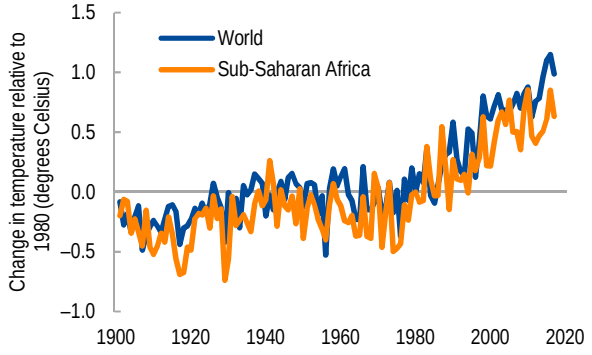
2. Adapting to Climate Change in Sub-Saharan Africa

INTRODUCTION

The intrinsic links between climate change and the COVID-19 pandemic have elevated global calls for policymakers to take immediate action on both fronts. Fiscal stimulus supporting recovery from the pandemic can be designed to simultaneously address climate change. In turn, this could help reduce the spread of future pandemics as climate change is a threat multiplier for pandemics. Destruction of the environment and biodiversity makes pandemics more likely while pollution and other man-made factors driving climate change weaken the health of human beings, raising their vulnerability to viruses and other diseases.

Sub-Saharan Africa is the region in the world most vulnerable to climate change. Rising temperatures, rising sea levels, and rainfall anomalies are increasing the frequency and intensity of natural disasters and are markedly transforming the region's geography (Figure 2.1; IPCC 2018; October 2017 *World Economic Outlook*, Chapter 3). Recent natural disasters include the devastating cyclones Idai and Kenneth; ongoing locust outbreaks in eastern Africa and droughts in southern and eastern Africa that threaten the lives of millions; and the Sahel's desertification, which is contributing to conflicts and mass migration (Rigaud and others 2019).

Figure 2.1. World and Sub-Saharan Africa: Change in Temperature Relative to 1980, Celsius



Sources: Harris and others (2014); and IMF staff calculations.

Economic development has brought considerable progress in recent decades, but resilience and coping mechanisms across sub-Saharan Africa remain limited, reflecting structural factors restricting countries' ability to respond to and recover from shocks. In particular, heavy reliance on rain-fed agriculture increases humanitarian, social, and macroeconomic vulnerabilities to rising temperatures and extreme weather shocks, which most heavily affect the poorest segments of the region's rapidly growing population.[1]

Adapting to climate change is critical to safeguarding and further advancing hard-earned improvements in incomes and education and health outcomes across sub-Saharan Africa over the past three decades. However, adaptation will be especially challenging given countries' limited capacity and financial resources. Several studies have clearly shown the importance of advancing economic development in raising resilience to climate change and improving coping mechanisms (IMF 2017; IMF 2019a; Hallegatte and others 2017). Policy recommendations range from building buffers (such as international reserves) and social safety nets to strengthening institutions and frameworks that foster structural transformation. However, implementing all of these recommendations while managing competing development needs is beyond the region's human and financial capacity. In some cases, additional challenges arise from political uncertainty and security issues. Given these constraints, which reform areas should sub-Saharan African policymakers prioritize? This is the subject of mounting policy debates across the region, especially with youth pressing policymakers for more immediate action.

This chapter examines policies and structural areas that could help the region make strides in adapting to climate change by building resilience and improving coping mechanisms. The first section applies big data, econometric analysis, and

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[1] Indicators on vulnerabilities, including the World Risk Index (Radtke and Weller 2019) and Notre Dame Global Adaptation Index, suggest that most sub-Saharan African countries have low adaptive capacities, including a lack of economic, governance, and social readiness needed for adaptation.

event studies to provide an overview of how climate change affects sub-Saharan African countries, focusing on the consequences for economic growth and inequality. The second section highlights the key policy areas most effective in building resilience and coping mechanisms, relying on econometric analysis of macro-level data, household surveys, and case studies. The third section concludes with an analysis of financing implications.

Main Findings

Financing adaptation to climate change will be more cost-effective than frequent disaster relief. For sub-Saharan Africa, adaptation will be expensive—estimated at US$30–50 billion (2–3 percent of regional GDP) each year over the next decade—but less costly than frequent disaster relief. This chapter's analysis finds that savings from reduced post-disaster spending could be many times the cost of upfront investment in resilience and coping mechanisms. Adaptation to climate change would also benefit other development areas, such as resilience to pandemics, and ultimately boost growth, reduce inequalities, and sustain macroeconomic stability.

Stepped up financial support from development partners, beyond disaster relief, targeting resilience building and bolstering coping mechanisms will be critical. Containing and managing the COVID-19 pandemic is taking a toll on already limited fiscal space and raising debt vulnerabilities in sub-Saharan Africa. A green recovery from the pandemic will ultimately boost economic growth and resilience but, in the interim, support of the international community will be paramount as securing other sources of financing can be challenging. For example, macroeconomic insurance, such as climate funds and state-contingent bonds, have been difficult for the region's countries to access so far, given large risk premiums—partly reflecting governance issues in much of the region that raise investors' risk aversion.

Climatic change in sub-Saharan Africa is especially pronounced with intensified temperature extremes, precipitation anomalies, and natural disasters that annually leave millions in peril, injured, homeless, or food insecure, and cause serious and costly economic damage. One-third of the world's droughts occur in sub-Saharan Africa, and the frequency of storms and floods is growing fastest in this region.

The potential impact of rising temperatures and extreme weather events on growth is larger and longer lasting in sub-Saharan Africa than in the rest of the world, reflecting the region's lower resilience and coping mechanisms, and its dependence on rain-fed agriculture. The resulting amplification of inequalities and scarcity of fertile lands, combined with high population growth, risk contributing to mass migration and conflict.

- The analysis in this chapter suggests that economic activity in a given month can shrink by 1 percent when the average temperature is 0.5°C above that month's 30-year average. This impact is 60 percent larger than the average for emerging market and developing economies in other regions, reflecting sub-Saharan Africa's agricultural dependence and the temperature sensitivity of its crops.

- The analysis also finds that climate-induced natural disasters have a lasting impact, especially droughts, possibly reflecting their prolonged nature. For example, medium-term annual economic growth can decline by 1 percentage point with the occurrence of one additional drought. This impact is about eight times that in emerging market and developing economies in other regions.

Climate change is threatening food security of the poor in both rural and urban areas. Reducing this risk requires improving the resilience of agricultural production and households, partly by prioritizing the necessary measures in government budgets (outlined in the section on adaptation strategies), and closer coordination across various ministries (Finance, Agriculture, Education, Environment, and Health) and across development partners. Targeted social assistance and insurance are key to helping populations cope after a shock. The empirical investigation of household surveys in this chapter suggests:

- Improved seeds, insecticide, fertilizer, anti-erosion measures, irrigation, and access to finance are critical for building resilience in agricultural production.

- Better access to finance and telecommunications (which improve accessibility to early warning systems), robust housing, sanitation, and education (which improves decision-making and incomes) boost the resilience of rural and urban households to climate change shocks and could reduce the chances of post-shock food insecurity by 30 percentage points.

More broadly, adaptation strategies will depend on the types of climate change effects a country is facing. Strong macroeconomic, institutional, and structural policies are a must, but cross-country regression analysis finds that the following combinations of structural reform areas need to be prioritized:

- For droughts, increasing access to finance, irrigation, drinking water, and electricity (which powers irrigation and pumps) is essential for minimizing economic damage.

- For storms and floods—which can also contribute to the spread of pandemics—accelerating progress in improving health and education outcomes,[2] access to finance, telecommunications, and the use of machines and weather-resilient infrastructure limits economic damage and supports recovery efforts.

