CHAPTER 8

Economics of Climate Adaptation for Resilient Food Systems in Africa

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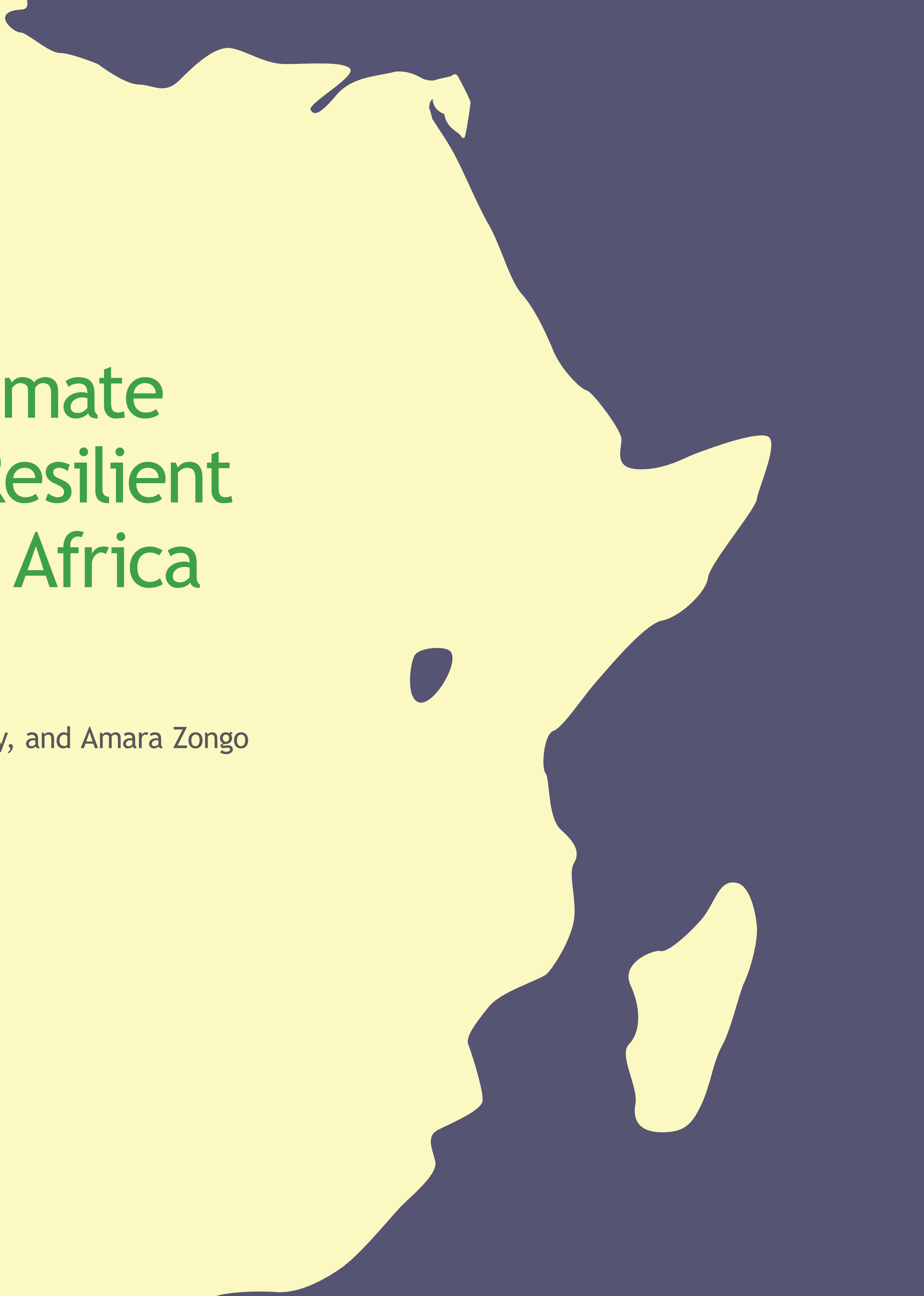

Introduction

Around 690 million people worldwide suffer from hunger daily, and two-thirds of people who are hungry live in rural areas. Meanwhile, the prevalence of undernourishment in Africa rose from 19.4 percent in 2021 to 19.7 percent in 2022, driven mostly by increases in northern and southern Africa. The number of people facing hunger in Africa has increased by 11 million people since 2021 and by more than 57 million people since the outbreak of the COVID-19 pandemic (FAO et al. 2023).

Climate extremes are the second leading cause of food insecurity in Africa, after armed conflict and before economic slowdowns and growing inequality (FAO et al. 2023). While there are significant uncertainties about Africa's climate future, models project that parts of northern, southwestern, and central Africa will continue to experience a drying trend—and almost all regions of the continent are expected to be struck by more frequent and more intense rainstorms, causing greater numbers of potentially devastating floods. Future warming will shorten growing seasons and increase water stress. A temperature increase of more than 2°C will result in yield reductions for staple crops across most of Africa, compared to 2005 yields (IPCC 2022). A temperature increase of 4°C or more above late-20th-century levels is expected to reduce maize and wheat yields in countries across Africa south of the Sahara by up to 50 percent (Mbow et al. 2019). Smallholder farming systems that continue to dominate the agriculture sector in many African countries have been recognized as highly vulnerable to climate change because farmers are heavily dependent on agriculture and livestock for their livelihoods (Mbow et al. 2019). African governments are well aware of the need to accelerate adaptation of the agriculture sector to a changing climate. Most have drafted National Adaptation Plans (NAPs) with the objective of integrating adaptation into new and existing national, sectoral, and subnational policies and programs, especially development strategies, plans, and budgets, and direct investments in strengthening the capacity of the population to cope with climate change.

