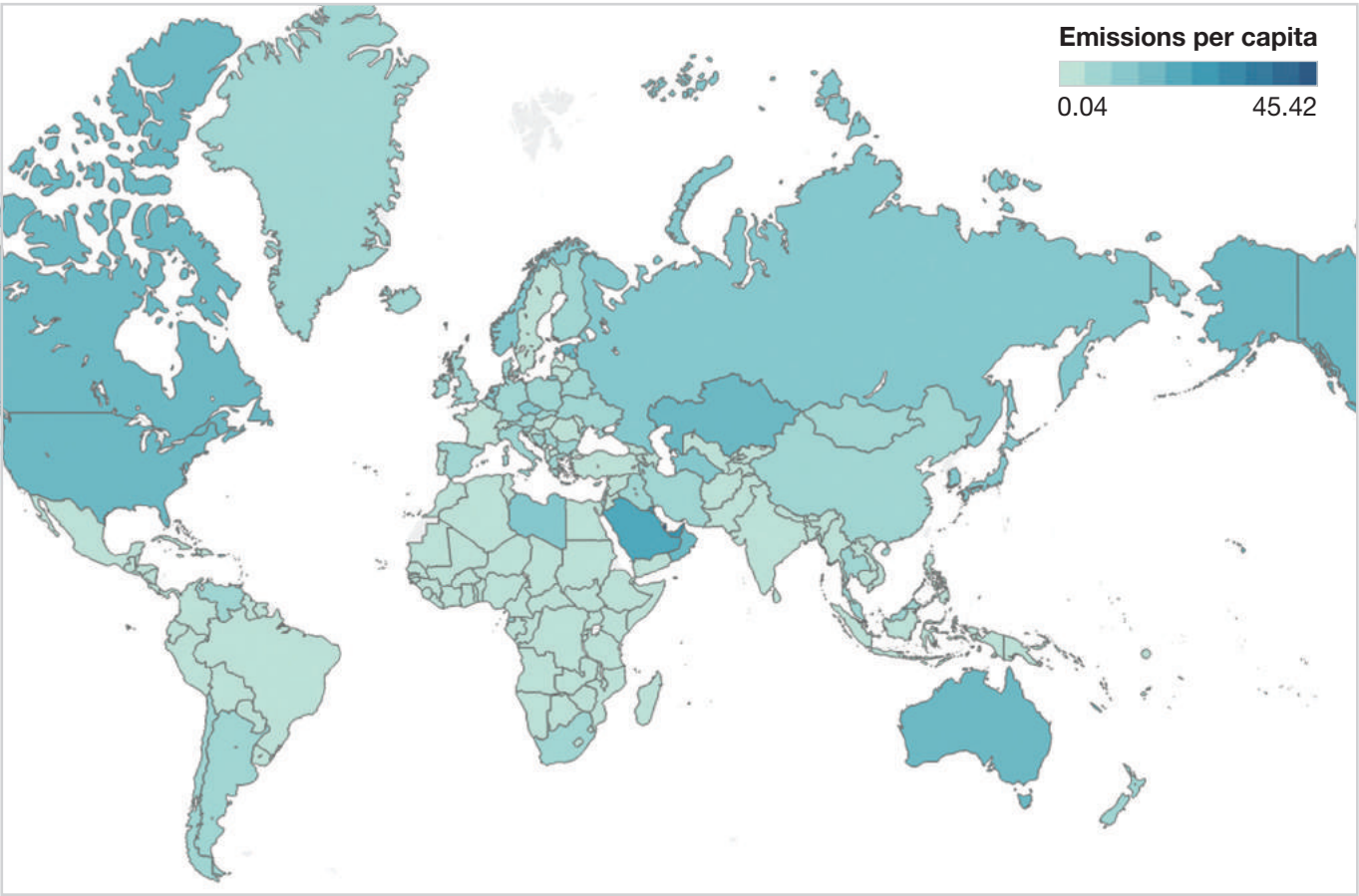
Figure 6 shows that Africa's energy demand, currently the lowest in the world, is projected to rise steadily as the population grows, surpassing that of Latin America and the Caribbean and the Middle East and North Africa around mid-century. This will increase pressure

Figure 4: Carbon dioxide emissions, world regions[75]