ECONOMIC IMPACT OF CLIMATE CHANGE

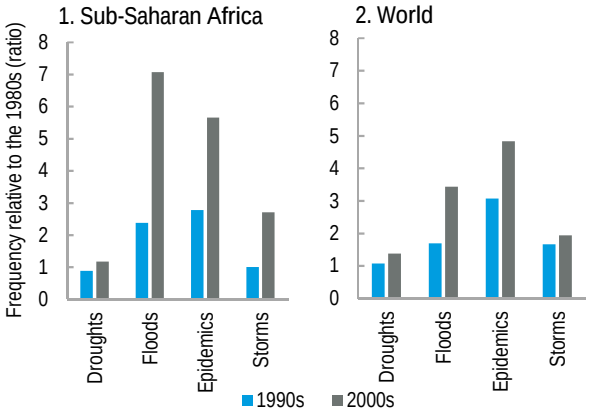
What Does Climate Change Mean for Sub-Saharan Africa?

Recent increases in global temperatures are unprecedented and expected to accelerate. Even extreme restraint of greenhouse gas emissions can only slow the pace of temperature increases, given that past emissions remain in the atmosphere (IPCC 2018). The 0.7°C rise in global temperatures over the past 30 years (or 1°C over the past 50 years) is significantly higher than in any equivalent period during the last 10,000 years (Marcott and others 2013). This aggregate figure masks substantial heterogeneity across seasons and geographic locations. Natural disasters have always been present, but there is clear evidence that rising temperatures and changes in precipitation lead to more frequent droughts, desertification, climbing sea levels, and higher vapor pressure—much of which fuels more frequent floods and storms such as hurricanes and tropical cyclones (IPCC 2018; October 2017 *World Economic Outlook*, Chapter 3).

Climatic change in sub-Saharan Africa is especially pronounced with intensified temperature extremes, precipitation anomalies, and natural disasters—annually responsible for at least 1,000 deaths, 13 million people seriously affected (injured, left homeless, food insecure, or lacking water and sanitation), and US$520 million in direct economic damages since the turn of the century. One-third of the world's droughts occur in sub-Saharan Africa, and the frequency of storms and floods is growing fastest in this region (Figure 2.2).[3]

- Temperature increases are starkest in eastern Africa—having risen almost 1°C over the past 30 years—where daily summer temperature highs average 28°C (Figure 2.3). The increases in southern and western Africa, spanning some

Figure 2.2. Sub-Saharan Africa and the World: Frequency of Natural Disasters Relative to the 1980s



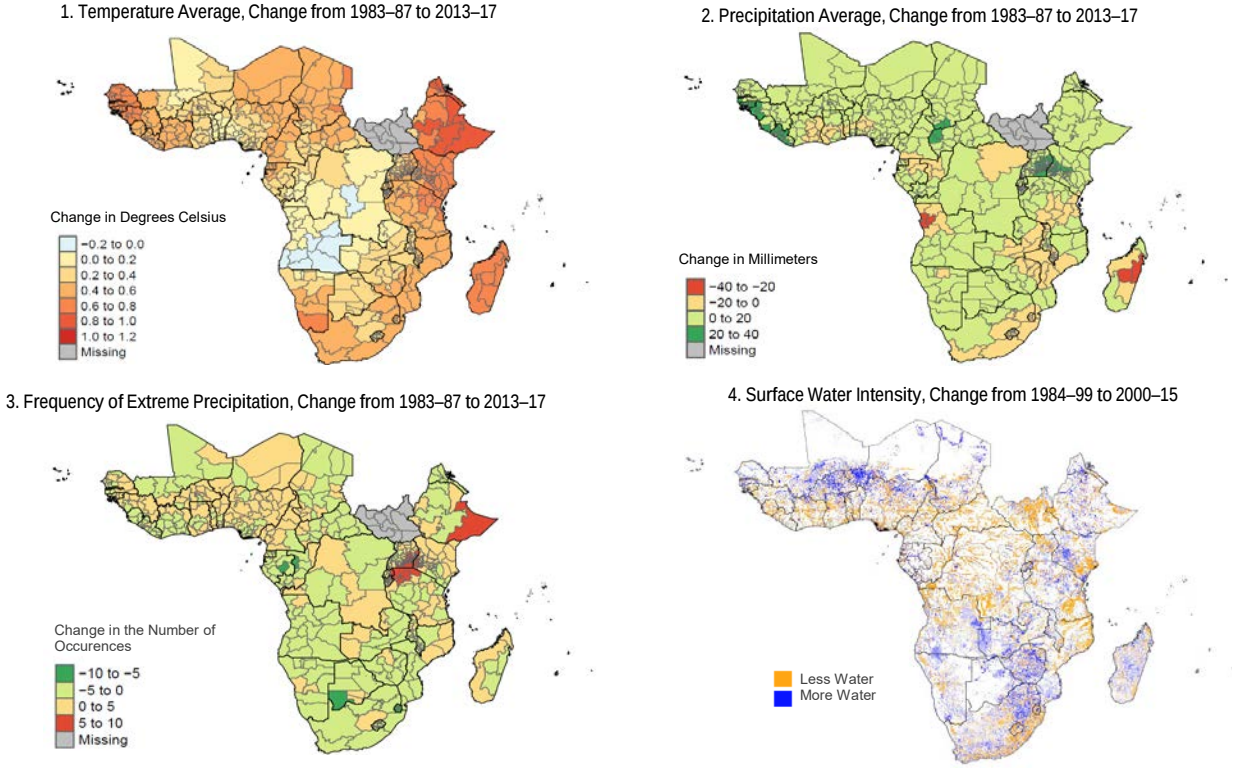
Sources: Centre for Research on the Epidemiology of Disasters, Emergency Events Database; and IMF staff calculations.

Note: The bars in this chart can be interpreted as multiples of the sum of disasters that occurred during 1980–89. For example, all the floods in sub-Saharan Africa during 2000–09 were about seven times the floods during 1980–89.

[2] Improved health outcomes reduce out-of-pocket health care spending and facilitate a quicker return to work; improved education outcomes increase productivity, decision-making, and incomes.

[3] The chapter relies on the Emergency Events Database maintained by the Centre for Research on the Epidemiology of Disasters, including for the definition of events. The database includes all disasters meeting one of the following criteria: 10 people killed, 100 people affected, a declaration of a state of emergency, or a call for international assistance. Although part of the observed increase in frequency might reflect an improvement in reporting, it is believed that similar reporting standards have been applied since the 1980s.

Figure 2.3. Sub-Saharan Africa: Temperatures, Precipitation, and Water Intensity, 1983–2017



Sources: University of East Anglia Climate Research Unit; and IMF staff calculations.

Note: Extreme precipitation events occur when precipitation is more than two standard deviations away from the same-month average. Surface water intensity is the frequency with which water was present on the surface.

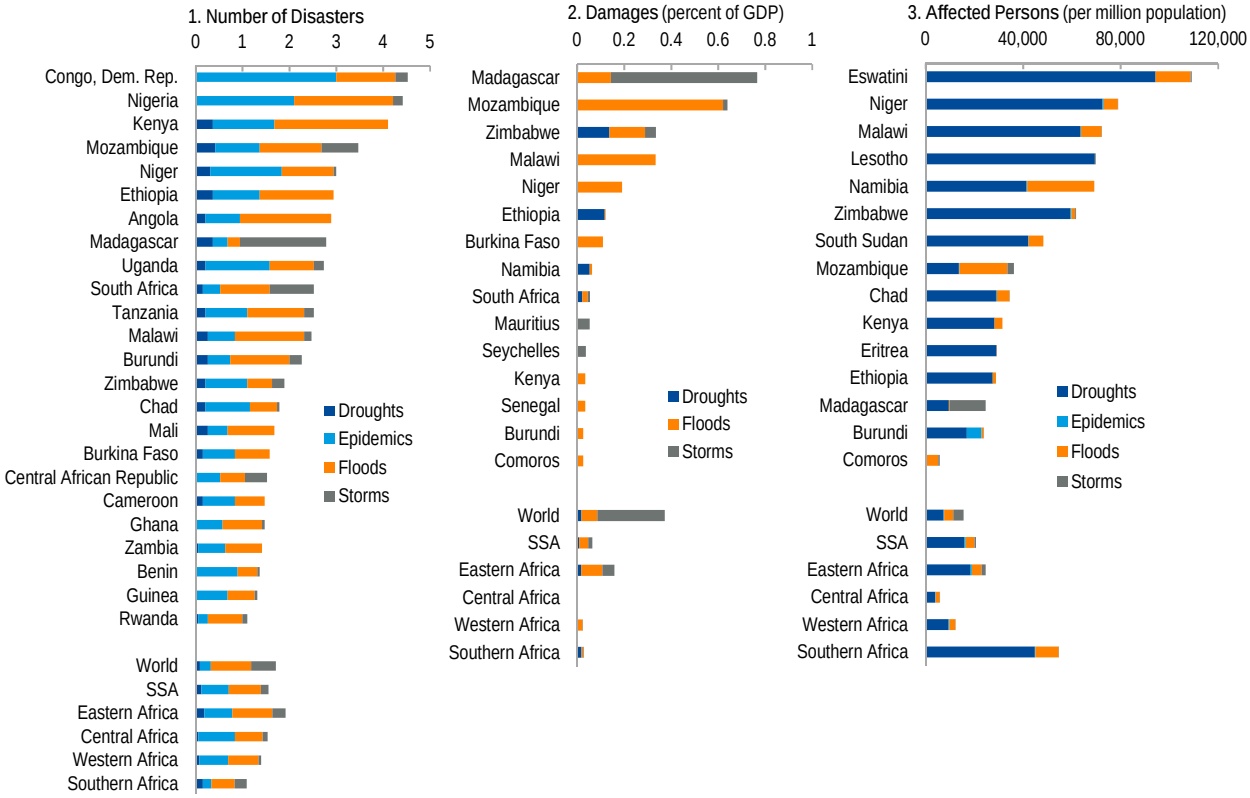
of the hottest locations on the planet, are not far behind. By contrast, some central African countries (including Angola and the Democratic Republic of the Congo) are benefiting from modest temperature declines.