The provision of food security and nutrition is one of three key functions of the food system, which comprises the entire range of actors, their interlinked value-adding activities, and the broader economic, societal, and physical environments in which they are embedded. Other functions of the food system include providing livelihoods for millions in agriculture and food production, as well as across the broader supply chain and complementary sectors, and contributing to the protection and enhancement of ecosystems (von Braun 2021). To build and sustain resilient, viable, and inclusive food systems, African countries are looking to galvanize the necessary set of individual and collective actions, including policy alignment and increased investments (African Union and AUDA-NEPAD 2021). Such a transformation of food systems has been linked to the aspirations of the 2063 Agenda and achievement of the Sustainable Development Goals (von Braun et al. 2021). Because these actions can only enhance the functioning of food systems if interventions account for climate risk, integrate the changes required to reduce climate risk to agrifood system–based livelihoods, and create the enabling conditions to implement these changes, the food system–climate change nexus needs further examination (African Union and AUDA-NEPAD 2021).

In this chapter, we examine this nexus, focusing on the food security function of food systems, and build the evidence base for policymakers to mainstream climate risk and adaptation solutions in food system transformation efforts. We discuss climate change in the next section, invoking the examples of Kenya and Mali. The third section addresses climate risk and its components using national-level examples from Kenya, Mali, Nigeria, and Senegal and farm-household-level data from Ethiopia and Niger. In the fourth section, we assess the economic implications of climate change for Kenya, Mali, Nigeria, and Senegal, followed in the fifth section by a discussion of the economic potential of two adaptive production strategies—soil and water conservation measures and use of improved seed—using the cases of Kenya and Mali. In the sixth section, we examine adoption drivers for these adaptive strategies and diverse environments using the examples of Ethiopia and Niger. In the seventh section, we develop a microregion climate risk typology and, using the examples of Ethiopia and Niger, discuss how such a typology could improve the targeting as well as the efficiency of interventions that reduce the risk of food insecurity. We conclude by drawing out four key findings for policymakers.

Climate Change

Africa's climate and weather are largely controlled by the El Niño–Southern Oscillation (ENSO), a weather system driven by changes in atmospheric and ocean circulation across the equatorial Pacific Ocean, and by two monsoons. The West African monsoon brings rain to the western Sahel from June to September, and the East African monsoon drops precipitation in eastern and central Africa from March to May and from October to December. In addition, Africa's east coast is regularly struck by strong cyclones. Variations in these large-scale climate phenomena have enormous implications for the amounts and patterns of rainfall and storms in individual African countries and have historically caused numerous natural disasters such as floods and droughts. Now, however, climate change is increasing the frequency and intensity of those extreme weather events. The number of floods in Africa has jumped fivefold since the 1990s, and many floods are more extreme. Droughts are becoming more intense as well. Asian monsoon lows, which draw warm, dry air from the Arabian Peninsula to North Africa, caused temperatures to rise to 47°C in Egypt in August 2021. Such dangerous heatwaves are becoming more frequent (GCA 2021). Regional integrated assessments in Africa south of the Sahara show that temperatures are expected to increase in all locations, and rainfall decreases are projected for the western portion of West Africa and southern Africa, while increases in rainfall are projected for eastern West Africa. Studies project that climate change will lead to yield decreases in key staple crops in large parts of the continent (Rosenzweig et al. 2014). Integrated assessments have found that climate change adds pressure to smallholder farmers across Africa south of the Sahara, with winners and losers within each area studied (Mbow et al. 2019).

In a recent paper, Wouterse and colleagues (2023) use remote sensing data to produce maps depicting climate change with a much higher spatial resolution than was previously possible. In Figures 8.1 and 8.2, we reproduce the results of the anomaly analysis for Kenya and Mali, respectively, for daytime land surface temperatures, rainfall patterns, and normalized difference vegetation index (NDVI) to reveal to what extent the climate is changing.[1,2,3]

Kenya is located in the Horn of Africa, and the country's seasonal climatic changes are controlled by the large-scale pressure systems of the Western Indian Ocean. The country has two main rainy seasons: March to May (long rains) and June to August (short rains). Panel A shows that in November, about 20 percent of the country's area experienced a temperature anomaly of between 4°C and 6°C and that about 14 percent of the country's area experienced warming of more than 6°C. Panel B shows that more than half of the country experienced a rainfall decrease of 20 to 50 mm compared to the average. Panel C shows that in November, half of the country's total area lost more than a quarter to a half of its usual level of NDVI.

Mali is in West Africa and experiences three main seasons: a dry season from March to June, a rainy season from June to September, and an off-season or cold season from October to February. Anomaly analysis reveals that in Mali in October 2021, a warming pattern (2°C–4°C) was observed as an extension of the hot season on about a quarter of the land area. This is depicted in Panel A of Figure 8.2. In March 2021, the country experienced its lowest level of warming, with only about a fifth of the country observing warming. Panel B shows that in March 2021, almost half the country experienced an increase in rainfall of up to 10 mm while panel C shows that almost half of the country experienced a modest increase in its level of NDVI. The latter anomaly was also observed in April and May, but only on about 40 percent of the country's territory.

