McKinsey Global Institute

Climate risk and response: Physical hazards and socioeconomic impacts

How will African farmers adjust to changing patterns of precipitation?

Case study

May 2020

McKinsey Global Institute

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Introduction to case studies

In January 2020, the McKinsey Global Institute published *Climate risk and response: Physical hazards and socioeconomic impacts*. In that report, we measured the impact of climate change by the extent to which it could affect human beings, human-made physical assets, and the natural world. We explored risks today and over the next three decades and examined specific cases to understand the mechanisms through which climate change leads to increased socioeconomic risk. This is one of our case studies, focused on agriculture in Africa.

We investigated cases that cover a range of sectors and geographies and provide the basis of a “micro-to-macro” approach that is a characteristic of McKinsey Global Institute research. To inform our selection of cases, we considered over 30 potential combinations of climate hazards, sectors, and geographies based on a review of the literature and expert interviews on the potential direct impacts of physical climate hazards. We found these hazards affect five different key socioeconomic systems: livability and workability, food systems, physical assets, infrastructure services, and natural capital.

We ultimately chose nine cases to reflect these systems and based on their exposure to the extremes of climate change and their proximity today to key physiological, human-made, and ecological thresholds (Exhibit 1). As such, these cases represent leading-edge examples of climate change risk. Each case is specific to a geography and an exposed system, and thus is not representative of an “average” environment or level of risk across the world. Our cases show that the direct risk from climate hazards is determined by the severity of the hazard and its likelihood, the exposure of various “stocks” of capital (people, physical capital, and natural capital) to these hazards, and the resilience of these stocks to the hazards (for example, the ability of physical assets to withstand flooding). We typically define the climate state today as the average conditions between 1998 and 2017, in 2030 as the average between 2021 and 2040, and in 2050 between 2041 and 2060. Through our case studies, we also assess the knock-on effects that could occur, for example to downstream sectors or consumers. We primarily rely on past examples and empirical estimates for this assessment of knock-on effects, which is likely not exhaustive given the complexities associated with socioeconomic systems. Through this “micro” approach, we offer decision makers a methodology by which to assess direct physical climate risk, its characteristics, and its potential knock-on impacts.

Climate science makes extensive use of scenarios ranging from lower (Representative Concentration Pathway 2.6) to higher (RCP 8.5) CO_2 concentrations. We have chosen to focus on RCP 8.5, because the higher-emission scenario it portrays enables us to assess physical risk in the absence of further decarbonization. Such an “inherent risk” assessment allows us to understand the magnitude of the challenge and highlight the case for action. (We also choose a sea level rise scenario for one of our cases that is consistent with the RCP 8.5 trajectory). Our case studies cover each of the five systems we assess to be directly affected by physical climate risk, across geographies and sectors. While climate change will have an economic impact across many sectors, our cases highlight the impact on construction, agriculture, finance, fishing, tourism, manufacturing, real estate, and a range of infrastructure-based sectors. The cases include the following:

— For livability and workability, we look at the risk of exposure to extreme heat and humidity in India and what that could mean for that country's urban population and outdoor-based sectors, as well as at the changing Mediterranean climate and how that could affect sectors such as wine and tourism.

— For food systems, we focus on the likelihood of a multiple-breadbasket failure affecting wheat, corn, rice, and soy, as well as, specifically in Africa, the impact on wheat and coffee production in Ethiopia and cotton and corn production in Mozambique.

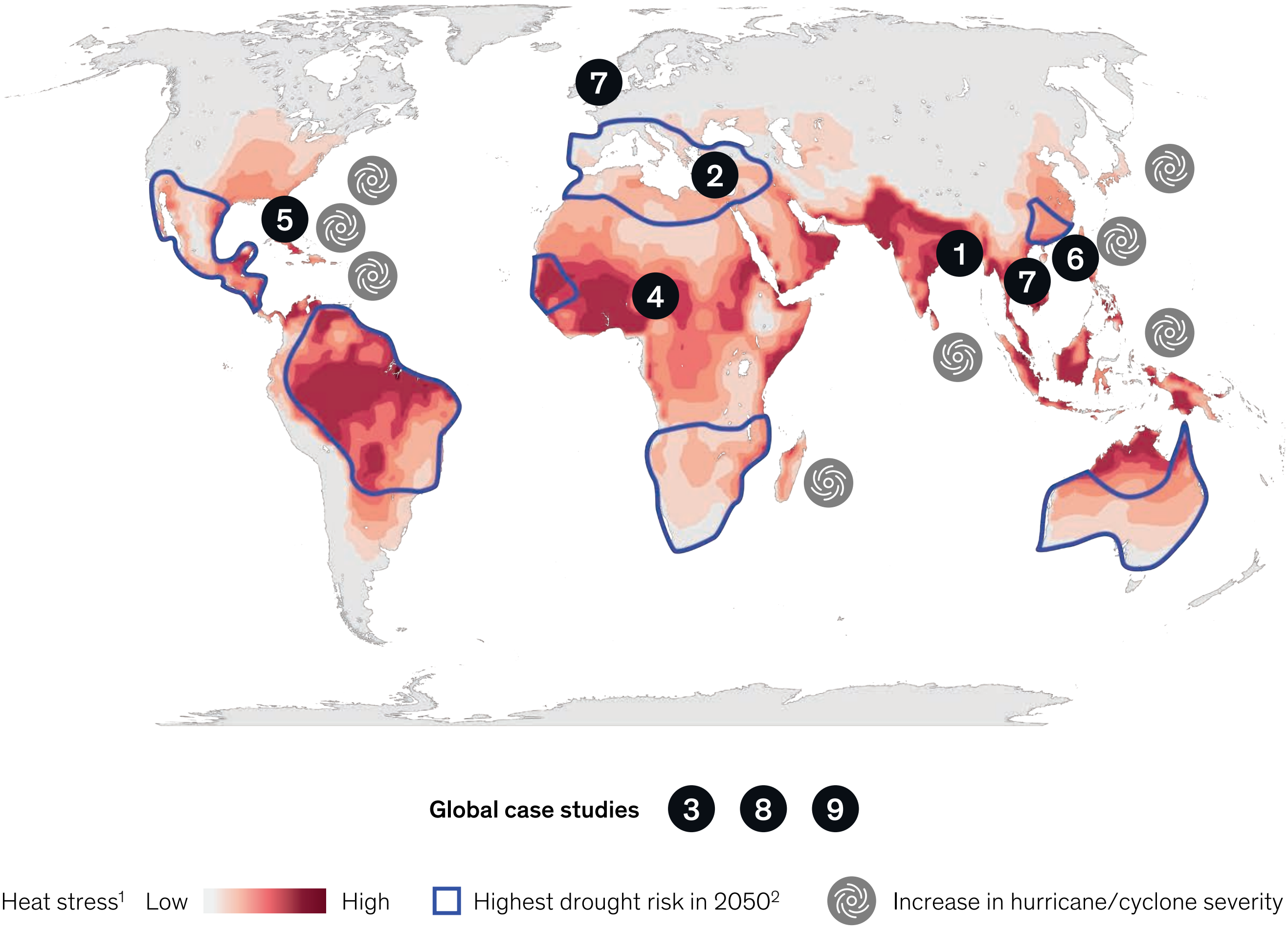
— For physical assets, we look at the potential impact of storm surge and tidal flooding on Florida real estate and the extent to which global supply chains, including for semiconductors and rare earths, could be vulnerable to the changing climate.