- The impact of climate change on precipitation is more complex. Western and southern Africa, including some of sub-Saharan Africa's driest locations, are experiencing marked precipitation declines (Figure 2.3). Madagascar, Malawi, South Africa, and Zimbabwe stand out, with some provinces rapidly drying out while others face massive rainfall increases. Across the rest of sub-Saharan Africa, increased episodes of extreme rainfall, which hurt agricultural production, often outweigh the benefits from more precipitation. Surface water—critical for farming, fishing, and hydroelectricity—is shrinking, particularly in central Africa.

- Droughts spurred by prolonged heat and dryness are taking the largest toll on people's lives and livelihoods and threaten to undo the past three decades' progress in raising life expectancy and reducing infant mortality and malnutrition (Figure 2.4). The Sahel and southeastern Africa are most affected, with a particularly large impact in Eswatini, Lesotho, and Niger.

- Floods and storms, the most common natural disasters in sub-Saharan Africa, are seriously damaging infrastructure (Figure 2.4). Comoros, Madagascar, Malawi, and Mozambique are particularly susceptible to tropical cyclones from the Indian Ocean. Similarly, Guinea Bissau and Sierra Leone are susceptible to storms from the Atlantic Ocean. Large coastal cities (Abidjan, Accra, Dakar, Dar es Salaam, and Lagos) are vulnerable to floods from rising sea levels. Floods can also spread diseases because they create breeding grounds for mosquitoes and contaminate drinking water (October 2016 *Regional Economic Outlook: Sub-Saharan Africa*, Chapter 3), creating challenges to safeguarding recent years' achievements in reduced incidences of malaria and improved access to drinking water.

Figure 2.4. Sub-Saharan Africa: Annual Impacts of Natural Disasters by Country, 2000–18



Sources: Centre for Research on the Epidemiology of Disasters, Emergency Events Database; and IMF staff calculations.
Note: Actual damages are likely higher as some disasters are missing data on damage. SSA = sub-Saharan Africa.

Climate Change Matters for Economic Growth and Inequality

Climate change weighs on economic growth by taking lives, depressing productivity (including deteriorated worker health and education), destroying housing and physical infrastructure, and dampening hydroelectric production (October 2017 *World Economic Outlook,* Chapter 3; Burke and others 2009; Hsiang, Meng, and Cane 2011). Agricultural output suffers the most through shrinking yields and a reduction in arable lands, and this puts food security at risk. Spillovers from agriculture; reduced productivity; slowed investment; and damage to capital, the environment, and biodiversity hurt manufacturing, wholesale and retail trade, and tourism (October 2017 *World Economic Outlook,* Chapter 3; Jones and Olken 2010; Garcia-Verdu and others 2019).[4]

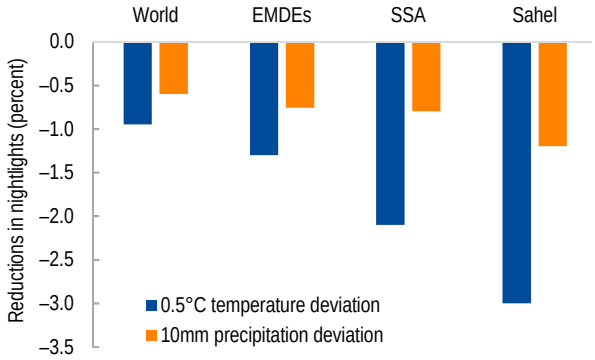
Combined, these pressures can contribute to mass migration and conflict; and can also result in poor nutrition and health care outcomes which reduce populations' resilience to pandemics.

Growth Impact is Larger and Lasts Longer in Sub-Saharan Africa

Rising temperatures and precipitation anomalies are affecting economic activity more in sub-Saharan Africa than elsewhere (Figure 2.5), reflecting the region's limited resilience and coping mechanisms and its reliance on rain-fed agriculture. Using satellite-recorded nightlights as a proxy for economic activity, this chapter's empirical analysis of provincial-level data reveals that in sub-Saharan Africa for a given month, a 0.5°C increase in temperature from that month's 30-year average corresponds to a 2.1 percent reduction of

[4] Additional potential channels include negative wealth effects from stranded assets and increased growth volatility (due to greater frequency and intensity of weather-related disasters). Studies measuring the impact of climate change on financial markets in sub-Saharan Africa or comparable regions are limited, but for more advanced economies, the May 2020 *Global Financial Stability Report* finds no significant effect of disasters on aggregate equity prices except when they are very large.

Figure 2.5. Selected Economies: Impact of Weather Anomalies on Nightlights



Sources: National Oceanic and Atmospheric Administration; University of East Anglia Climate Research Unit; and IMF staff calculations.

Note: Anomalies occur when the temperature or precipitation for a given month is at least 0.5°C or 10 millimeters higher than the 30-year average for that month. Data cover January 2013 through December 2017. EMDE = emerging market and developing economies; mm = millimeter; SSA = sub-Saharan Africa.

nightlights.[5] This translates into a 1 percent decline in monthly real GDP for that province (applying elasticity estimates from Hu and Yao 2019), although the effects may not persist through the year and may be offset by other factors, including a moderation of temperatures in subsequent months.[6] This impact is broadly double the global average and 1.6 times the emerging market and developing economy average.[7] Similarly, a 10-millimeter deviation in precipitation relative to the 30-year average for that month could reduce nightlights in sub-Saharan Africa by 0.8 percent, implying a reduction in real GDP of 0.4 percent. If the precipitation shock hits during peak growing season, the effect could persist for more than a year.

More than half the provinces across sub-Saharan African countries already experience these magnitudes of temperature or rainfall fluctuations in a given month. Although the impact in most subregions (with sufficient electrification for this analysis) are near the sub-Saharan African average, the Sahel is the striking exception, highlighting its weak resilience and coping mechanisms and already high average temperatures (October 2017 *World Economic Outlook*, Chapter 3; Burke, Hsiang, and Miguel 2015). For example, a temperature increase from 35°C to 36°C will have a direct, adverse impact on the well-being of a farmer in weak health who has to walk an extra kilometer to get water. The farmer's productivity and income earning potential will also decline.