Combining the panels, we can say that compared to the past 20 years, changing climate patterns can be detected in both Kenya and Mali but that these changes are very different. Large parts of Kenya experienced extreme warming in October and November of 2021. The warming pattern seems to have resulted from rainfall regime disruptions, as more than half of the country experienced reduced precipitation in November 2021. The decreased rainfall is associated with more than 50 percent of the country's total area losing more than a quarter to a half of its usual level of greenness. Mali, in contrast, experienced an increased level of greenness outside the rainy season, particularly in the months of March, April and May.

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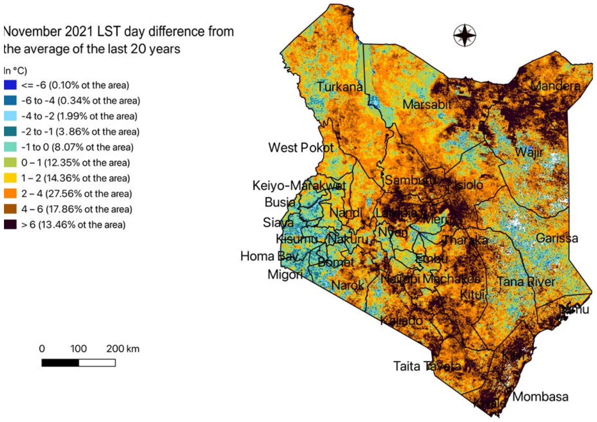
[1] The data are scaled over 20 years (2001 to 2021), and the approach consists of three steps. First, for each year from 2001 to 2021, the data were averaged by month. The resulting dataset consisted of 240 raster files (20 years x 12 months). Second, the average raster was computed by month from the above dataset and for 2001–-2020, resulting in 12 average rasters (1 for each month). Third, each month's raster in 2021 was compared (difference) with the mean raster of the corresponding month generated in the previous step. The result was the deviation of the biophysical parameter (by month in 2021) compared to the last 19 years.

[2] To estimate the variability of climate change, it is necessary to have access to the vulnerability mapping and assessment of each country.

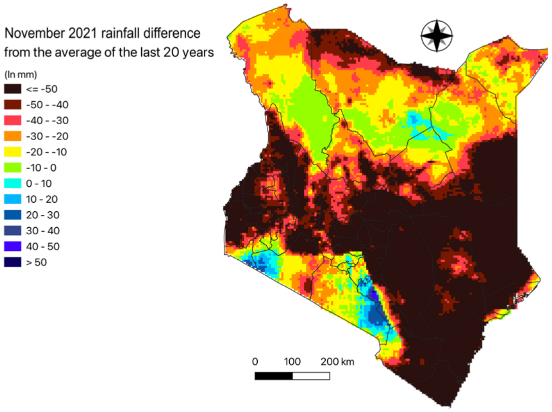
[3] Remote sensing products have several advantages compared to field data, as (1) they allow coverage of large areas with a small number of samples; (2) the images are captured several times a year, therefore allowing monitoring of changes throughout the year; and (3) the spatial resolution allows observation of more details in the ground dynamics.

FIGURE 8.1—KENYA CLIMATE ANOMALY ANALYSIS, 2021

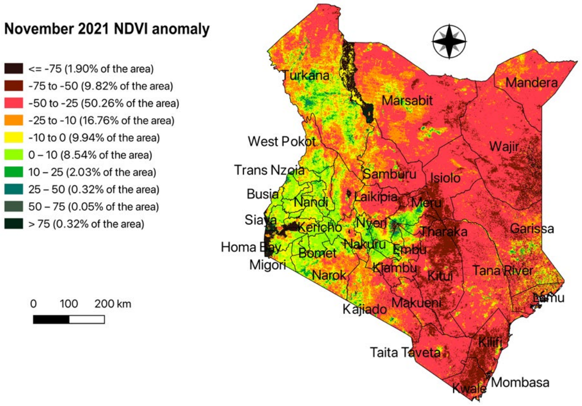
Panel A: Temperature



Panel B: Rainfall



Panel C: NDVI

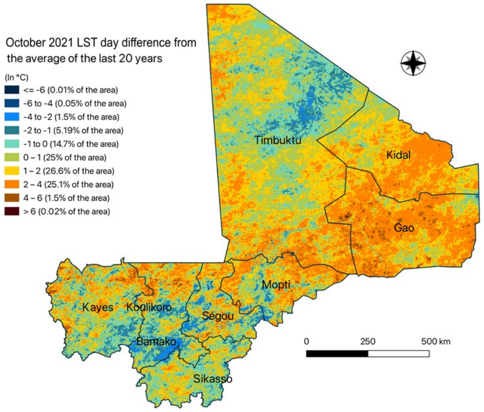


Source: Fofana et al. 2023.

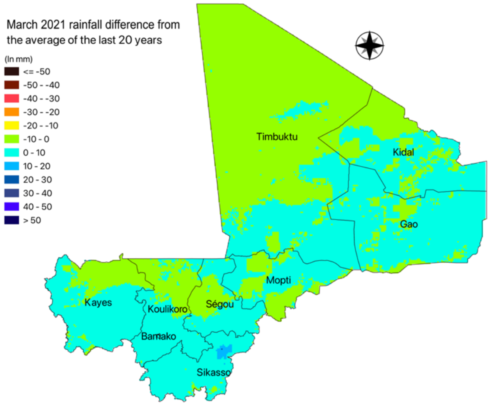
Note: LST = land surface temperature; NDVI = normalized difference vegetation index.