— For infrastructure services, we examine 17 types of infrastructure assets, including the potential impact on coastal cities such as Bristol in England and Ho Chi Minh City in Vietnam.

— Finally, for natural capital, we examine the potential impacts of glacial melt and runoff in the Hindu Kush region of the Himalayas; what ocean warming and acidification could mean for global fishing and the people whose livelihoods depend on it; as well as potential disturbance to forests, which cover nearly one-third of the world's land and are key to the way of life for 2.4 billion people.

Exhibit 1

We have selected nine case studies of leading-edge climate change impacts across all major geographies, sectors, and affected systems.



Livability and workability	1	Will India get too hot to work?
	2	A Mediterranean basin without a Mediterranean climate?
Food systems	3	Will the world's breadbaskets become less reliable?
	4	How will African farmers adjust to changing patterns of precipitation?
Physical assets	5	Will mortgages and markets stay afloat in Florida?
	6	Could climate become the weak link in your supply chain?
Infrastructure services	7	Can coastal cities turn the tide on rising flood risk?
	8	Will infrastructure bend or break under climate stress?
Natural capital	9	Reduced dividends on natural capital?

1. Heat stress measured in wet-bulb temperatures.
2. Drought risk defined based on time in drought according to Palmer Drought Severity index (PDSI).

Source: Woods Hole Research Center; McKinsey Global Institute analysis

Rural communities facing hotter, drier conditions.

Agriculture in Africa

How will African farmers adjust to changing patterns of precipitation?

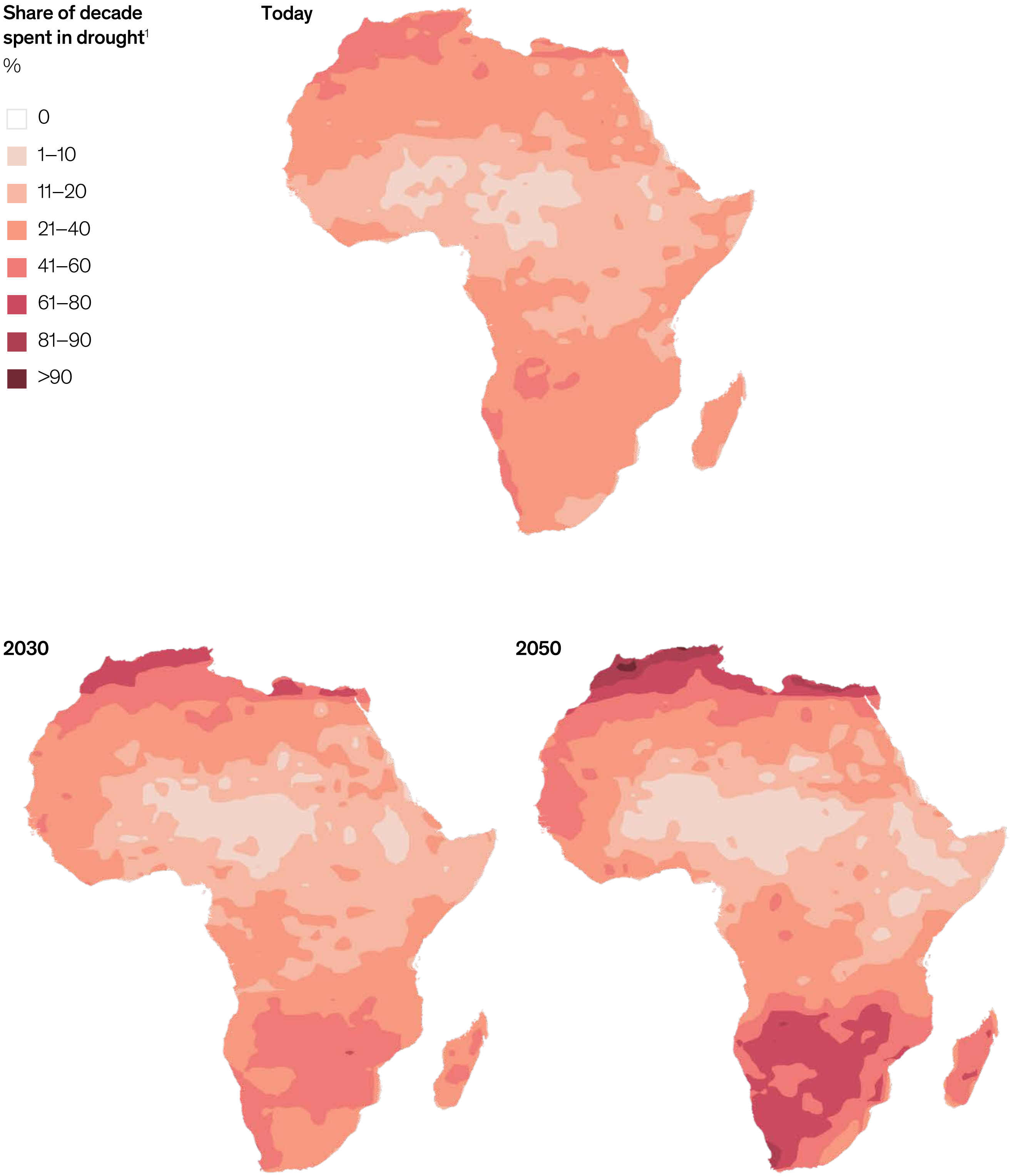
Agriculture is critical to Africa's economic growth and development, generating more than one-fifth of sub-Saharan Africa's economic output. But much of African agriculture lags behind more developed systems. Very little cropland is irrigated (African livestock and cropping systems are 95 percent rainfed), the use of improved seeds and fertilizer is expanding but remains limited, and 50 to 85 percent of farming work is done manually, without machinery or even draft animals.[1] Because of these conditions, modernizing Africa's agriculture and food systems is an effective way to improve the lives of millions in poverty and accelerate economic growth.[2]