Natural disasters, especially droughts, have lasting adverse economic consequences. Foreign financial assistance, remittances, and reconstruction often offset the negative near-term impact on economic activity, which is substantial for droughts and extreme storms like cyclones (Figure 2.6). Over the medium-term, from an economic perspective, it is possible to offset some losses to physical capital (for example, with upgrades to damaged infrastructure). However, the human capital loss from deaths, malnutrition, or lower school enrollment after a disaster is unrecoverable. This chapter's analysis of country-level panel regressions of five-year GDP growth on the frequency and intensity of natural disasters finds the following (Figure 2.7):[8]

- A significant negative impact of natural disasters on medium-term growth—especially droughts, possibly reflecting their prolonged nature. The occurrence of one additional drought in a sub-Saharan African country can reduce its medium-term annual economic growth by one percentage point, in addition to any lasting level effects. Each additional flood takes about half the toll on medium-term growth.[9]

- Climate-induced natural disasters weigh substantially more on growth in sub-Saharan Africa, reflecting the region's limited resilience

[5] Nightlights are generated mostly by human activity. They are visible from outer space and recorded by satellites. Nightlights are positively correlated with economic activity and have often been used as a supplementary measure of real GDP (Hu and Yao 2019). For example, when higher temperatures reduce economic activity, businesses and households react to lower incomes by reducing their electricity consumption.

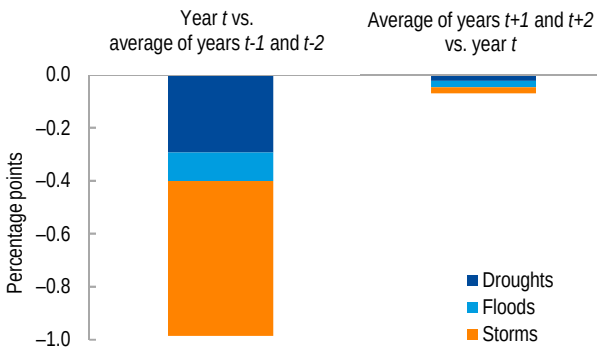
[6] With annual data, the October 2017 *World Economic Outlook*, Chapter 3 finds that a 1°C rise in temperature lowers per capita GDP by 1–1.5 percent. Based on the estimations in this *Regional Economic Outlook* chapter, the larger reduction in sub-Saharan Africa's economic activity holds even after controlling for differences in initial temperatures in other regions of the world. However, these results are subject to important caveats. First, climate change could affect economic activity through channels other than changes in temperature and precipitation, such as rising sea levels, increased frequency and intensity of weather-related disasters, changes in ecosystem, mass migration, and conflicts. Second, households, businesses, and governments could adapt their behaviors as climate change continues, reducing the effects of climate change on economic activity.

[7] The results are robust to limiting the comparison to emerging market and developing economies at similar latitudes.

[8] The analysis in this chapter follows the estimation strategy in Loayza and others (2012). The frequency is the average five-year death rate. The intensity is the proportion of disruptive disasters out of all disasters in a five-year window. Here, a disaster is "disruptive" when fatalities plus 0.3 times the affected persons exceeds 0.01 percent of the population.

[9] Floods include the aftereffect of extreme storms such as cyclones.

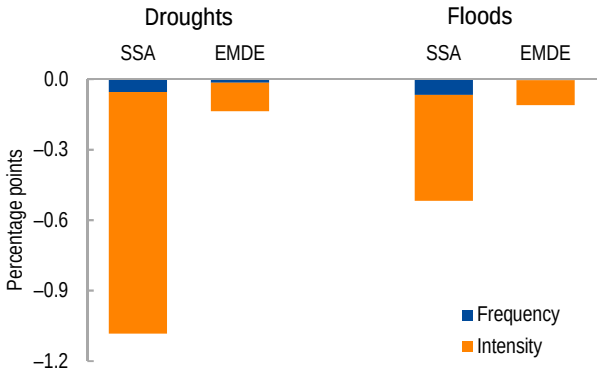
Figure 2.6. Sub-Saharan Africa: Evolution of Real GDP Growth around Disruptive Droughts, Floods, and Storms, 1990–2018



Sources: IMF International Financial Statistics; and IMF staff calculations.

Note: A disaster is "disruptive" when fatalities plus 0.3 times the affected persons exceeds 0.01 percent of the population. The charts illustrate the averages. *t* = the year of a disaster, *t-1* is one year before the disaster, *t-2* is two years before the disaster, *t+1* is one year after the disaster, and *t+2* is two years after the disaster.

Figure 2.7. Selected Economies: Medium-Term Impact of Frequency and Intensity of One Additional Natural Disaster on Growth



Sources: Centre for Research on the Epidemiology of Disasters, Emergency Events Database; IMF International Financial Statistics; World Bank World Development Indicators Database; and IMF staff calculations.

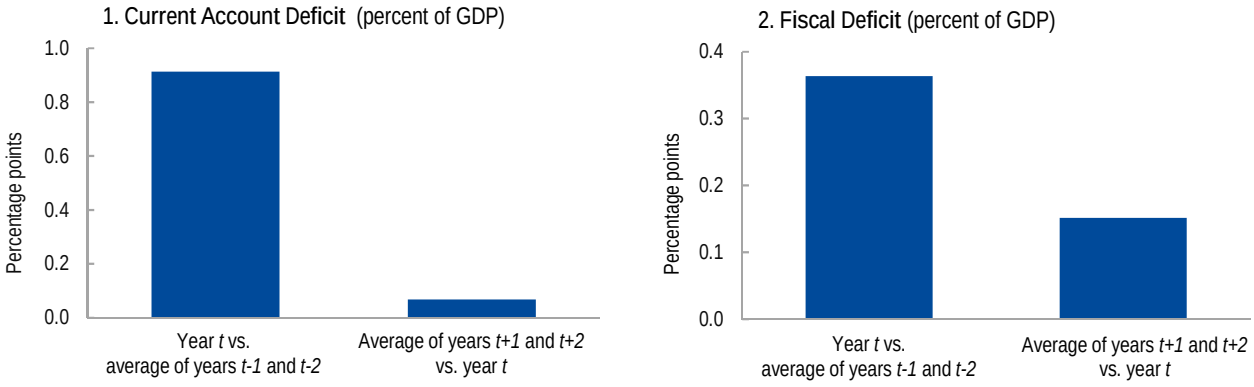
Note: Disaster intensity is the fraction of disruptive disasters out of all disasters within a five-year window. A disaster is "disruptive" when fatalities plus 0.3 times the affected persons exceeds 0.01 percent of the population. EMDE = emerging market and developing economies; SSA = sub-Saharan Africa.

and coping mechanisms and its dependence on rain-fed agriculture. This impact is about eight times that in other emerging market and developing economies for droughts.

- A disaster's intensity matters much more than its frequency (consistent with the findings of Cavallo and others 2013 and Fomby, Ikeda, and Loayza 2013).[10]

Challenges to economic growth are compounded by widening fiscal and current account deficits and corresponding pressures on public debt and international reserves after a natural disaster (Figure 2.8). Reduced economic activity translates into lower tax revenues while spending needs accelerate with the demands of post-disaster relief and rebuilding damaged infrastructure (IMF 2016). Post-disaster foreign financial assistance or remittances seldom fully offset strains on external positions from reduced agricultural exports and increased imports for reconstruction. Setting aside

Figure 2.8. Sub-Saharan Africa: Evolution of Macroeconomic Indicators around Disruptive Droughts, Floods, and Storms, 1990–2018



Sources: IMF International Financial Statistics; and IMF staff calculations.

Note: A disaster is "disruptive" when fatalities plus 0.3 times the affected persons exceeds 0.01 percent of the population. Charts illustrate the averages. *t* = the year of a disaster, *t-1* is one year before the disaster, *t-2* is two years before the disaster, *t+1* is one year after the disaster, and *t+2* is two years after the disaster.

[10] The larger impact of intensity on economic activity relative to that of frequency may reflect the observation that frequent disasters result in increasing intensities. That is, if an economy has not yet recovered from one disaster and is hit with another, then the intensity of the second disaster in deaths and damage becomes higher than the first disaster (keeping all else equal).