FIGURE 8.2—MALI CLIMATE ANOMALY ANALYSIS, 2021

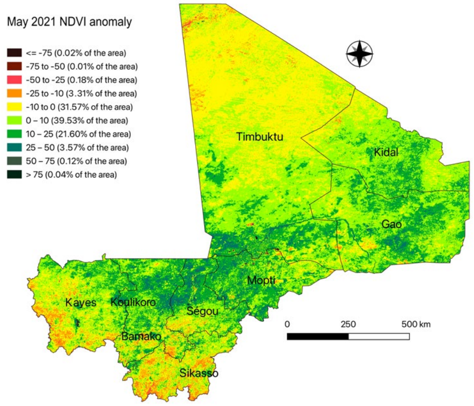
Panel A: Temperature



Panel B: Rainfall



Panel C: NDVI



Source: Fofana et al. 2023.

Note: LST = land surface temperature; NDVI = normalized difference vegetation index.

There are major uncertainties about Africa's climate future. Whether or not certain regions will experience greater rainfall or suffer from more droughts is highly dependent on small changes in ENSO and the monsoons, which today's climate models cannot yet accurately predict. But many of the general trends are clear. By midcentury, average temperatures will be 2°C higher, or more, than preindustrial levels. The number of days with life-threatening temperatures above 41°C is projected to increase by 50 to 200 per year, depending on the region and the world's pace of cutting greenhouse gas emissions.

The climate models do project that parts of northern, southwestern, and central Africa will continue to experience a drying trend—and that almost all regions of the continent will be struck by more frequent and more intense rainstorms, causing greater numbers of potentially devastating floods. At the same time, higher temperatures, enhanced evaporation, and more erratic monsoons are expected to increase the number and severity of droughts. Meanwhile, sea levels are virtually certain to climb by half a meter by the end of the century and could rise nearly a meter unless greenhouse gas emissions are quickly curbed, while cyclones are expected to become more powerful. The combination of higher seas and stronger storms will mean that today's 100-year coastal flooding events will happen once every 10 to 20 years by midcentury (IPCC 2021).

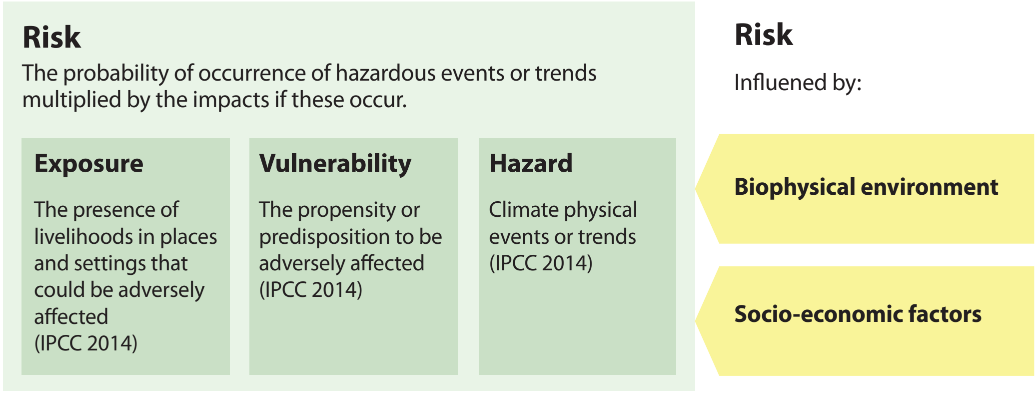
Climate Risk and Its Components

The previous section described current and future climate hazards and the physical phenomena associated with climate change, such as the mean temperature change and frequency or intensity of droughts, floods, or storms. As shown in Figure 8.3, hazards are one component of climate risk, which is defined as the probability of occurrence of hazardous events or trends multiplied by the impacts if these occur (IPCC 2014).

One of three representative key risks that have been identified for the African continent is land-based food insecurity. This risk is already present and is projected to increase in the medium term (2030–2040) and long term (2800–2100) (Niang et al. 2014). Due to a lack of connectivity to regional, national, or international markets, smallholders in Africa south of the Sahara tend to produce largely for subsistence and trade in local markets. This means that the risk of food insecurity tends to be relatively local and can be direct or indirect. To illustrate the impact of hazards, a 2016–2017 drought in Somalia caused US$1.5 billion in losses to agriculture, along with widespread malnutrition, and a 2019 drought lowered water levels behind the Kariba Dam, leading to US$200 million in lost production in Zimbabwe due to power shortages. Cyclone Idai destroyed 90 percent of the homes in the city of Beira in Mozambique and damaged 1.4 million hectares of arable land in Zimbabwe (GCA 2021).

In terms of the future risk for crop productivity, maize, rice, wheat, and soybean yields in tropical regions (20°S–20°N) are projected to decrease approximately 5 percent per degree Celsius of global warming in a multimodel ensemble (Rosenzweig et al. 2014; Franke et al. 2020). A synthesis of projected staple crop impacts across 35 studies for nearly 1,040 locations and cases shows, on average, decreases in yields across staple crops in Africa with increasing global warming, including when accounting for CO_2 increases and adaptation measures. For example, for maize in West Africa, compared to 2005 yield levels, median projected yields decrease 9 percent at 1.5°C global warming and 41 percent at 4°C, without adaptation (Mbow et al. 2019). However, uncertainties in projected impacts across crops and regions are driven by uncertainties in crop responses to increasing CO_2 and adaptation impacts, especially for maize in East Africa and wheat in North Africa and East Africa (Hasegawa et al. 2021). In terms of

FIGURE 8.3—CLIMATE RISK AND ITS COMPONENTS



Risk
The probability of occurrence of hazardous events or trends multiplied by the impacts if these occur.