Climate change, however, is expected to make agricultural development in Africa more challenging in many places. Weather patterns are becoming less favorable in most instances, increasing the volatility of crop and livestock yields. The frequency and/or severity of extreme events is increasing as temperatures are projected to continue rising, and rainfall patterns are expected to shift more than they have already (Agriculture in Africa-1, -2, and -3). It is important to note that this volatility may vary considerably across crops and countries. Many indirect effects of climate change can cause harm, too. The health of livestock, for example, is at risk from changes in the quantity and quality of forage, the availability of water, and extreme heat. Climate change also alters the evolution and movement of pests and diseases and can weaken the defenses of crops and livestock. Overall, Africa is vulnerable because for many of its crops, it is at the edge of physical thresholds beyond which yields decline. Finally, some aspects of adaptation may be challenging; for example, African farmers are generally more vulnerable to higher temperatures, fluctuations in rainfall, and variable yields than farmers in developed countries, who can usually more easily secure crop insurance, adjust what they plant, irrigate their fields, or apply crop-protection chemicals or fertilizer.

1 Malabo Montpellier Panel, *Mechanized: Transforming Africa's agriculture value chains*, 2018.
2 Sara Boettiger, Nicolas Denis, and Sunil Sanghvi, "Successful agricultural transformations: Six core elements of planning and delivery," McKinsey and Company, December 2017.

Expected evolution of drought differs by region in Africa, with the most affected areas in the north and south.

Based on RCP 8.5



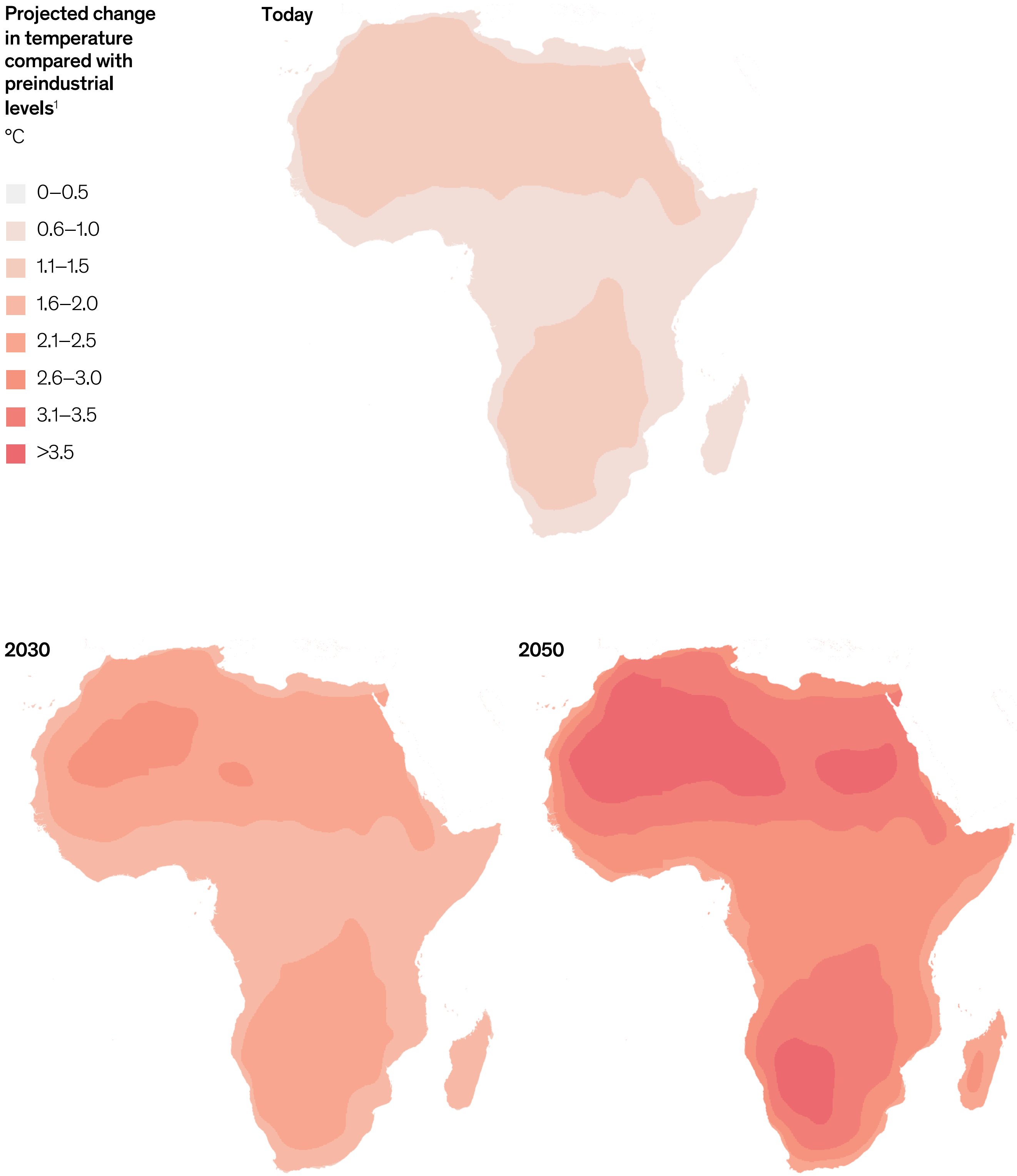
1. Drought is defined as a rolling 3-month period with Average Palmer Drought Severity Index (PDSI) <-2. PDSI is a temperature- and precipitation-based drought index calculated based on deviation from historical mean. Values range from +4 (extremely wet) to -4 (extremely dry).