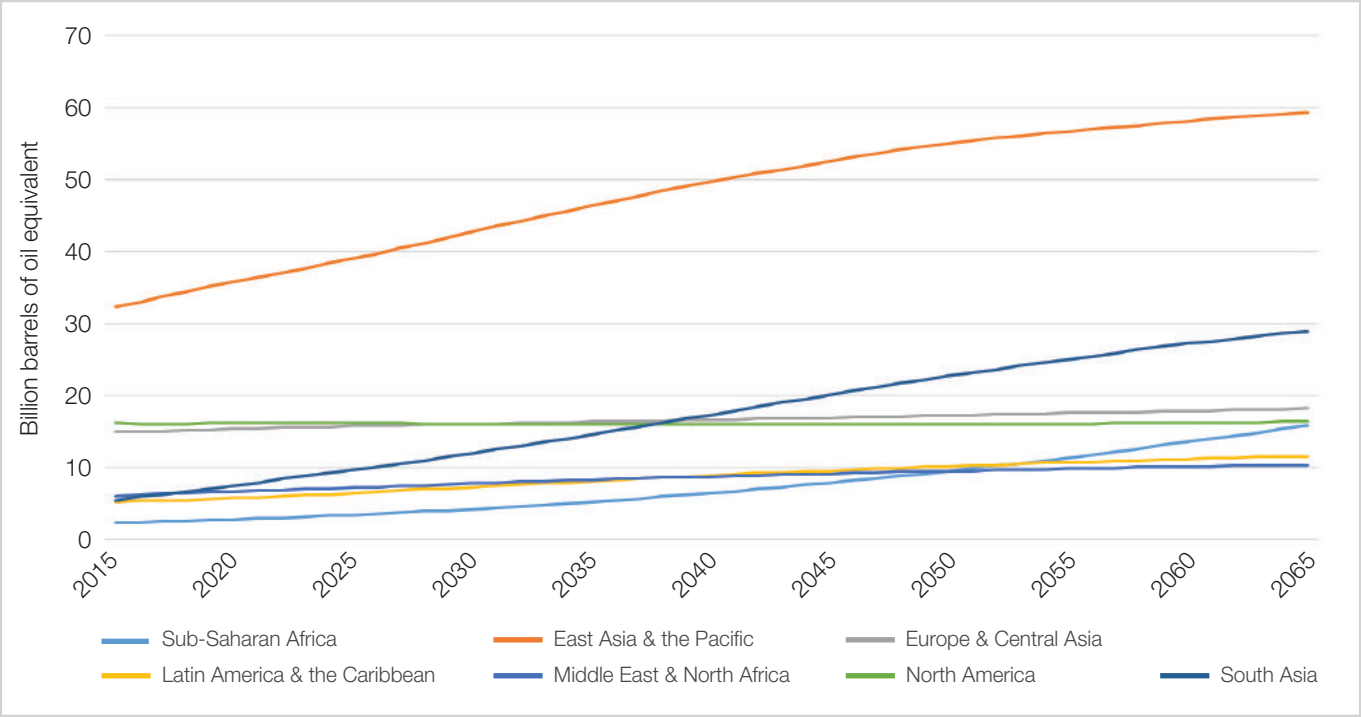
Source: Carbon Dioxide Information and Analysis Center

Figure 5: Carbon dioxide emissions per capita by country, 2014 (metric tons per capita)



Source: Carbon Dioxide Information Analysis Center

Figure 6: Energy demand



Source: IFs v 7.36 initialised from International Energy Agency data

on governments in Africa to expand existing sources of energy or find new ones.

Africa's abundant fossil fuels offer one solution for African countries as they struggle to meet rising energy demand. However, Africa also has vast potential for renewable energy, which offer a complementary source of energy to fossil fuels. Though importing technology for renewable energy is still expensive, options for domestic production could become more cost competitive in the short to medium term. When this happens, renewable energy will replace fossil fuels as the more strategic way of addressing immediate development needs while mitigating the effects of climate change in the second half of the century and beyond.

Projecting vulnerability and adaptive capacity in Africa

Though development outcomes in Africa are improving, Africa's capacity to adapt to climate change is low and its vulnerable populations are growing. Low levels of development and generally weak state capacity, especially in sub-Saharan Africa, pose formidable obstacles to adapting to climate change.[76] Extreme poverty, infrastructure deficits and poor state capacity remain pervasive issues and render millions of Africans highly vulnerable to climate change. On the Current Path, the number of people in Africa living in extreme poverty will continue rising to 2040, as will the number of people without access to an improved source of drinking water.

> Africa's capacity to adapt to climate change is low and vulnerable populations are growing

Africa has an extremely poor population of roughly 490 million people per the World Bank definition of extreme poverty as earning less than US$1.90 per day. Poor populations are disproportionately vulnerable to climate-related disasters and have little to no capacity to adapt. The UN and other intergovernmental bodies are increasingly sounding the alarm over how climate change undermines poverty reduction efforts. The IPCC has asserted 'climate change will exacerbate and further entrench poverty"[77] and the World Bank calculated that geophysical and climate-related disasters put an additional 26 million people into poverty globally each year.[78]

Box 4: What is adaptive capacity, vulnerability and exposure?

'Adaptive capacity refers to the potential, capability, or ability of a system to adapt to climate change … effects or impacts. Adaptive capacity greatly influences the vulnerability of communities and regions to climate change effects and hazards.'[79] Leading climate research contends that adaptive capacity is broadly determined by levels of development and state capacity – particularly of local governments.[80]

Vulnerability is the '[d]egree to which a system is susceptible to injury, damage, or harm … the vulnerability of a given system or society is a function of its physical exposure to climate change effects and its ability to adapt to these conditions.'[81] Moreover, the IPCC notes that '[t]he poor are more vulnerable to natural disasters than the rich because they live in more hazardous places, have less protection, and have less reserves, insurance, and alternatives.'[82]

'Exposure is the presence of people; livelihoods; infrastructure; ecosystem services and resources; and economic, social, and cultural assets in places that could be adversely affected by a climate hazard. For example, a population that is concentrated near a coastline has potentially high exposure to the impacts of sea level rise, while one that is heavily concentrated in urban areas has potentially high exposure to urban heatwaves.'[83]

Africa's extremely poor population is projected to grow for another thirty years, peaking at 590 million by 2040, before falling to around 390 million by 2063. These forecasts exclude those who may fall into poverty owing to natural disasters, rising temperatures and conflict. Nearly all of this population is in sub-Saharan Africa.