Exposure
The presence of livelihoods in places and settings that could be adversely affected (IPCC 2014)

Vulnerability
The propensity or predisposition to be adversely affected (IPCC 2014)

Hazard
Climate physical events or trends (IPCC 2014)

Risk
Influened by:

Biophysical environment

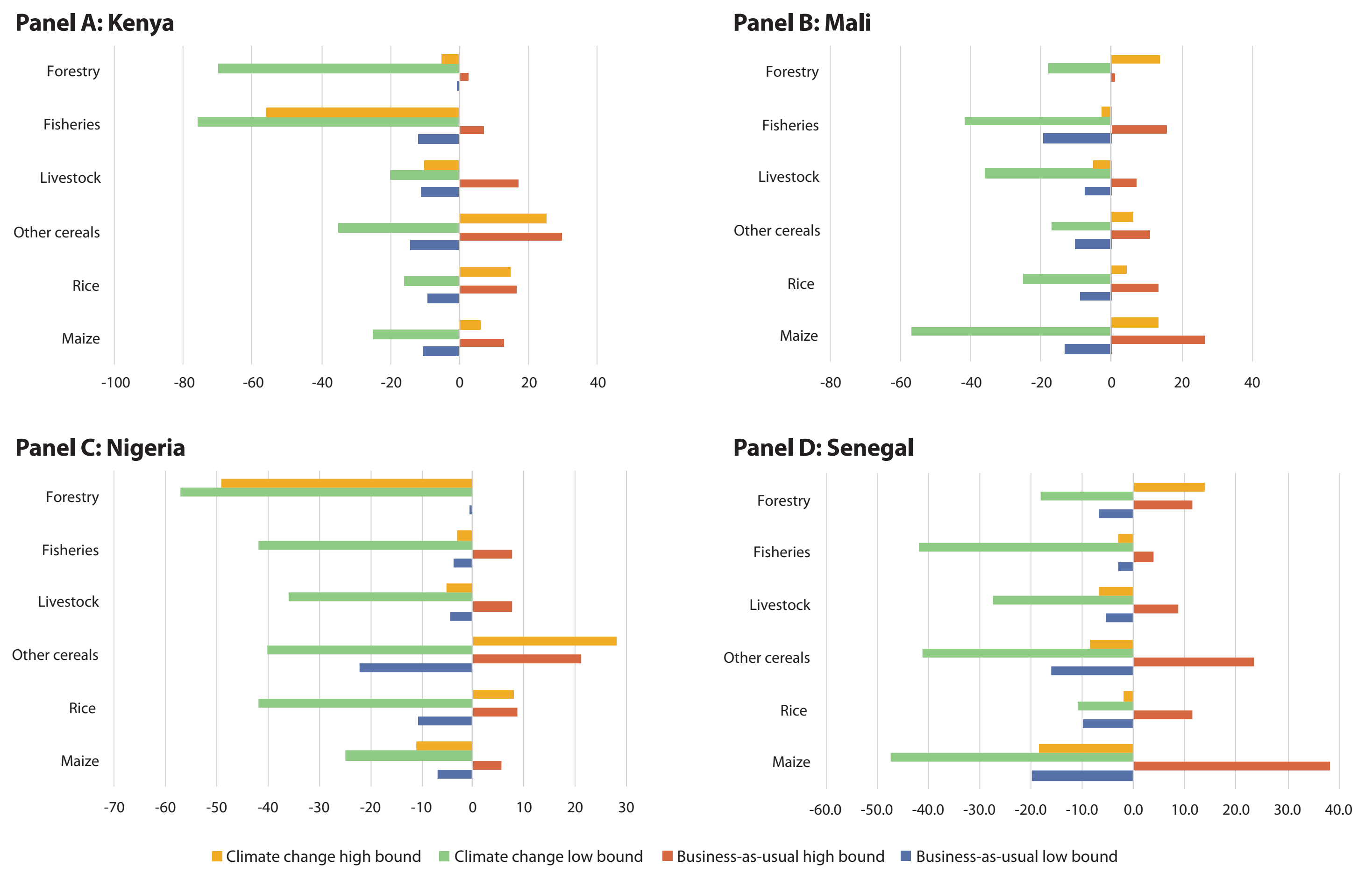
Socio-economic factors

Source: Authors, based on IPCC (2014).

indirect impacts, in countries such as Burkina Faso, Chad, and Togo, more than 7 percent of all working hours are expected to be lost because of heat stress, which is likely to affect productivity.

Wouterse and colleagues (2023) have analyzed the agricultural yield trends of the past 20 years (2000–2019) for Kenya and Mali. Similar reports have been produced for Nigeria and Senegal. Figure 8.4 reproduces these results, labeled "business-as-usual," for Kenya, Mali, Nigeria, and Senegal. Low bounds are average values of negative changes of agricultural yields, while high bounds are average values of positive changes in agricultural yields. A climate change scenario (2020–2050) has also been constructed using existing empirical evidence for various levels of global warming (0.5°C to 5.5°C) and a range of projected precipitation levels. In Figure 8.4, this scenario is labeled "climate change" and here the low and high bounds are those predicted by the empirical studies used in the analysis.[4] Panel A of Figure 8.4 shows that in Kenya, fisheries and forestry are by far the subsectors most affected by climate change, with a decline of 66 percent and 38 percent on average, respectively, compared to business-as-usual. Panel B shows that in Mali, fisheries and maize production are the most affected by climate change, with a decrease of around 20 percent on average for both sectors

FIGURE 8.4—AGRICULTURAL YIELD CHANGES UNDER CLIMATE CHANGE, 2020–2050



Source: Authors' computations.