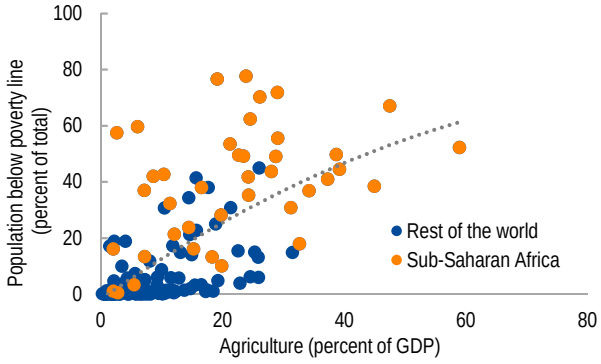
natural disasters, coping with temperature increases and precipitation anomalies can lower exports (Jones and Olken 2010)—ultimately changing trade patterns—and necessitate increased social assistance and public investment. Financial system stability can also be affected, especially through rapid increases in nonperforming loans and deposit withdrawals for banks and deteriorated balance sheets for insurance companies. More broadly, assets stranded because of weather-related disasters could lower collateral values and hurt the soundness of financial institutions.

Amplified Inequalities

Climate change is exacerbating already large inequalities in sub-Saharan Africa. Almost half of the population lives below the poverty line and depends on weather-sensitive activities such as rain-fed agriculture, herding, and fishing for their livelihoods (Figure 2.9). Limited financial buffers and low levels of education and health care impede their ability to adapt, raising vulnerabilities to food insecurity, income losses, and unemployment. For example, the analysis in this chapter finds that in Ethiopia, Malawi, Mali, Niger, and Tanzania, food insecurity increases by 5–20 percentage points with each flood or drought.[11] Associated deteriorations in health and in children's school attendance worsen longer-term income and gender inequalities (Shahidul and Zehadul Karim 2015).[12]

Increased urban poverty is a growing risk. Rapid urbanization is likely as rural populations, unable to cope with weather shocks, relocate to cities (often migrating across borders) searching for jobs and shelter, as evidenced in the Sahel. However, sub-Saharan African cities are struggling to accommodate already high population densities and build more climate-resilient infrastructure. The region's rapid population growth will intensify these challenges. Conflicts spurred by these developments would further depress growth and raise inequalities (Burke and others 2009; Hsiang, Meng, and Cane 2011; April 2019 *Regional Economic Outlook: Sub-Saharan Africa,* Chapter 2).

Figure 2.9. Sub-Saharan Africa and the World: Agricultural Dependence and Poverty, 2018 or Latest



Source: World Bank World Development Indicators Database.

Note: The poverty line is measured as the poverty head count at US$1.90 a day in terms of 2011 purchasing power parity.

ADAPTATION STRATEGIES

Containing the adverse humanitarian, social, and economic costs of climate change and its role in amplifying pandemics will depend on both adaptation and mitigation strategies (Box 2.1).[13] Their inclusion in the Sustainable Development Goals highlights their criticality. Sub-Saharan Africa can step up mitigation and its contribution to a green economic recovery from the COVID-19 pandemic through carbon taxes, phasing out energy subsidies, transitioning to green energy sources, reforestation which promotes carbon capture (October 2019 *Fiscal Monitor,* Chapter 1; IMF 2019b; Nyiwul 2019), and financial regulations that limit investment in polluting capital. However, adaptation strategies play a greater role for sub-Saharan Africa from several perspectives. First, rapid implementation of adaptation strategies (which will also spur economic development) will generate more jobs in support of economic recovery from the COVID-19 pandemic. Second, sub-Saharan African economies are particularly dependent on climate-sensitive sectors. Third, the region has limited influence on climate compared with advanced and large emerging market economies emitting the bulk of greenhouse gases. How to approach adaptation is the subject of mounting policy debates across the region, especially with youth pressing policymakers for

[11] These results are based on this chapter's analysis of household surveys for Ethiopia (2015–16), Malawi (2016–17), Mali (2017–18), Niger (2014), and Tanzania (2014–15).

[12] See October 2016 *Regional Economic Outlook: Sub-Saharan Africa*, Chapter 3 for further discussions on inequality and other social indicators.

[13] The 2016 Paris Agreement considers adaptation as a parallel component to mitigation. Most sub-Saharan African countries have submitted some adaptation goals and measures as part of their climate strategies for the agreement. They will revisit these strategies at the 26th session of the Conference of the Parties to the United Nations Framework Convention on Climate Change in November 2020.

more immediate action. This section outlines some key considerations and policy recommendations.

Awareness of the positive synergies across adaptation, the macroeconomy, and development outcomes—creating a virtuous cycle that boosts inclusive growth—will help governments develop comprehensive adaptation strategies. For example, the ability of improved seeds to reduce the weather-sensitivity of crops can benefit agricultural productivity even without climate change. Similarly, strong institutions support economic efficiency and governance, including the enforcement of regulations targeting weather resilience. Access to finance for households and small and medium enterprises helps grow their livelihoods and build resilience to economic shocks, whether climate change–induced or otherwise. Land reforms and effective social protection incentivize ownership among rural households to protect their land and assets against climate change (Kosec and Mo 2017). Good macroeconomic and structural policies—promoting economic diversification, creating fiscal space, building fiscal and reserves buffers, and pursuing exchange rate flexibility—limit the impact of climate shocks and help the economy recover faster. In turn, a quicker rebound frees resources to invest in other development areas.

Regional cooperation will be a key element of adaptation. Climate change transcends international borders. Consider, for example, the drying of Lake Chad and the Volta Basin, jeopardizing the production of food and hydroelectricity across several countries, including Cameroon, Chad, Niger, and Nigeria (for Lake Chad) and Benin, Burkina Faso, Côte d'Ivoire, Ghana, Mali, and Togo (for the Volta Basin). Active sharing of technologies, knowledge, and effective institutional practices, especially through regional initiatives, can make strides in accelerating adaptation (African Union 2014; EAC 2011; Lesolle 2012; Sembiring 2018). Developing regional agricultural markets could lower food prices and help ensure food security.

Resilience and coping mechanisms are the pillars of adaptation. Improving resilience reduces exposure and vulnerability to climate change while coping mechanisms help buffer the impact from them. Accelerating the development of these pillars will be critical to safeguarding food security and shaping broad-based adaptability. To this end, the next subsections assess the potential impact of key policies. Implementing these policies will require strong coordination within the government (particularly across the Ministries of Finance, Agriculture, Education, Environment, and Health, and those ministries and agencies responsible for specific types of infrastructure) and with development partners. This begins by developing comprehensive adaptation strategies, assessing whether governments' multiyear expenditure frameworks (from programs supporting improved seeds or social protection to building irrigation infrastructure) already account for key adaptation policies, and reviewing project selection and prioritization criteria to ensure implementation of the most impactful combination of resilience-building projects. Financing challenges (in relation to access to finance for households and businesses and, more broadly, on public financing of adaptation; discussed in the section on financing adaptation) and informational asymmetries will need to be addressed.

Safeguarding Food Security

Weather-related crop damage can plunge poor households into food insecurity. Subsistence farmers suffer directly while shortages elevate food prices for other households. Tackling this challenge requires strengthening the resilience of households and agricultural output and bolstering post-shock support.

Building household resilience and improving coping mechanisms can reduce the risk of food insecurity significantly. This chapter's empirical analysis of household surveys for Ethiopia, Malawi, Mali, Niger, and Tanzania finds, on average, that the following factors are likely to have the largest influence, potentially reducing the chance of food insecurity by 30 percentage points (Figure 2.10):

- *Higher incomes coming from diversified sources and access to finance* enable households to buy food even when prices rise and invest in resilience ahead of a shock, and they provide buffers afterward.