Note: See the Technical Appendix of the full report for why we chose RCP 8.5. All projections based on RCP 8.5, CMIP 5 multi model ensemble. Heat data bias corrected. Following standard practice, we define current and future (2030, 2050) states as average climatic behavior over multidecade periods. Climate state today is defined as average conditions between 1998 and 2017, in 2030 as average between 2021 and 2040, and in 2050 as average between 2041 and 2060.

Source: Woods Hole Research Center; McKinsey Global Institute analysis

Average temperatures in Africa are expected to increase in most regions, with increases of more than 3.5°C from preindustrial levels in some areas in the north and south.

Based on RCP 8.5



1. Preindustrial levels defined as period between 1880 and 1910.

Note: See the Technical Appendix of the full report for why we chose RCP 8.5. All projections based on RCP 8.5, CMIP 5 multi model ensemble. Heat data bias corrected. Following standard practice, we define current and future (2030, 2050) states as average climatic behavior over multidecade periods. Climate state today is defined as average conditions between 1998 and 2017, in 2030 as average between 2021 and 2040, and in 2050 as average between 2041 and 2060.

Source: climate-lab-book.ac.uk; KNMI Climate Explorer, 2019; Woods Hole Research Center

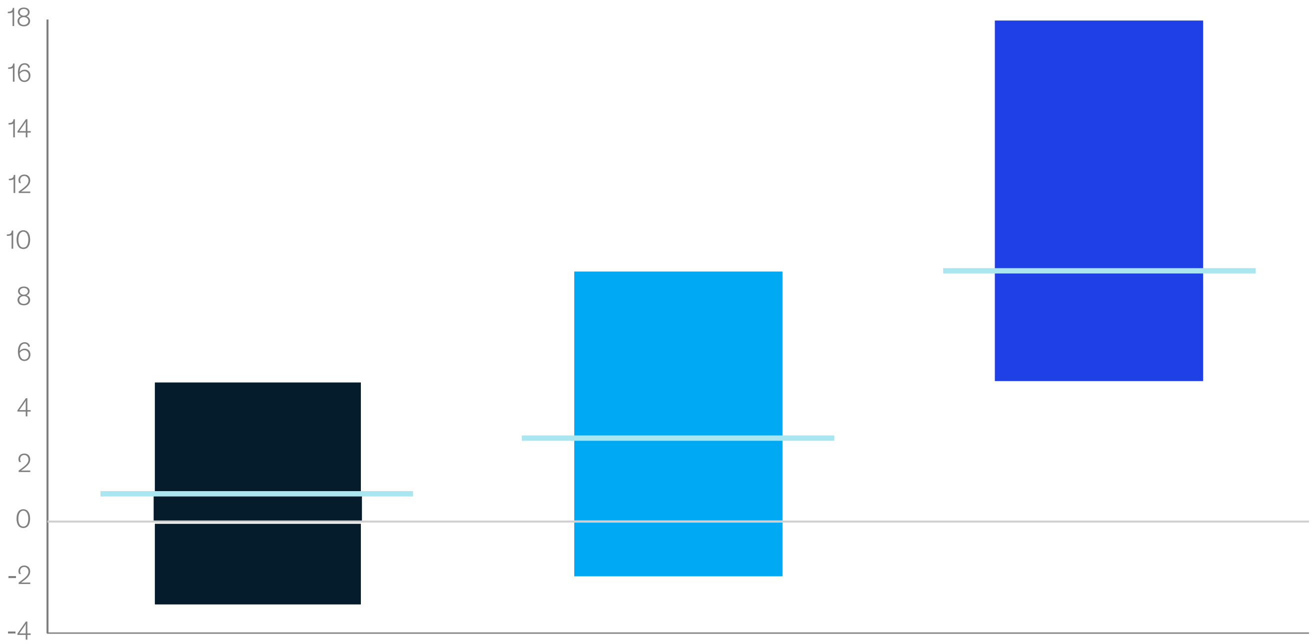
The number and intensity of extreme weather events in sub-Saharan Africa are forecast to increase.