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[4] For each country, several peer-reviewed articles were considered. An overview is available from the authors on request.

by 2050 compared to business-as-usual. Panel C shows that for Nigeria, forestry, fisheries, livestock, other cereals, and maize are by far the subsectors most affected by climate change shocks. In Senegal (Panel D), the subsectors expected to be most affected by climate change as an average of the low and high bounds are maize (–34 percent), forestry (–23 percent), other cereals (–25.2 percent), and livestock. Clearly, climate change is expected to result in sizable negative effects on agricultural yields, although different sectors will be affected in each country.

In addition to hazards, Figure 8.3 shows that exposure and vulnerability are dimensions of climate risk. Exposure measures the presence of livelihoods in places and settings that could be adversely affected. Dryland agricultural areas, for example, are more exposed to changes in rainfall. Vulnerability is defined as the propensity and the predisposition of a system to be adversely affected by external shocks and is thus linked to the characteristics that determine a social-ecological system's or community's level of preparedness to anticipate or respond to risks (IPCC 2014; Sharma and Ravindranath 2019).

Agriculture in Africa is especially vulnerable to future climate change in part because production is overwhelmingly rainfed. At the farm household level, levels of exposure and vulnerability can be considered the outcome of changes in economic behavior to maintain welfare in the face of climate disruptions (Rising et al., 2022; Wouterse, Andrijevic, and Schaeffer 2022). Many smallholders have adopted changes in production and income-generating activities to reduce the vulnerability and exposure of their livelihoods to climate shocks (Di Falco, Chavas, and Smale 2007; Kato et al. 2011; Kosmowski 2018). There are a host of so-called climate-smart production technologies that are practiced on farms across the continent (see Box 8.1).

BOX 8.1—CLIMATE-SMART PRODUCTION STRATEGIES

- Change the timing of specific farming activities or amounts of inputs applied
- Use insurance and other financial risk-management solutions
- Use new agricultural inputs (for example, climate-smart seeds)
- Adopt different production practices (for example, cover crops, residue management)
- Adopt new technologies (for example, soil testing, water management, controlled drainage, tree management)
- Transition to new farming systems and agroecological practices
- Diversify primary crops and livestock produced

Source: FAO (2017); CCAFS (2017).

In Ethiopia, a country where around two-thirds of the population is dependent on rainfed agriculture, severe droughts regularly lead to production that falls short of basic subsistence levels for many farm households (Di Falco and Veronesi 2018). Tree planting on plots is an important soil conserving and conditioning measure in the country. The adoption of this climate-smart production strategy is also due to its promotion under Ethiopia's Productive Safety Net Program (Andersson, Mekonnen, and Stage 2011). Similarly, in Niger, where below-average rainfall—as in 2009, 2011, and 2013—has triggered a deceleration in growth (Wouterse and Badiane 2018), and where food insecurity is a concern even in years of average rainfall, zaï pits, which are small holes (20–40 cm in diameter and 10–20 cm deep) filled with compost and planted with seeds, are relatively common. Zaï pits have been shown to help increase both the agronomic and economic productivity and resilience of households (Wouterse 2017).

According to recent data, the use of improved seed has remained relatively low in both countries, with, respectively, 12 and 4 percent of farm households using improved seed in Ethiopia and Niger.[5] Income diversification strategies, in contrast, are relatively common in both countries. In Ethiopia, households earn income from selling processed agricultural products or from nonagricultural businesses or services such as shops and trading of goods on the street or in a market. Some households are involved in firewood collection, preparation, and sale and taxi/pickup truck services (Proctor 2014). In Niger, activities are more likely to be off-farm and include individual nonagricultural enterprises such as extraction, manufacturing, trading, and services (Dedehouanou et al. 2018).

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[5] Data are from the most recent wave of the World Bank Living Standards Measurement Study–Integrated Surveys on Agriculture (LSMS-ISA) survey, the 2015–2016 Ethiopia Socioeconomic Survey (ESS) in Ethiopia, and the 2014 Enquête Nationale sur les Conditions de Vie des Ménages et l'Agriculture (ECVMA) in Niger.

Engagement in wage labor is limited in both countries, accounting for less than 5 percent of rural income (Davis, Di Giuseppe, and Zezza 2018; Dillon and Barrett 2017). Households that have diversified their incomes are less exposed to direct impacts of droughts and floods, provided that their alternative income sources are neither correlated with rainfall nor directly or indirectly dependent on agriculture (that is, exposure falls to the extent that complementary sources of income and food are not covariates) (Devereux 2007).

An incomplete understanding of exposure and vulnerability and how they are produced may lead to adaptation efforts that instead increase, redistribute, or create new sources of vulnerability. This is referred to as maladaptation (Barnett and O'Neill 2013). The IPCC special report on the impacts of 1.5°C warming (2018) identified several ways in which adaptation efforts can increase economic, social, and environmental costs or undermine existing local adaptation strategies. For example, increased water harvesting upstream to cope with erratic rainfall may harm communities downstream and reduce their opportunities to manage their own risks.