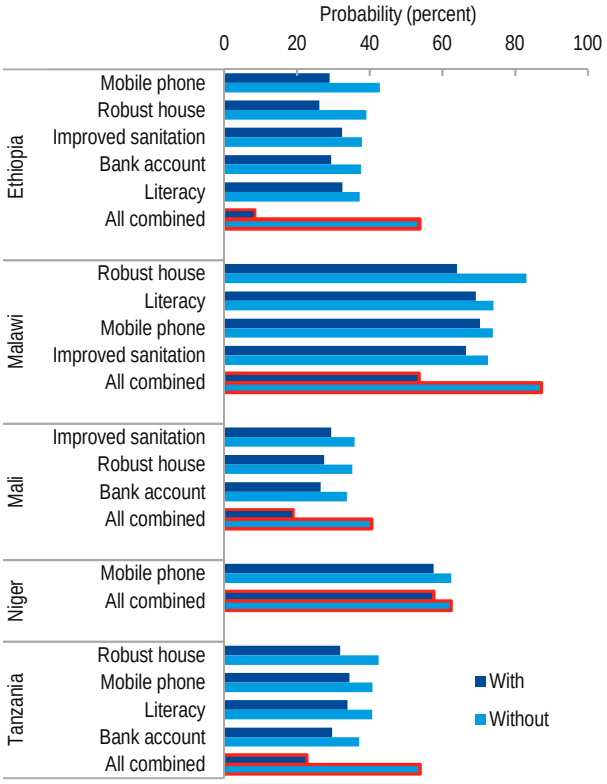
- *Solid mobile phone coverage and availability* help address information asymmetries by broadening the reach of early warning systems and information on food prices and weather (even with simple text or voice messages) that inform

farmers' decisions on when to plant, irrigate, or fertilize, enabling climate-smart agriculture (Ethiopia). Chapter 3 provides an overview of progress in digitalization across the continent.

- More *robust homes* and other structures facilitate food storage. Combined with good *sanitation* and drainage systems, they also preserve earning capacity by preventing injuries and the spread of disease and ensuring safe drinking water (Erman and others 2018; Erman, Obolensky, and Hallegatte 2019). To this end, government programs that widen accessibility to quality building materials for the poor and require high standards for building codes and regulations, effective land-use planning, and zoning rules are important.

- Improved *health care* and *education,* more generally, raise productivity and income potential and facilitate better-informed decision-making.

Figure 2.10. Selected Sub-Saharan African Countries: Probability of Food Insecurity for a Household Hit by a Shock



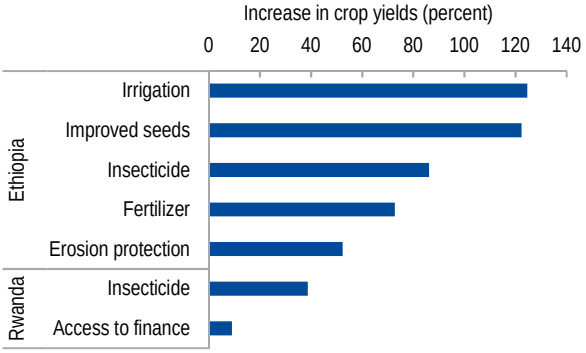
Sources: World Bank Living Standards Measurement Study; and IMF staff calculations.

Note: The probability of food insecurity is estimated for a household with average values for the explanatory variables other than the one considered. Only estimates that are statistically significant (at the 10 percent level) are illustrated. The regressions control for household wealth. Statistically significant estimates confirm correlation but not necessarily causality.

Reducing the weather sensitivity of crops helps protect the food supply. This chapter's empirical analysis of household surveys in Ethiopia and Rwanda finds that the use of improved seeds, fertilizer and insecticide, protection against erosion, irrigation, and access to finance can mitigate crop damage (Figure 2.11).[14,15] In this context, accelerating research and development in engineering improved seeds and livestock to withstand more diverse climate conditions and shifting from monocultures toward diversified agroforestry production can have a sizeable impact (Ethiopia, Sudan; Box 2.2). Raising farmers' awareness and facilitating access to many of these measures will accelerate their implementation.

Social assistance and insurance payouts compensate for lost income and purchasing power in the aftermath of a severe weather shock. For example, Kenya's Hunger Safety Net Program targeting

Figure 2.11. Selected Sub-Saharan African Countries: Impact of Key Measures on Crop Yields for Households with Crop Damage



Sources: World Bank Living Standards Measurement Study; and IMF staff calculations.

Note: The impact is relative to households that have not taken these measures. Only estimates that are statistically significant (at the 10 percent level) are illustrated. Statistically significant estimates confirm correlation but not necessarily causality.

[14] Thomas, forthcoming, provides details.

[15] Beyond erosion, strategies for broader environmental protection, such as preventing land degradation (that is, the productive capacity of soil) and saving water should be considered. IPBES (2018) discusses the ecological intensification of agriculture. Similarly, although better irrigation usually benefits farmers, the supply of free or underpriced water could encourage cultivation of water-intensive crops, which increases vulnerability to drought (Damania and others 2017).

drought-prone households (Song and Imai 2018) and Ethiopia's Productive Safety Net Program have supported poverty reduction (Box 2.2). Insurance and disaster risk financing can also be critical (World Bank 2014), but the success of these programs in sub-Saharan Africa often relies on government subsidies and improvements in financial literacy (Giné and Yang 2009; Mobarak and Rosenzweig 2013; Cole and others 2013; Hill, Hoddinott, and Kumar 2013; Hallegatte and others 2017).

Shaping Broad-Based Adaptability

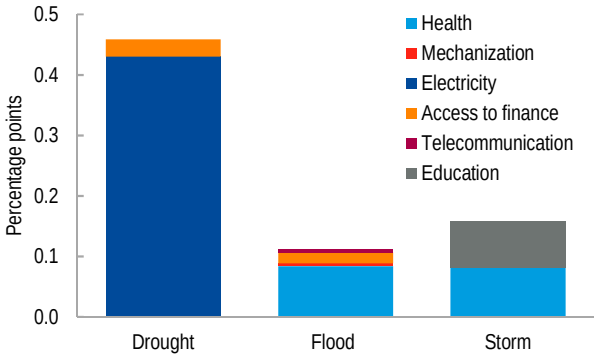
At an economy-wide level, raising resilience and bolstering coping mechanisms will require combinations of reforms targeted at the types of climate change challenges a country faces. Strong macroeconomic, institutional, and structural policies, along with the measures discussed previously to ensure food security, are necessary. However, beyond that, there are critical combinations of structural reform areas—based on specific climate change difficulties—where improvement could lead to substantial gains in containing the impact of climate change on economic growth and inequality. Ultimately, high resilience and strong coping mechanisms could avoid disastrous results altogether (Acevedo and Noah, forthcoming). This section examines these combinations, while the literature discusses at length the costs and policies to make progress in any individual structural area (IMF 2015; October 2019 *World Economic Outlook*, Chapter 3).

Droughts

Improved *irrigation systems* and broader *access to drinking water*, *electricity*, and *finance* would support higher economic growth and poverty reduction during prolonged dry spells and water shortages. These factors work hand in hand—electricity powers irrigation systems and deep tube-well pumps, and access to finance facilitates the building and maintenance of all three.[16] This chapter's regression analysis finds that the negative impact on per capita annual medium-term growth in sub-Saharan African countries is reduced by almost 0.5 percentage points if gaps are closed relative to the average for emerging market and developing economies in access to electricity (given existing irrigation and pumping systems) and to finance (Figure 2.12).[17] Although the exact magnitude of this analysis should be interpreted as suggestive, the relative impact of these reform areas is a robust indication of their importance.

A major component in increasing access to electricity will be the *diversification of electricity sources* toward renewable energy sources, such as geothermal, solar, and wind power. Hydropower, which generates one-fifth of sub-Saharan Africa's electricity, is susceptible to droughts (Castellano and others 2015). Building more reservoirs, dams, and power plants are a near-term solution. Over the long term, decentralization of renewable energy sources may be a more sustainable solution while supporting electrification and job creation (Kenya, Box 2.2). Reduced reliance on hydroelectricity also facilitates water management, where improvements in water access, constructing and rehabilitating small dams and boreholes, and setting up solar irrigation programs will be key (Ghana).

Figure 2.12. Sub-Saharan Africa: Reduction in Impact of Disasters on Per Capita Annual Medium-Term Growth when Structural Factors Improve to the Emerging Market and Developing Economy Average



Sources: World Bank World Development Indicators Database; and IMF staff calculations.

Note: Based on panel regressions of annual medium-term per capita growth on key structural areas. The bars show the impact when sub-Saharan African countries improve their structural factors to average levels in emerging market and developing economies. Applying an interaction term, the regression identifies the marginal impact of a structural area in improving the resilience of growth. Each bar in the chart illustrates this marginal impact multiplied by the gap between sub-Saharan Africa and the emerging market and developing economy average for that structural area. The impacts illustrated here are separate from each structural area's impact on growth through all other channels, which are also included in the estimation. Variables are included one at a time and only statistically significant estimates (at the 10 percent level) are illustrated. Statistically significant estimates confirm correlation but not necessarily causality.