Western and Eastern Africa are home to the Africa's largest regional populations of people living in extreme poverty. Their combined extremely poor populations (an estimated 310 million people in 2018) are more than double the number of extremely poor people in the rest of the continent (an estimated 150 million people in 2018). (See Figure 7).

WESTERN AFRICA'S EXTREMELY POOR POPULATION OF

165 million

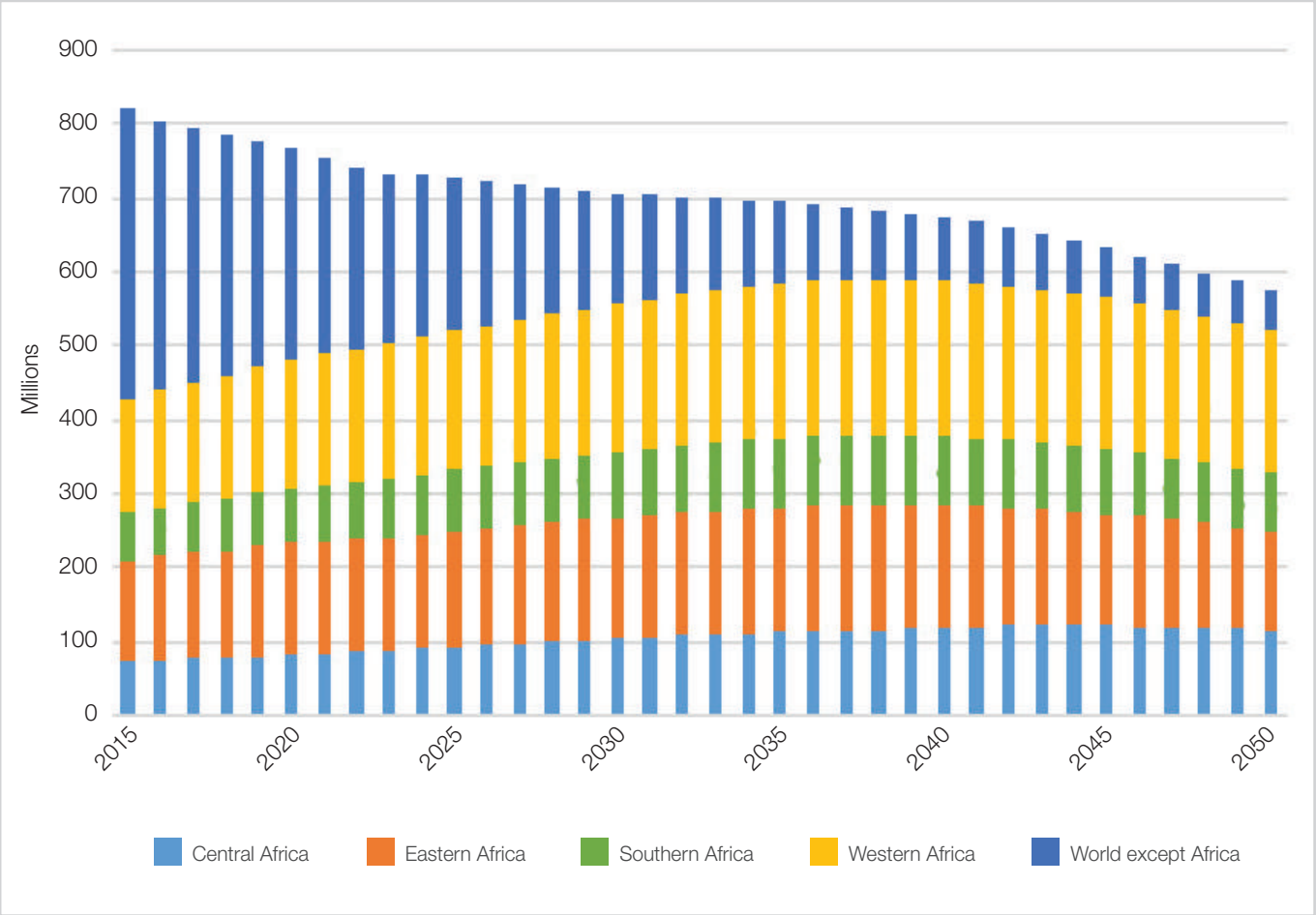
IS GROWING AND IS PROJECTED TO PEAK AROUND 2040 AT ROUGHLY

210 million

Western Africa currently has and will continue to have more people who are highly vulnerable to the impacts of climate change than any other African region. The region's extremely poor population of 165 million is growing and is projected to peak around 2040 at roughly 210 million before decreasing to 160 million by 2063. Nigeria alone is home to two-thirds (103 million people) of Western Africa's extremely poor population.