Projected change in sub-Saharan Africa by mid-century, compared to today[1]

25th–75th percentile[2] West Africa East Africa Southern Africa Median

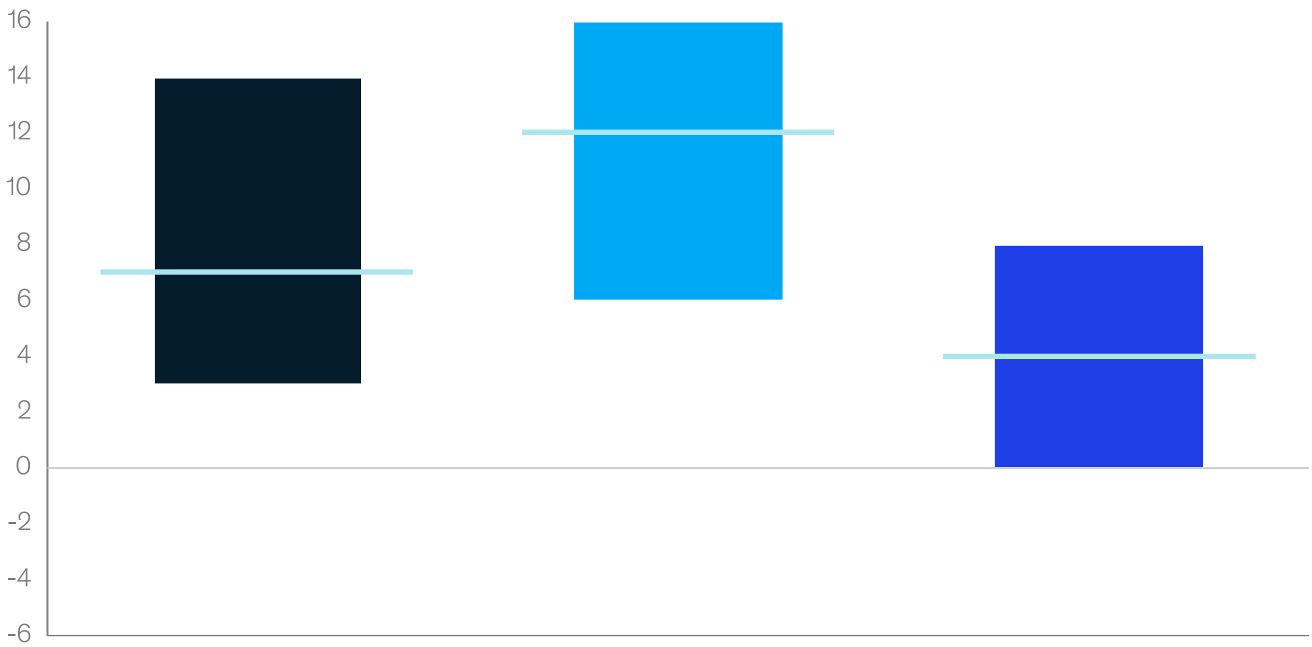
Projected change in maximum dry spell length

Days



Projected change in 5-day precipitation

%



1. When global mean temperature exceeds 2°C above preindustrial levels (projected to be reached in approximately 2050 under RCP 8.5).
2. Boxes represent interquartile range from 25th to 75th percentile centered around the median and therefore contain half of all datapoints.

Source: ETH Zurich

In this case study, we focus on major crops in Ethiopia and Mozambique. Using crop yield models, we assess the expected impact of climate change in 2030 on wheat and coffee in Ethiopia and on corn (maize) and cotton in Mozambique.[3] According to our yield projections and to economic projections developed by the International Food Policy Research Institute (IFPRI), increased volatility in African agricultural systems, which already suffer from widely varying output and quality, could destabilize local markets (through supply shocks), curb economic growth, and heighten risk for agricultural investors. While volatility is often symmetric, meaning positive and negative shocks are roughly equally likely, the overall effect of increasing volatility is negative. Farmers and other players in the value chain usually do not fully capture the benefits from good years due to a limited ability to sell bumper harvest into shallow local markets, absence of storage infrastructure to smooth supply over many years, and poor transportation infrastructure that makes sale into other markets difficult. At the same time, a bad year can have longer-lasting effects for farmers. Subsistence farmers in particular may have to incur debt (or end up defaulting on existing debt).

Specifically, we find that by 2030, Ethiopia's wheat farmers are projected to face an 11 percent greater likelihood than today of a 10 percent or greater drop in annual yield.[4] For coffee farmers in Ethiopia, the chance of experiencing a 25 percent or greater drop in annual yield could climb from 3.2 percent to 4.2 percent in 2030, a 31 percent increase, and a 28 percent cumulative likelihood over the next decade.[5] Should yield shocks of this magnitude take place for both crops in the same year, we estimate that Ethiopia's GDP growth rate would be cut by approximately three percent. In Mozambique, we find a large seasonal loss (more than 30 percent) of the corn crop is expected to go from a highly improbable event to a 100-year event. We estimate that a 25 percent or greater drop in corn yields would reduce Mozambique's GDP by 2.5 percent. Conversely, we find that cotton yields would become more stable; however, given the small size of cotton farming, this does not provide a strong counterbalance to the negative impacts on corn (Agriculture in Africa-4). It is important to note that Africa is a climatologically diverse continent and that the results presented here are not representative of the challenges or changes faced by other African nations. Climate change will affect some regions of Africa more or less than it affects Ethiopia and Mozambique.

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3 To estimate the impact of climate change on African agriculture, we leveraged insights from ACRE, McKinsey's center of excellence for advanced analytics in agriculture. ACRE's crop yield models were applied to assess the impact of climate change on corn and cotton in Mozambique and wheat and coffee in Ethiopia in 2030. Yield, crop acreage, and historical observed weather data were used to train statistical models that predicted future yields using the CORDEX ensemble of regional climate models. First, historical yield data were detrended to isolate the effects of climate on yield by removing external effects such as technology change and sociopolitical events. Modeled future climate scenarios were also debiased in order to make observed and projected data comparable. Then crop-specific features were created. Machine-learning-based models were used to select the best predictors of yield performance for each crop, and based on that, yield response under various climate scenarios were modeled on climate data for 2020–40. If not indicated differently, we follow standard practice and define current and future (2030, 2050) states as average climatic behavior over multidecade periods. Climate state today is defined as average conditions between 1998 and 2017, in 2030 as average between 2021 and 2040, and in 2050 as average between 2041 and 2060. Also, if not indicated differently, the climatological analyses in this case use RCP 8.5 to represent the changes in atmospheric greenhouse gas concentrations that could occur absent a mitigation response. Please see technical appendix of the full report for details.