Economic Implications of Climate Change

The agricultural yield changes associated with climate change, as outlined in the previous section, are likely to have strong repercussions on African countries' economies, given that they have remained heavily agriculture focused. A recent meta-analysis of 56 studies indicates that, compared to 1995–2005, economic welfare in the agriculture sector in North Africa is projected to decline 5 percent with 2°C global warming and 20 percent with 3°C global warming; in Africa south of the Sahara, the declines are projected to be 5 percent with 2°C warming and 10 percent with 3°C warming. The modeling results also suggest a highly complex connection between yield and welfare change, which is perhaps better analyzed on a per country basis (Moore, Baldos, and Hertel 2017). In what follows, we use the yield projections depicted in Figure 8.4 above to shock a computable general equilibrium (CGE) model combined with a microsimulation model in order to assess the effects of climate change on economic growth and employment as well as on poverty and food security in our four case study countries: Kenya, Mali, Nigeria, and Senegal.[6]

A CGE model combines economic theory and empirical data to capture the effects of economic policies and shocks. A CGE model captures the interdependencies between different sectors, agents, and markets in the economy and can therefore shed light on the wider economic impact of policies and shocks and sometimes reveal their indirect or unintended effects. We have adapted the CGE model developed by Decaluwé and colleagues (2012) to the climate change issue by adopting a long-term closure rule to consider more accurately the time dimension. In our CGE model, labor, agricultural land, and other capital are fully mobile between economic activities, which represents a long-term situation in which the economy has time to adjust. Current public expenditure and fiscal balance are fixed relative to gross domestic product (GDP). Thus, the integration of a compensatory mechanism through a tax or subsidy on household gross income makes it possible to capture the effects of the variation in government income, following the climate shock, on household welfare. All four countries are small in terms of their trading links with the rest of the world, meaning that none of the countries has an influence on the international prices of either imported or exported products, which remain fixed in the model. The foreign trade current account balance is kept fixed relative to GDP, thereby effectively linking external financing to the performance of the economy. The volume of investment is also kept fixed relative to GDP through household savings. Thus, the model is investment-driven in the sense that total investments determine total savings, that is, the sum of private, government, and foreign savings. This closure rule allows us to capture the full effect of the climate shock. In other words, intergenerational transfers of welfare are not allowed. Flexible prices equilibrate demands and supplies of domestically marketed domestic output, and the exchange rate is the numeraire in the model.[7] Below we describe the results for the four countries.

In Kenya, backward linkages measured by the input intensity—the ratio of input costs to value added—of the industry and services sectors relative to the agriculture sector were 17 percent and 5 percent, respectively, in 2018. Forward linkages measured by the shares of total demand for agricultural products by the industry and services sectors were 18 percent and 3.5 percent, respectively,

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[6] The macro and micro models communicate in a top-down fashion through a set of interrelated variables available in both models.

[7] The CGE model uses the 2019 Social Accounting Matrix for Kenya and the 2018 Social Accounting Matrix for Mali, Nigeria, and Senegal. The microsimulation model uses household-level data from the 2015–2016 Kenya Integrated Household Budget Survey, the 2017–2018 Mali Living Standards Measurement Survey, the 2018–2019 Nigeria Living Standards Survey, and the 2018–2019 l'Enquête Harmonisée sur les Conditions de Vie des Ménages for Senegal.

in 2018. Due to the higher levels of backward and forward linkages for industry compared to the services sector, value added declines more in the former sector. Industrial subsectors that stand to lose in terms of value added as a result of climate change are wood and paper products.

In Mali, the industrial sector shows stronger linkages with the agricultural sector. The input intensities of the industrial and services sectors relative to the agricultural sector were almost 12 percent and a little over 4 percent, respectively, in 2018, representing backward linkages. Forward linkages were almost 24 percent and a little over 1 percent, respectively, in the industry and services sectors in 2018. Because of the integration of the industrial sector into the global economy, industry value added declines less than services value added under climate change. Public administration, health and social work, and education are negatively affected by climate change shocks on agricultural yields because of their linkages with the agricultural and food industries. Public administration, education, and health services play a crucial role in Mali's economy and are less exposed to external trade. Given the high intensity of agricultural inputs in this sector, a decrease in agricultural value added induced by climate change leads to a lower value added in tertiary and quaternary services. In Mali, several nonagricultural industries, such as metals and mining, stand to benefit from climate change shocks on agricultural yields through the real exchange rate depreciation effect, that is, the relative increase in domestic prices compared to external prices.

In Nigeria, the input intensities of the industrial and services sectors relative to the agricultural sector were 9.4 and 1.0 percent, respectively, in 2018, representing backward linkages. Forward linkages were 7.2 and 1.5 percent, respectively, in 2018. Under climate change, services value added declines less than industry value added (–0.9 against –2.5 percent, respectively), indicating the relative dominance and resilience of the services sector in the Nigerian economy compared to the industrial sector. Wood and paper products, accommodation and food services, and public administration are the sectors most negatively affected by climate change when compared to business-as-usual. The negative effect of climate change on wood and paper products is due to the substantial linkages of this sector with forestry activities. Accommodation and food services also have a strong linkage with the agricultural sector, explaining the poor performance of these subsectors in the face of climate shocks. Agricultural products represent 16 and 29 percent, respectively, of the total input costs of these industries. Public administration naturally contracts because of the fiscal policy effect arising from the underperformance of the economy. Some nonagricultural industries stand to benefit from climate shocks on agricultural yields because they do not require agricultural inputs. Other manufacturing industries, for example, would experience an increase in value added under climate change. Wholesale and retail trade industries do not consume any agricultural output as input and thus follow a similar pattern to that of the manufacturing industry.