Western Africa has a huge variety of climates, ranging from humid rainforests to hyper-arid desert; in a sense, the region is a microcosm of the climatic diversity of the entire continent. Owing to this climatic diversity, the 165 million Western Africans living in extreme poverty face threats ranging from coastal

Figure 7: Number of people in extreme poverty



Source: IFs v 7.36 initialised from UNPD data

flooding, extreme heatwaves with average summer temperatures exceeding 35 °C to more frequent and intense droughts. Growing urban poor populations, especially in coastal cities, are especially vulnerable to flooding and extreme heat. The risks include major loss of life from flooding, deepening food insecurity as a result of diminishing agricultural productivity and increasing likelihood of mass migration and conflict. Pressure on governing institutions at all levels to respond to major climate-related humanitarian crises in the region will intensify through the foreseeable future.

In Eastern Africa, the countries with the largest populations of extremely poor people are Ethiopia (25 million), Tanzania (25 million) and Madagascar (20 million). While poverty in Tanzania and Ethiopia is projected to decline in next few decades, it is expected to increase until around mid-century in Madagascar. More concerning is Somalia's rising poverty rate from an already high 60% in 2015 to 80% by mid-century.

Somalia's extremely poor population of around 10 million is projected to continue growing for the next several decades, to reach over 40 million people by 2070, when it will be four times the size of Madagascar's. This forecast suggests that the Horn of Africa will continue to depend on the international community for food, healthcare and other basic necessities as droughts intensify and agricultural productivity falls.

> Pressure on governments to respond to major climate-related crises in Western Africa will intensify

In Central Africa, however, nearly 60% of the population is living in extreme poverty – by far the highest regional poverty rate in Africa. On the Current Path, this population is projected to grow from an estimated 80 million in 2018 to around 120 million before mid-century. The Democratic

Republic of Congo alone is home to nearly 80% of the region's extremely poor.

Africa's generally poor water infrastructure is also concerning in the context of rising temperatures, increasingly variable rainfall and rising sea levels. Climate change is projected to significantly reduce renewable surface and ground water in the dry subtropical climates that cover Northern Africa and parts of Southern Africa. Droughts will become more frequent and the quality and quantity of surface and ground water will be compromised.[84] Communities who rely upon unimproved sources of drinking water,[85] such as untreated surface water (e.g., lakes, ponds and rivers) and unprotected springs and wells are disproportionately affected by these developments.[86]

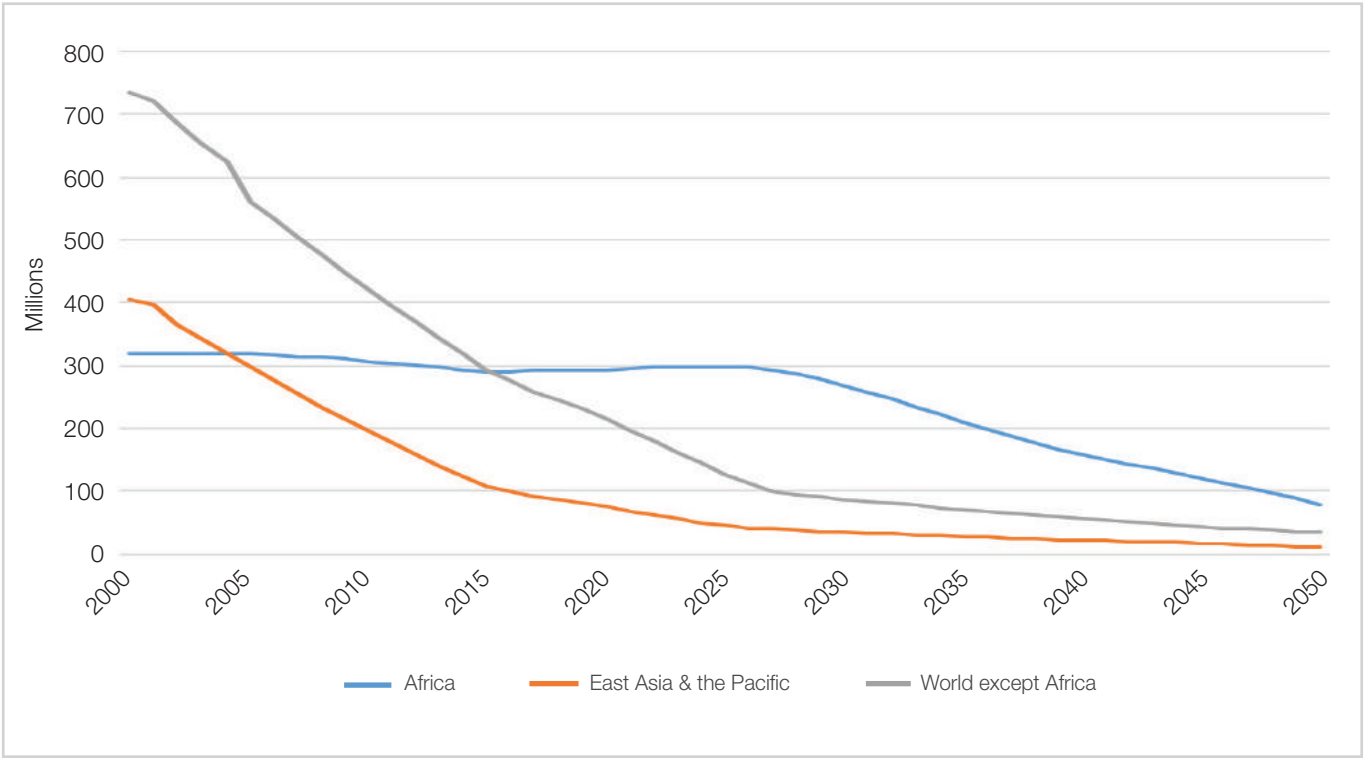
An estimated 290 million people in Africa are living without access to improved water owing to poor and insufficient physical water infrastructure – a consequence of poor governance. This means that half of all people globally who rely on unimproved water for drinking are in Africa. On the Current Path, the number of people without access to improved water is projected to grow for the next five to 10 years in all African regions except Northern Africa, although the region will face increasing water scarcity and likely deteriorating water quality as well.[87]

Box 5: What is improved water?