4 Yield decline scenarios for each country crop combination were selected based on two considerations: the scenario is plausible, i.e., the likelihood of occurrence is meaningful for most stakeholders (i.e., once in a generation); and, the decline is meaningful in terms of economic impact.

5 This calculation is a rough approximation. It assumes that the annual probability of 3.2 percent applies to every year in the next decade.

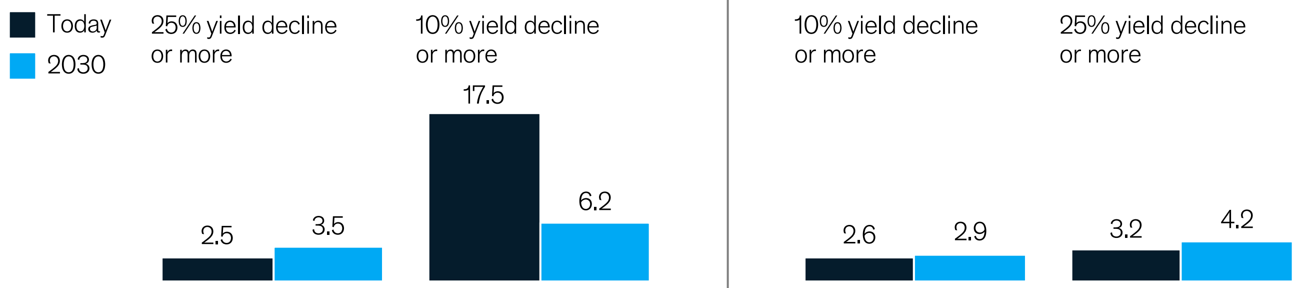
The effects of climate change on African crop yields in 2030 are projected to be uneven.

Based on RCP 8.5

	Mozambique		**Ethiopia**	
	Corn (maize)	**Cotton**	**Wheat**	**Coffee**

Likelihood of extreme yield changes[1]

%



Main climatological drivers

	Corn (maize)	Cotton	Wheat	Coffee
Positive	Increasing rainfall during rainy season, which coincides with crop development	Rising temperatures from October–December	Minimum temperatures during wheat reproductive and primary growth phases are increasing	
Negative	Temperatures are rising and rainfall is decreasing around time of planting, potentially delaying planting	Less rainfall at end of dry season (October) may delay planting	Majority of wheat-growing regions will experience less rainfall	Temperatures are increasing and rainfall is decreasing during flowering and early fruit development, resulting in decreased water availability

1. Change in yield in a given year, relative to long-term average. Yield decline scenarios for each country crop combination were selected based on two considerations: the scenario is plausible, ie, the likelihood of occurrence is meaningful for most stakeholders (eg, once in a generation); and the decline is meaningful in terms of economic impact.

Note: See the Technical Appendix of the full report for why we chose RCP 8.5. All projections based on RCP 8.5, CMIP 5 multimodel ensemble. Heat data bias corrected. Following standard practice, we define current and future (2030, 2050) states as average climatic behavior over multidecade periods. Climate state today is defined as average conditions between 1998 and 2017, in 2030 as average between 2021 and 2040, and in 2050 as average between 2041 and 2060.

Source: CORDEX regional climate models; McKinsey Global Institute analysis

By 2030, Ethiopia may face significant volatility in coffee yields but little change in wheat yields

Ethiopia, Africa's second-most-populous country, depends heavily on agriculture, which accounts for about one third of GDP.[6] More than 7 in 10 Ethiopians depend on income from agriculture, and smallholder farmers produce 95 percent of the country's agricultural output. The country has made major improvements to its agriculture and food systems in recent years. Ethiopia has expanded irrigation faster than any other African country, with irrigated farmland increasing more than 50 percent between 2002 and 2014.[7] The country also invested in a digital soil-fertility map in 2012, which now informs recommendations for crop-specific fertilizers across agricultural areas.[8] Although challenges remain, Ethiopia's food security has become more robust in recent decades and the poverty rate fell from 44 percent in 2000 to 21 percent in 2018.[9] These achievements have set the country on a trajectory to reach the United Nations Sustainable Development Goal of eradicating extreme poverty by 2032.

However, climate change could hinder Ethiopia's continued agricultural development. To illustrate how these trends will influence Ethiopia's food security and agricultural exports, we modeled their effects on wheat and coffee.[10]

Wheat provides 13 percent of the calories Ethiopians consume.[11] It is also essential to the welfare of many Ethiopian households. Some 4.7 million of Ethiopia's 12 million farming households depend on income from selling the wheat they grow, largely on small, rainfed plots of land.[12] Ethiopia's wheat production increased fourfold during the decade ending in 2015–16, largely because of land expansion, investment in infrastructure, and improvements in farming practices and technologies, such as the use of modern wheat varieties and fertilizers. Today, the country is among the top three wheat producers in Africa, but its domestic consumption continues to rise. More than a quarter of its domestic demand for wheat is met with subsidized imports.[13]

According to our projections, which focus on near-term (to 2030) changes in the probability distributions of yields due to changes in precipitation, climate change will cause only a slight increase in the volatility of wheat yields. We project that by 2030, Ethiopian wheat farmers will be 11 percent more likely to experience a 10 percent or greater decrease in yield in a given year than they are today. The same decrease becomes 23 percent more likely by 2050, according to our projections. These increases in volatility will likely be mitigated to some extent by changes in technology, such as more irrigation, increased fertilizer use, and new varieties of crops that are better adapted.[14]