[16] When access to finance is available but the amount of financing available to a household is limited by its low income level and asset values, targeted government subsidies could fill the gap.

[17] Data limitations on irrigation and drinking water systems precluded their inclusion in the regression analysis.

Floods and Storms

Policies for containing the impact of floods and storms often overlap given that extreme storms, such as tropical cyclones, also result in severe flooding. *Health care* plays an important role in reducing the medium-term economic growth impact of floods and storms (Figure 2.12)—which can also spread pandemics—by (i) reducing out-of-pocket health care expenditures, which safeguards household savings; (ii) facilitating a quicker return to work; and (iii) along with *education*, improving productivity, income potential, gender inequalities, and better-informed decision-making (Hallegatte, Rentschler, and Rozenberg 2019).

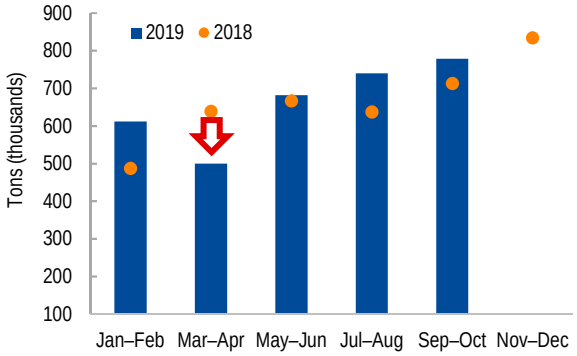
Reinforcing the results of the household survey analysis, *access to finance* helps households and businesses invest in *weather-resilient infrastructure* and provides buffers after a shock (Figure 2.12). In this vein, the *use of machinery* can improve the resilience of agricultural production by facilitating the creation of dikes, erosion protection, and deeper seed planting. Widening the coverage of *mobile networks,* especially in rural areas, supports access to early warning systems.

In an urban context, weather-resilient infrastructure, including extensive drainage and broad beaches, can protect cities from coastal flooding and erosion (Hinkel and others 2012). Because of such efforts, Mozambique's Beira port—a major regional trade and transportation hub—was able to resume operations three days after being hit by cyclone Idai, and rail and road connections were operational within two weeks (Figure 2.13; Box 2.2).

Migration and Urbanization

As rural populations seek relief from the consequences of climate change (where agricultural communities are the most adversely affected), many people move to cities, resulting in rapid urbanization, which requires a multipronged approach. Expansion of urban infrastructure (housing, drainage, sanitary facilities, and roads), health care, education, and targeted social assistance programs, in addition to improved labor market flexibility and access to finance, will facilitate this relocation of people and capital across geographic areas and sectors of production.

Figure 2.13. Beira Port in Mozambique: Total Traffic, 2018–19



Source: Cornelder de Moçambique.
Note: Cyclones Idai and Kenneth hit Beira Port in March–April 2019.

FINANCING ADAPTATION

Responding to climate change by financing adaptation measures will be expensive for sub-Saharan Africa—estimated at US$30–50 billion (2–3 percent of regional GDP) each year over the next decade,[18] but substantially less costly than frequent disaster relief.

- This chapter's analysis of Post-Disaster Needs Assessments finds that up-front investment in resilience and coping mechanisms results in long-term savings (measured by reduced disaster relief spending) that are almost three times the up-front investment cost for droughts and about 12 times the up-front investment cost for storms (Figure 2.14). Hallegatte and others (2019) have similar findings.

- The broader benefits of building resilience are explored through a dynamic general equilibrium model (Box 2.3). The results highlight that public debt levels rise by less than 25 percent of the scenario where resilience is not built (even when resilient infrastructure is 25 percent more expensive than regular infrastructure), and the post-disaster widening of inequality is markedly contained. Efficiency gains in construction, operations, and management could reduce the cost of building resilient infrastructure (Rozenberg and Fay 2019).

- Some non-infrastructure adaptation measures are more affordable and could be implemented quickly. For example, programs supporting farmers in purchasing improved seeds and

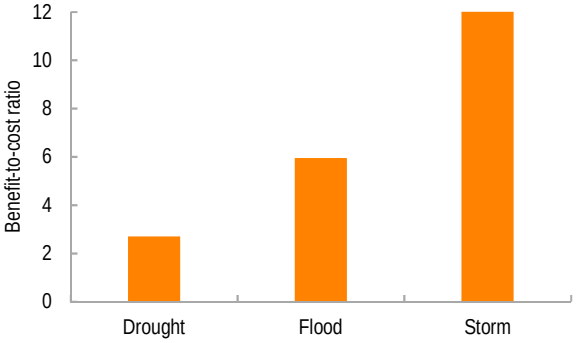
[18] This is derived from Narain, Margulis, and Essam (2011) and UNEP (2016).

other crop-protection measures and those that provide early warnings on weather events show relatively high benefit-to-cost ratios (Hallegatte 2012; GCA 2019). The same applies for swift and targeted social assistance—Ethiopia spent only 1.2 percent of GDP annually and achieved remarkable results for households facing food insecurity (Del Ninno, Coll-Black, and Fallavier 2016).

Despite its benefits, financing adaptation is challenging for sub-Saharan African countries constrained by limited fiscal space. Most of these countries already face moderate to high debt vulnerabilities, which have been further aggravated by the high costs of containing and managing the COVID-19 pandemic. Consequently, before taking on additional debt obligations, countries have to consider competing development needs (notwithstanding some overlap across policies). Countries are actively pursuing reforms to mobilize more revenues (including through environmental taxes) and improve spending efficiency, but their scope is limited, and progress is slow. Oil and coal exporters face the additional challenge of shrinking revenues if global mitigation measures move forward—emphasizing the criticality for these countries to step up economic diversification.[19] In this context, some countries have created disaster funds, including Mozambique, where part of the financing comes from annual budget allocations. Sub-Saharan African countries are also finding ways to support each other—for example, the African Risk Capacity is a regional macroeconomic insurance program with 34 member countries as of March 2020. Using macroeconomic insurance products, such as climate funds and issuing state-contingent bonds, has so far been difficult given large risk premiums, which partly reflect governance issues in many sub-Saharan African countries that raise the risk aversion of investors and development partners.

The international community can make a meaningful difference. Development partners should expand support beyond disaster relief to target resilience building and bolster coping mechanisms (including the provision of international insurance products). It is not only a humanitarian obligation but will help offset the failure of those most responsible for climate change to fully internalize the costs of greenhouse gas emissions (October 2017 *World Economic Outlook,* Chapter 3; IMF 2019a). Estimates of financing needs for developing countries far exceed the pledged US$25 billion of international public finance for adaptation (Puig and others 2016). Moreover, development partner–financed resilient infrastructure achieves the same welfare level as frequent disaster relief, with at least a 30 percent cost savings (Cantelmo, Melina, and Papageorgiou 2019).

Figure 2.14. Sub-Saharan Africa: Post-Disaster Savings Relative to Cost of Building Resilience



Sources: Post-Disaster Needs Assessment; Centre for Research on the Epidemiology of Disasters, Emergency Events Database; and IMF staff calculations.

Note: The frequency of disasters and the damage at the time of a disaster in the Emergency Events Database are applied to calculate the expected damage for 20 years. Resilience building is assumed to halve the expected damage. The cost of resilience building is inferred from Post-Disaster Needs Assessment estimates of medium-term and long-term financing needs.

International financial institutions can also play an active role (IMF 2019a). They can unlock finance pools for adaptation through a range of instruments (including loans and guarantees) and by reducing the investment risk. The IMF has been increasingly involved in the region's resilience building and ex post execution of recovery plans by providing financial assistance, policy advice, and capacity building. For example, in the aftermath of cyclones Idai and Kenneth, the IMF provided US$130 million in support to Comoros and Mozambique through the Rapid Credit Facility and US$40 million to Malawi by augmenting the existing Extended Credit Facility. Efforts to develop policies and capacity in response to climate change challenges include the joint work of the IMF and the World Bank on Seychelles' Climate Change Policy Assessment (IMF 2017).