The WHO/UNICEF Joint Monitoring Project for Water Supply, Sanitation and Hygiene (WHO/UNICEF JMP) defines '[i]mproved drinking water sources [as] those which by nature of their design and construction have the potential to deliver safe water.'[88] Improved drinking water sources 'include piped supplies (such as households with tap water in their dwelling, yard or plot; or public standposts) and non-piped supplies (such as boreholes, protected wells and springs, rainwater and packaged or delivered water).'[89]

WHO/UNICEF JMP defines unimproved water sources as unprotected wells and springs and water taken directly from lakes, rivers, dams, ponds, streams, canals and irrigation canals.[90]

Figure 8: Number of people without access to improved water



Source: IFs v 7.36 initialised from WHO/UNICEF Joint Monitoring Programme data

Average rates of access to improved water are projected to modestly improve in Africa in the coming decades, but not fast enough. On the Current Path there will still be 270 million people lacking access to improved water by 2030 and around 80 million by mid-century.

Eastern Africa is particularly concerning in terms of insufficient water infrastructure. Although climate change is expected to place the most stress on water scarcity in the semi-arid regions of Northern and Southern Africa, Eastern Africa is home to 30% (112 million people) of the continent's population without access to improved water. This population is expected to grow for another decade before falling to around 70 million people by 2050 and 34 million by 2060. Despite this decline, Eastern Africa's population without access to improved water is projected to make up nearly half of the continent's total population without access to improved water by 2060.

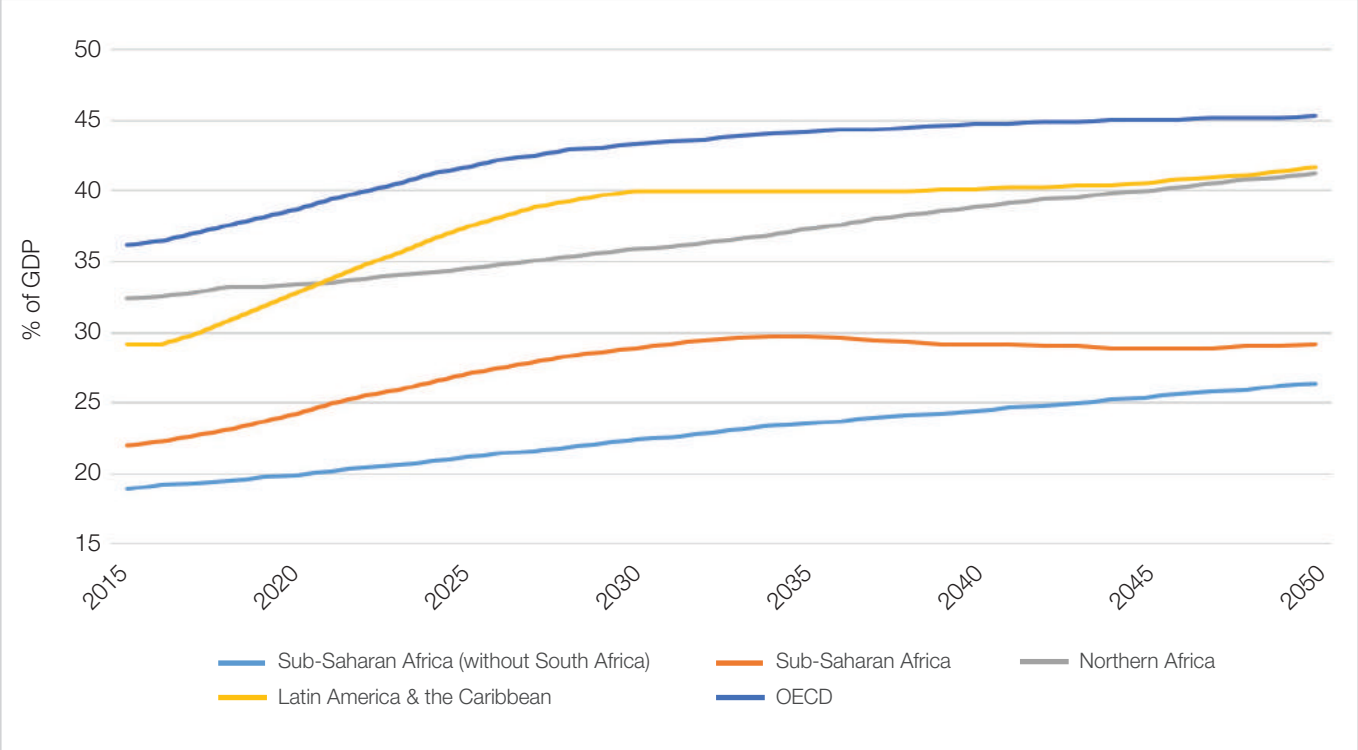
Poor state capacity in Africa also challenges development and renders adapting to climate change more difficult than in states with greater capacity.[91] Effective institutions are necessary to identify climate change hazards, design adaptation strategies and implement them across communities with highly variable climate, economic and social conditions.