6 IndexMundi 2019.
7 Gebisa Ejeta, "'Investment in irrigation is paying off for Ethiopia's fast-growing economy," *Quartz*, January 21, 2019.
8 Ethiopian ATA, "EthioSIS," 2019.
9 Khosla, Adya, "Successful development: Reducing poverty in Ethiopia," The Borgen Project, July 26, 2019.
10 Our analysis draws on climate data from 18 CORDEX models and a statistical model built to correlate past crop yield volatility to various temperatures and precipitation variables, detrending the data to isolate the effects of weather.
11 Food and Agriculture Organization of the United Nations, FAOSTAT, "Food balance sheets," fao.org/faostat/en/#data/FBS
12 Food and Agriculture Organization of the United Nations, "Ethiopia at a glance," fao.org/ethiopia/fao-in-ethiopia/ethiopia-at-a-glance/en. Only about 5 percent of wheat production comes from large-scale commercial farms; US Department of Agriculture Foreign Agricultural Service, *Ethiopia grain and feed annual report*, Global Agricultural Information Network (GAIN) report ET1903, March 2019.
13 Warmer areas of production are generally forecast to have yield losses, while wheat growing is likely to move into cooler regions where wheat production will benefit from warmer climate and extended growing season.
14 In addition, people change their farming practices and what they grow to adapt to the changing climate. Our analysis does not account for the potential migration of planting areas for a crop within a country. For farmers who can change what they grow, this can afford opportunities. For example, a high-latitude country like Canada is predicted to have significantly increased agricultural opportunities due to climate change. But in many countries, as the crop-growing regions shift, farmers will not be able to adapt.

The outlook for Ethiopia's coffee growers is less promising. Ethiopia is the top coffee producer in Africa and the tenth largest in the world.[15] Coffee is Ethiopia's most valuable export crop, responsible for more than one-third of the country's export earnings. Growing coffee provides many low-income families with their livelihoods: 95 percent of Ethiopia's coffee crop is produced by smallholder farmers.[16] Our analysis predicts that future shifts in precipitation will significantly increase the chance that Ethiopia's coffee farmers experience poor yields in any given season. The likelihood of a 25 percent or greater drop in coffee yields in a given year currently stands at 3.2 percent but could climb to 4.2 percent by 2030—a 31 percent increase; that is, a cumulative likelihood of 28 percent over the next decade.

To gauge the potential economic effects of changes in Ethiopia's wheat and coffee production, we relied on the economic modeling capabilities of IFPRI. Researchers there incorporated our near-term yield predictions in their country economic models. These models estimate how reduced crop production affects downstream sectors (such as food processing and trade) and the broader economy (for example, GDP, foreign trade, and rural and urban household incomes), along with input-output flows between sectors and consumers, accounting for macroeconomic and resource constraints (foreign exchange constraints on food imports, for example).[17]

IFPRI estimates that one-year yield declines in wheat of 10 percent or greater and coffee of 25 percent or greater would reduce Ethiopia's GDP growth rate in that year by approximately 3 percent.[18] This reduction would mainly come from the agriculture sector of the economy, which is projected to shrink by 8 percent as a result of the one-year yield shock. Minor (1 percent) contractions are projected to occur in downstream industries such as food processing. Agricultural exports are projected to decline by 17 percent, causing a 6 percent decline in total exports. The reduced wheat yield is also projected to increase agricultural imports by 9 percent as Ethiopia would likely buy more foreign wheat to make up for the shortfall in domestic production.

15 Calculated for 2017–18; US Department of Agriculture Foreign Agricultural Service, *Ethiopia coffee annual report*, GAIN report ET1904, May 2019.
16 US Department of Agriculture Foreign Agricultural Service, *Ethiopia coffee annual report*, GAIN report ET1904, May 2019.
17 Note that the structure of each economy is based on 2011 data for Ethiopia and 2012 data for Mozambique.
18 Likelihood of 2.9 percent in 2030 (one in 34 years), up from 2.6 percent in 2018; likelihood of 16.3 percent in 2030 (one in six years), up from 11.1 percent in 2018.

Mozambique faces greater volatility in corn production, a major driver of the country's economic output

Mozambique's economic development has been held back by the legacy of its long civil war, which left the country with eroded infrastructure and caused the displacement of about six million people. Approximately 70 percent of the population lives below the poverty line, and Mozambique ranks 180th out of 189 countries in the most recent UNDP Human Development Index. In 2018, more than one-fifth of the country's GDP came from agriculture.[19] Nearly three-quarters of Mozambique's population makes a living by raising livestock or crops. Two of the most important crops are corn, which is grown primarily as a food crop, and cotton, grown primarily as a cash crop for export.

Corn is widely grown in Mozambique. About 8 in 10 rural households cultivate it for their own consumption on small plots of land, and this practice can be observed in almost all of the country's agricultural production. Corn cultivation is highly susceptible to the projected local effects of climate change: rising temperatures and decreasing rainfall near the usual time of year when corn is planted could worsen planting conditions and potentially delay planting. Our analysis suggests that these effects will make corn yields more volatile. The likelihood of a large seasonal crop loss (one exceeding 30 percent) is currently near zero. By 2030, we project that such a loss will be a 100-year event. Similarly, our projections indicate that the likelihood of unusually high yields (20 to 30 percent greater than normal) will increase.[20]

Cotton growers in Mozambique, by contrast, are projected to experience more stability in yields as the effects of climate change take hold. Cotton grows well in the hot temperatures that are expected to become more common in Mozambique. We project that a 20 percent or greater drop in yields, compared with average yields, will be 95 percent less likely in 2030 than it was between 1990 and now. Barring other influences, like changes in pests, this reduction in volatility should help the many rural households that rely on cotton crops for much of their income. (Overall, cotton contributes about one-fifth of Mozambique's agricultural export earnings.) By the same token, exceptionally high crop yields are projected to become less likely. A 20 percent or greater jump in cotton yields now occurs about once every 17 years. By 2030, our projections suggest, such a result will be virtually impossible.

When IFPRI modeled the economic impacts of higher volatility in corn and lower volatility of cotton yields, it became clear that the increased volatility of corn yields has a significant economic impact, while the change in the volatility of cotton yields makes relatively little economic difference. Regardless of how cotton yields change, a 25 percent decline in corn yields in a given year is projected to reduce Mozambique's economic output by roughly 2.5 percent in that year. (Even the highest projected change in cotton yields would change economic output by just one-tenth of one percent.) However, the decline in corn production would not alter Mozambique's balance of trade because most corn is grown for domestic consumption.