[19] Full implementation of pledges under the Paris Agreement, which aims to contain global temperature increases to 2°C above pre-industrial levels, would lower the projected crude oil price to US$113 per barrel by 2040 (October 2019 *Fiscal Monitor*, Chapter 1). However, experts believe a more ambitious climate change mitigation scenario is needed to achieve the "two-degree limit," which would result in crude oil prices of US$64 per barrel in 2040 (IEA 2018).

Box 2.1. What's the Difference between Mitigation and Adaptation?

Responding to climate change generally involves two approaches: mitigation (reducing or stabilizing heat-trapping greenhouse gases in the atmosphere) and adaptation (adjusting to changes in the climate). Chapter 1 of the October 2019 *Fiscal Monitor*, IMF (2019b), and Nyiwul (2019) provide details.

- Mitigation can be achieved by (i) reducing greenhouse gas emissions (examples include transitioning to green energy sources and charging for carbon emissions from fossil fuels through carbon taxation or emissions trading), and (ii) taking existing greenhouse gases out of the atmosphere through forestation, agricultural practices that sequester carbon in soils, ocean fertilization, and developing technology that captures and sequesters carbon dioxide from the air (still in the early stages of development).
- Adaptation measures include (i) resilience building (reducing exposure and vulnerability to climate change), and (ii) improving coping mechanisms (measures that help buffer the impact from climate change, such as disaster relief).

Mitigation and adaptation measures overlap in some cases. For example, preserving and expanding the Congolese rainforest (one-quarter of the world's remaining tropical forests) would remove carbon dioxide from the atmosphere. At the same time, the forest reduces exposure and vulnerability to climate change by regulating water (for example, forest cover increases rainwater infiltration and replenishes streams), reducing erosion, and allowing the development of forest products that can be alternative sources of income for farmers hurt by climate change (WRI 2011).

Box 2.2. Case Studies: Adaptation Strategies Taken in Sub-Saharan Africa

Several countries in sub-Saharan Africa have already developed successful adaptation strategies that could serve as models for other countries.

Raising agricultural productivity:

- In Ethiopia, countering wheat rust (induced by increased temperatures and rainfall volatility) by developing rust-resistant wheat varieties is increasing yields by 30–40 percent for some farmers (Jaleta and others 2019). Developed by the International Centre for Agricultural Research in the Dry Areas and the Ethiopian Institute of Agricultural Research, the seeds were distributed to smallholder farmers, who accelerated the distribution process by multiplying and distributing the seeds to their neighbors (CGIAR 2013).
- Farmers in Chad are improving water retention through a rainwater harvesting technique called Zaï. This involves digging small pits to capture rainwater and sowing crops in them. They also practice agroforestry, which combines crops and trees in the same patch of land to reduce erosion during heavy rainfalls.
- Ghana has taken a multipronged approach to improve cocoa's drought resistance by distributing improved seed varieties, planting non-cocoa trees to provide shade, improving irrigation systems and cocoa plant fertility, rehabilitating aged and disease-infected farms, and raising farmer awareness about improved cultivation methods.
- Mozambique is beginning a global pilot to test new heat-tolerant bean seeds developed by the International Center for Tropical Agriculture.

Risk sharing (Ethiopia): The Productive Safety Net Program, providing cash and in-kind transfers to the food insecure, has helped improve financial inclusiveness by requiring bank accounts for the transfers. Using these transfer systems has helped to improve the efficiency of emergency responses to natural disasters and, combined with improved seeds, has lowered food shortages from 22 percent to 10 percent during 2011–16 (World Bank 2019).

Renewable energy investment (Kenya): Kenya is aiming for universal energy access by 2022 using off-grid systems such as mini-grids and stand-alone solar systems (World Bank 2018). The electricity

Box 2.2 *continued*

access rate has already increased from about 40 percent to 70 percent during 2012–17 (according to the World Bank World Development Indicators Database). This pay-as-you-go solar energy model receives inputs from decentralized and small-scale, off-grid solar-powered energy plants. It facilitates expansion by using low-cost mobile money technologies for payment. Given the support needed for installation, long-term technical assistance, and customer support, this system is also producing 10 times more jobs than traditional utilities (GOGLA 2018).

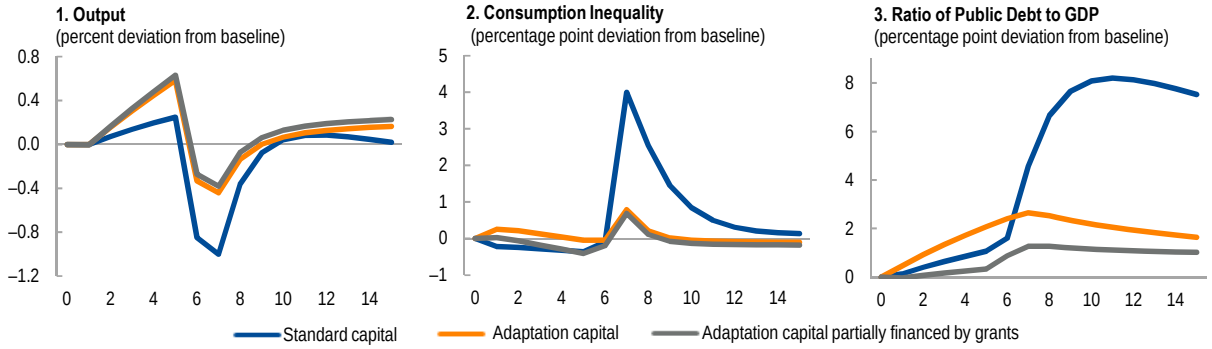
Upgrading infrastructure in coastal cities (Mozambique): Cyclones Idai and Kenneth killed more than 600 people and affected almost 2 million in Mozambique. However, the resilience of the infrastructure in the port of Beira—a regional container shipping hub that is exposed to floods and sea level rises—prevented further loss of life and allowed the port to quickly resume operations. To this end, upgrading the primary drainage system to reduce flooding risks and contingency planning by the port's firms were elemental. Solar-powered street lighting withstood the cyclones and became one of the city's few sources of post-disaster lighting. Emergency restoration of transport and logistic services were critical to distributing aid.

Box 2.3. Macroeconomic Gains from Resilient Infrastructure

Investing in resilient infrastructure, though costly, benefits long-term growth and reduces inequality. This chapter's simulations, based on the dynamic general equilibrium model of Marto, Papageorgiou, and Klyuev (2018) and Buffie and others (2012), illustrate this point (Figure 2.3.1). The negative impact of a natural disaster (assumed to hit in year 6) on output is considerably lower when a country spends additional funds on more resilient infrastructure versus investing in cheaper but less resilient infrastructure (over the previous five years, for example). Although post-disaster consumption inequality always widens across households, the gap is much less pronounced in the presence of resilient infrastructure, which shelters poor households from consumption cuts.

Ultimately, investing in resilient infrastructure reduces the toll of climate shocks on public debt. Before a disaster strikes, resilient infrastructure requires faster accumulation of public debt because it is more costly than investments in standard infrastructure. However, after a disaster, rebuilding costs are limited in a scenario with resilient infrastructure. By contrast, a disaster damages or destroys standard infrastructure, and reconstruction costs weigh on debt to a larger extent. Grant financing of a portion of resilient infrastructure would considerably reduce the impact on public debt.

Figure 2.3.1. Sub-Saharan Africa: Simulated Impacts of Natural Disaster



Source: IMF staff calculations.

Note: Simulations are produced with the model outlined in Marto, Papageorgiou, and Klyuev (2018). The model is matched with an economy that has sub-Saharan African averages for macroeconomic indicators. Public investment is assumed to be scaled up by 1 percent of GDP annually in years 1–5 in standard infrastructure (first alternative scenario) and resilient infrastructure (second alternative scenario). In the third alternative scenario, grants cover 80 percent of investment in resilient infrastructure. A natural disaster occurs in year 6 and is calibrated to yield a fall in output of 1 percent under the first scenario. Consumption inequality is (i) the percent change of consumption of households with access to finance from the baseline, minus (ii) the percent change of consumption of financially constrained households from the baseline.

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