A core component of capacity is the mobilisation and use of revenues. On average, government revenues comprise around one fifth of GDP in sub-Saharan Africa (excluding South Africa). Both Northern Africa and Latin American and the Caribbean have revenue shares averaging around 30% while Organisation for Economic Co-operation and Development (OECD) countries average approximately 35%, reflecting stronger state capacity.[92] While masking regional variability, sub-Saharan Africa's low revenue shares are expected to grow but remain far below those of countries in North Africa. (See Figure 9).

> Eastern Africa is home to 30% of the continent's population without access to improved water

Net foreign aid receipts currently account for around one-fifth of government revenue in sub-Saharan Africa, suggesting that the region's capacity for resource mobilisation is poorly developed.[93] Africa also struggles to use these effectively, indicated by its score of 1.7 in the World Bank's government effectiveness index in 2015,

Figure 9: Total government revenue



Source: IFs v 7.36 initialised from IMF data

which ranges from 0 (lowest effectiveness) to 5 (highest effectiveness). This compares unfavourably to South Asia's 2, Latin America's 2.4 and North America's 4.1.

Fostering sustainability: Africa's development on the Green Road

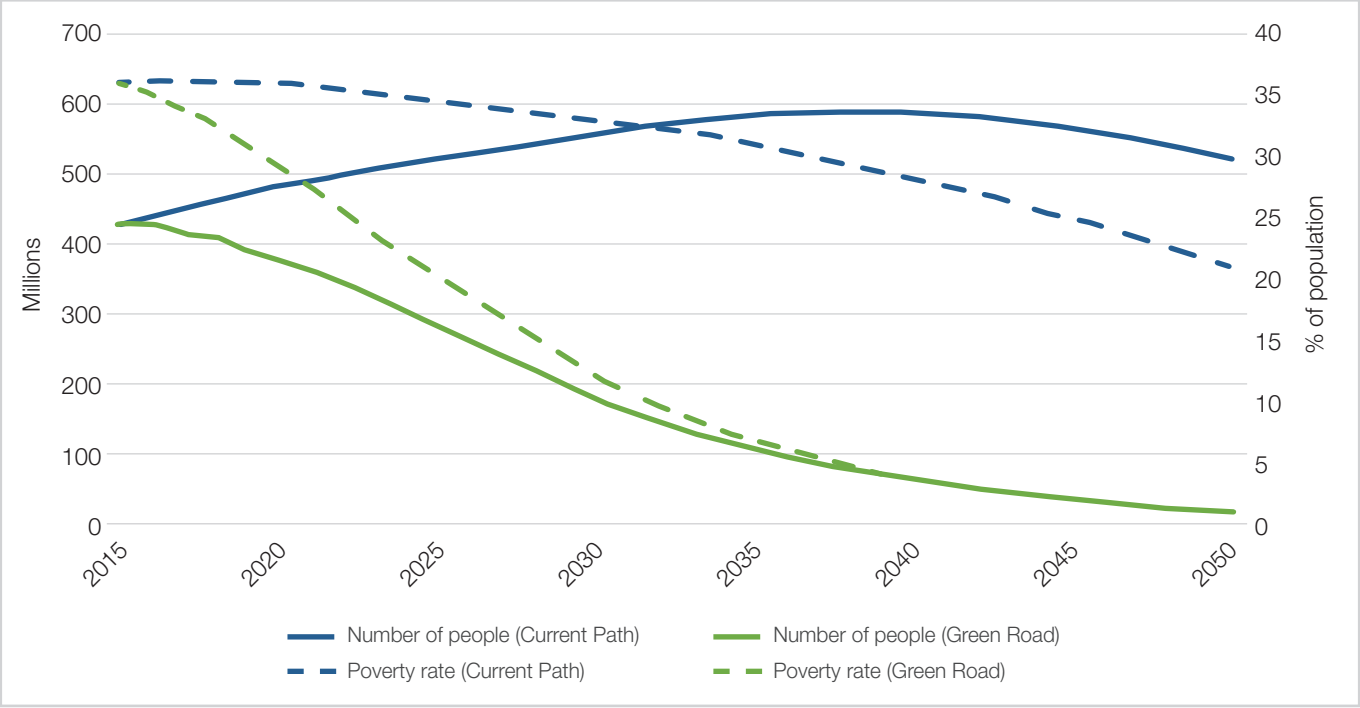
The above forecasts show that on the Current Path, Africa's faces formidable challenges to adapting to climate change. On Africa's current trajectory, the number of people living in extreme poverty in Africa is projected to rise for decades before beginning to decline. State capacity remains low and governments continue to struggle to provide basic services like improved water.