19 Statista.

20 Although the country's overall corn production is projected to become more volatile, the impacts that we modeled for corn crops obscure the possibility that impacts could differ from one area to another. Subnational predictions for agro-ecological zones will better inform country planning.

More localized planning and financial mobilization can help African agriculture counter climate-induced volatility

Higher volatility in the yields of major African food crops results in higher price volatility for both farmers and consumers. African countries are already working to counteract this volatility. Better and more localized planning and financial mobilization will be key.

Better planning for better investment decisions

Modernizing Africa's agriculture in the face of a changing climate will require significant investment. Investments in irrigation can increase the likelihood that farmers maintain yields even when the weather is unfavorable. Better roads contribute to improved market access for farmers, which helps with selling crops at fair prices. Improvements in the functioning of seed production systems provide farmers with new varieties of seed that are suited to new conditions. Upgraded crop-storage helps facilities prevent spoilage and food waste. One study estimated that fulfilling sub-Saharan Africa's agricultural potential will take investment of as much as $65 billion for irrigation, of which $3 billion would be required in Mozambique and $2.3 billion in Ethiopia.[21] Furthermore, McKinsey has estimated that at least $8 billion would be needed in sub-Saharan Africa for basic storage alone, along with further sums for infrastructure, fertilizer, and seed.[22]

All African governments are striving to furnish incentives for private investment in agriculture, but the uncertainty created by climate change works against them. Investors wish to understand the potential competitiveness (regionally or globally) of an agricultural commodity grown in a specific geography and what it takes to access the market. Decisions about infrastructure, agricultural subsidies, and investment in new production assets could be compromised unless they account for the near-term, local effects of changing climate. One analysis, for example, predicts that by 2050, the global area where coffee can grow will be reduced by half.[23] Potential investors in Ethiopia's coffee industry need to take into account the localized predictions of how climate change will affect the country's coffee production, as well as estimates of its impact on the global coffee supply.

Climate change's varying effects on regions and crops underscore the importance of targeted planning on the part of governments, investors, and international donors. Today's planning models have difficulty accounting for these effects. First, published projections of climate change's impacts typically focus on 2050 or 2100—too far out to aid nearer-term decisions.[24] Second, climate and economic models that focus on local contexts are less common than broader models. We believe that governments, companies, development banks, donors, and other organizations stand to benefit from bringing highly localized, commodity-specific forecasts into agricultural planning in Africa. Even if the models are imperfect, this information can improve estimates of potential competitiveness and future trade profitability.

Digital technologies can aid the efforts of agricultural planners to spot and adjust to the effects of climate change. In 2019, for example, the Kenyan government introduced a digital "food balance sheet," integrating data on corn stocks and trade to help planners see how much corn the country has at any one time and to make informed decisions about trade policies and emergency planning.[25]

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21 Liangzhi You et al., *What is the irrigation potential for Africa? A combined biophysical and socioeconomic approach*, IFPRI discussion paper number 993, International Food Policy Research Institute, 2010.
22 Lutz Goedde, Amandla Ooko-Ombaka, and Gillian Pais, "Winning in Africa's agricultural market," February 2019.
23 Christian Bunn et al., "A bitter cup: Climate change profile of global production of Arabica and Robusta coffee," *Climatic Change*, March 2015, Volume 129, Number 1–2.
24 Additionally, despite considerable progress in global climate modeling, African regional climate model development and evaluation are lagging. In regions where many lives depend on climate decision making about agricultural systems, stakeholders must do the best they can to rely on existing models and be prepared to update their analysis as the models improve. See Rachel James et al., "Evaluating climate models with an African lens," *Bulletin of the American Meteorological Society*, February 2018, Volume 99, Number 2.
25 Alberto Leny, "Big data is the sure seed for green revolution," PD Online, September 10, 2019.

Financial mobilization to support vulnerable communities

Wider access to agricultural financial instruments, such as crop insurance, would enable individual farmers and households to better manage climate-related risks. However, expanding crop insurance schemes may require support because most farmers are not able to pay the full premium. Based on previous programs, we estimate that for the 12 million farmers in Ethiopia, a total of approximately $800 million of assets would need to be insured.[26] Although greater access to insurance might encourage farmers to prepare for risks resulting from extreme weather events, it needs to be supported by other risk reduction measures—for instance, approaches described in the other case studies—because insurance cannot cover some climate related losses driven by long-term changes in temperatures, precipitation patterns as well as sea level rise.

Overseas development aid currently amounts to about $150 billion per year.[27] Increasingly, donors target problems related to climate change. For example, one widely accepted priority is ensuring that international crop and livestock breeding systems direct their research toward creating varieties of plants and animals that can cope with heat, droughts and flooding, pests, and diseases. However, many donors have their own, sometimes divergent views of priorities for helping African countries continue agricultural transformations within the context of climate change. Some focus on irrigation, some on precision agriculture solutions, others on drought-tolerant seed varieties. Many are investing in better data and modeling. The ability to translate climate change projections into planning forecasts may help international donors spend their money more effectively.

Overall, successful adaptation may depend primarily on changes in farmers' behavior (for example, storage improvements), institutional improvements (for example, localized, commodity-specific forecasts), as well as the collaboration of affected stakeholders on certain adaptation measures (for example, to solve storage issues).[28]

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26 For example, the World Food Programme established the R4 Rural Resilience Initiative in 2011 in Africa to compensate for climate-related losses; roughly 87,000 farmers took part in it in 2018. In Ethiopia, the initiative reached 29,300 farmers, with a total insured sum of approximately $2 million. World Food Programme and Oxfam America, *R4 Rural Resilience Initiative Annual Report January–December 2018*, April 2019.

27 OECD, Official Development Assistance.

28 Please see breadbasket failure case study for more details.

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