Conversely, in the Green Road scenario (or SSP 1), Africa is in a much better position to adapt to the projected impacts of climate change. In this scenario, governing institutions at global to local levels prioritise inclusive development, environmental sustainability and investment in human and social capital. Equity and sustainability as envisioned in the Sustainable Development Goals eclipse economic growth as the priority of national and international development agendas. As a result, the number of people in Africa vulnerable to climate change is substantially smaller than on the Current Path.[94]

On the Green Road, Africa's extreme poverty rate falls dramatically to 12% by 2030 – a roughly 65% drop from 2015 – and poverty is effectively eliminated (below 3%) by mid-century owing to rapid, equitable economic growth. Conversely, 1 out of 3 Africans is projected to be living in extreme poverty by 2030 on the Current Path, and by 2050, 1 out of 5 (see Figure 10). Achieving the rapid rate of poverty reduction would be extremely difficult: between 1993 to 2010, sub-Saharan Africa reduced its extreme poverty rate by about one fifth, according to the World Bank (from 59% to 47%). However, it is possible: China (the most cited example of rapid poverty reduction) cut its extreme poverty rate by 70% between 1990 and 2005 (from 67% to 19%).

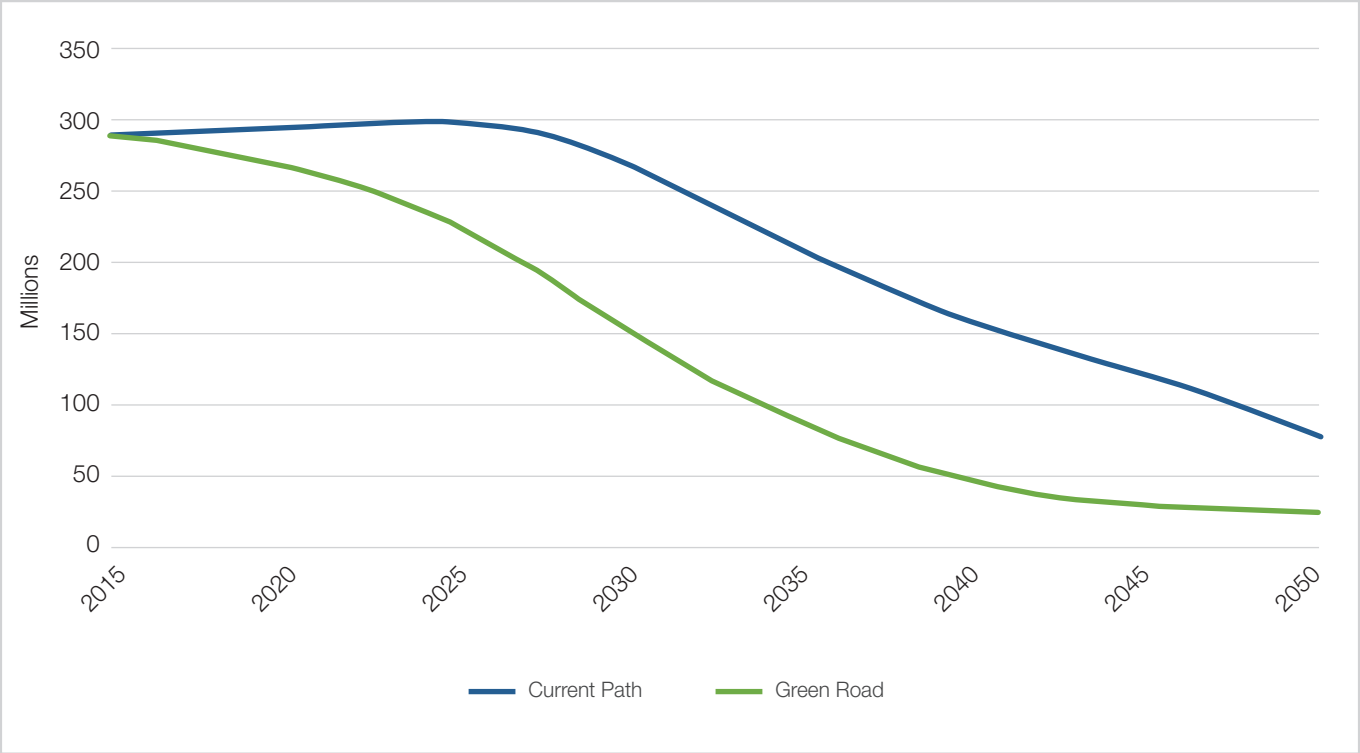
Africa's projected rates of access to improved water are also substantially better on the Green Road than on the Current Path, translating into roughly 100 million fewer people without access to improved water by 2030. Accomplishing this would require Africa's average annual growth rate in improved water access to be nearly twice as fast as it is on the Current Path (1 per cent per year versus 0.6 per cent per year). This is an achievable goal, but would require substantial investments in improving water infrastructure across the continent, particularly in sub-Saharan Africa.

Figure 10: Extreme poverty, Africa



Source: IFs v 7.36 initialised from IMF data

Figure 11: Number of people without access to improved water, Africa



Source: IFs v 7.36 initialised from JMP/WHO data

Moving towards the developmental path the Green Road represents requires African countries to increase investments in human development, namely in education, healthcare and basic infrastructure (i.e, water and sanitation). In addition to being indispensable to boosting communities' capacity to adapt to climate change, better educational outcomes and improved healthcare, especially of family planning services, lead to a slower population growth rate. On the Green Road, Africa's population reaches only two billion by 2060, compared to 2.8 billion on the Current Path.

Population size matters immensely to climate change. Africa's large and rapidly growing populations place enormous stress on environmental systems and compound the adverse effects of climate change. The shrinking of Lake Chad, for example, is the result not only of climate change but also of a rapid increase in the number of people living in the region and consequent changes in land use and agricultural practices. In fact, IPCC reports find that overpopulation is a key stressor of water quality and availability in Africa, and in some regions has caused more harm to water availability than climate change has.[95]

Conclusion

Climate change is a reality for Africa and governments need to both adapt to and mitigate climate change as they simultaneously manage a host of other development priorities. This is an extremely tall order.

Given that the impacts of climate change will inevitably worsen until at least mid-century, Africa's immediate priority is to reduce the vulnerability of its most exposed populations. Strengthening disaster risk governance is the best strategy for preventing further needless loss of lives to droughts, floods and other natural disasters.

> Improving human development is critical to enhancing climate resilience

The Current Path forecasts presented in this report suggest that Africa will continue to have little capacity to adapt to climate change. Without significant intervention, Africa's vulnerable population, as measured by extreme poverty and access to improved water, is projected to continue growing while state capacity is

expected to remain low. As the climate continues to warm, it is these populations who will suffer the most.

The Green Road scenario sheds light on the kinds of development priorities Africa – especially sub-Saharan Africa – needs to pursue in order to realise the enhanced adaptive capacity envisioned by Agenda 2063. It shows that improving human development by increasing investment in education and healthcare now will not only enhance communities' capacity to adapt to climate change, but also reduce the number of people who are vulnerable. The Green Road scenario also illustrates that economic development must be inclusive in order to foster vulnerable communities' resilience to the impacts of climate change. But, as climate change continues to compromise the ability of land and water resources to provide for human life, natural resource management practices will be vital to improving livelihoods while preserving the ecosystems on which all lives depend.

Appendices

Appendix 1: World Bank geographic regions

Country group	Countries
Sub-Saharan Africa	Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cabo Verde, Central African Republic, Chad, Comoros, Côte d'Ivoire, Republic of Congo, Democratic Republic of Congo, Equatorial Guinea, Eritrea, Eswatini, Ethiopia, Gabon, Ghana, The Gambia, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, São Tomé & Príncipe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, South Sudan, Sudan, Tanzania, Togo, Uganda, Zambia and Zimbabwe.
East Asia & the Pacific	Cambodia, China, Indonesia, Lao, Malaysia, Mongolia, Myanmar, Pacific Islands, Papua New Guinea, Philippines, Singapore, Thailand, Timor-Leste and Vietnam.
Europe & Central Asia	Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Georgia, Kazakhstan, Kosovo, Kyrgyz Republic, Macedonia, Moldova, Montenegro, Poland, Romania, Russian Federation, Serbia, Tajikistan, Turkey, Turkmenistan, Ukraine and Uzbekistan.
Latin America & the Caribbean	Antigua and Barbuda, Argentina, Belize, Bolivia, Brazil, Colombia, Chile, Costa Rica, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, St. Kitts and Nevis, St. Vincent and the Grenadines, St. Lucia, Suriname, Trinidad and Tobago, Uruguay and Venezuela.
Middle East & North Africa	Algeria, Bahrain, Djibouti, Egypt, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Qatar, Saudi Arabia, Syria, Tunisia, United Arab Emirates and Yemen.
North America	Canada and the United States.
South Asia	Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka.

Appendix 2: Exogenous series used for SSP 1

For the SSPs, IFs imports exogenous variables for certain variables that are normally forecasts endogenously. The table below shows the variables in IFs that are overridden by the exogenous forecasts of the SSPs.

Variable name	Description	Source
POP	Population	International Institute for Applied Systems Analysis (IIASA)
BIRTHS	Total number of births	IIASA
DEATHS	Total number of deaths	IIASA
TFR	Total fertility rate	IIASA
POPURBAN	Urban Population	US National Center for Atmospheric Research
EDYRSAG15	Education years obtained by population older than 15 years (Male, Female and Total)	IIASA
EDYRSAG25	Education years obtained by population older than 25 years (Male, Female and Total)	IIASA
GDPPCP	GDP per capita at PPP	OECD
migrater	Migration rate (net) as a percent of the population	IIASA

Appendix 3: Climate change in the IFs Current Path

Integrated in IFs is an environmental model that utilises data on global carbon emissions and other environmental indicators to forecast future emissions and their impacts across systems (e.g., agriculture). IFs Current Path forecasts of carbon emissions and consequent concentration of atmospheric carbon are consistent with RCP 4.5. Because RCP 4.5 is now understood by climate scientists to be optimistic given current emissions trends, it is possible that IFs' representation of climate change is conservative and underestimates the rate and magnitude of climate change.

For in-depth documentation on the environmental model in IFs, see Barry B Hughes and Steve Hedden, IFs Environment Model Documentation, Working paper, Pardee Center for International Futures, Josef Korbel School of International Studies, University of Denver, 2016, https://pardee.du.edu/sites/default/files/2016.03.21%20IFsDocumentation%20Environment%20v5.pdf.

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