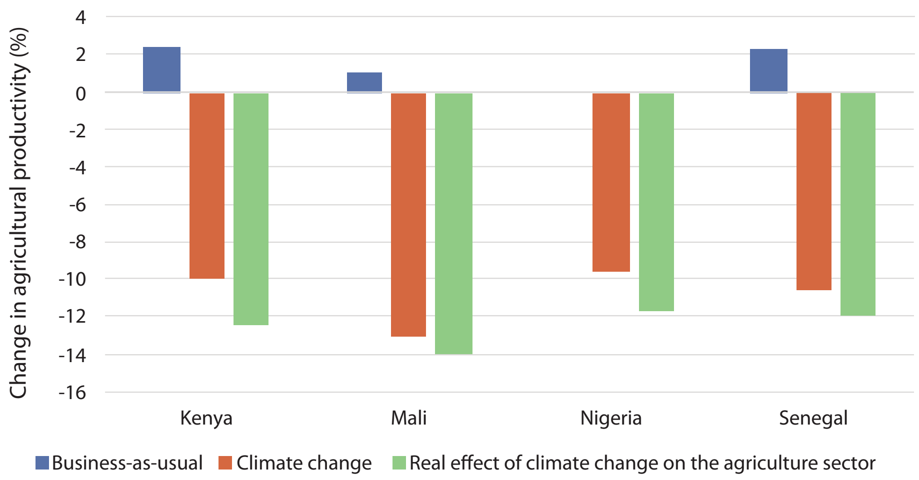
In Senegal, simulations indicate that the industrial sector could record a decline of about 1.5 percentage points, compared to a decline of 1.4 percentage points for services. Sectors that are affected by climate change are machinery, public administration, and hospitability. Some industries stand to benefit, for example, mining, chemical and oil extraction, and wholesale and retail trade.

Figure 8.5 shows that climate-induced yield changes result in a contraction of agricultural GDP compared to business-as-usual, of 10 percent in Kenya, 13 percent in Mali, almost 10 percent in Nigeria, and almost 11 percent in Senegal.

Given the agricultural productivity effects described above, we can assess the impact of climate change on GDP and employment. Figure 8.6 shows that under climate change, GDP is slated to fall by 6.5 and 8.3 percent in Kenya and Mali, respectively. In Nigeria, GDP is slated to fall by more than 4 percent and in Senegal by almost 2 percent. The smaller decline in Senegal is attributed to the fact that the country's economy is less agriculture based than those of the other three.

The effects of climate change on employment are sizable for all three categories of workers: low-, medium-, and high-skilled. Under climate change, the employment rate for low-skilled workers would fall by more than 5 percent and almost 7 percent, respectively, in Kenya and Mali. In terms of earnings, not shown here, high-skilled workers would be most affected by climate change, experiencing a drop of 2.5 percent and almost 2 percent in, respectively, Kenya and Mali. In Nigeria, changes in employment numbers due to climate change shocks on agricultural yields would be 2.5 percent for the medium-skilled employment category, against 1.9 and 1.1 percent for, respectively, high-skilled and low-skilled employment. Similarly, in terms of factor renumeration, not shown here, earnings of high-skilled and medium-skilled employees are less negatively affected by climate change shocks compared to low-skilled laborers. In Senegal, employment rates decline only marginally and not at all for high-skilled workers.

FIGURE 8.5—PERCENTAGE CHANGE IN AGRICULTURAL GDP UNDER BUSINESS-AS-USUAL AND CLIMATE CHANGE SCENARIOS



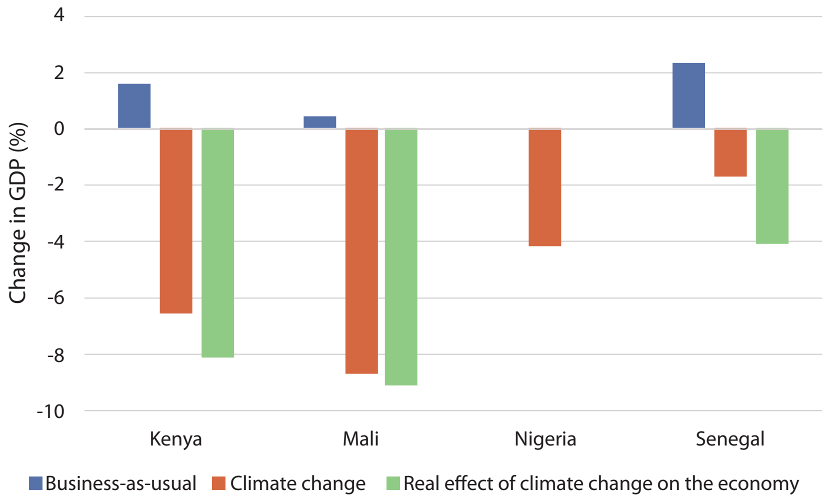
Source: Authors' computations.

Note: Real effect of climate change = business-as-usual plus climate change.

Income changes from the macro model can be integrated into the microsimulation model to evaluate poverty and food security outcomes. Figure 8.8 shows that in Kenya the number of poor people—that is, individuals with total consumption expenditures below the national poverty line—would increase by 3.3 percent with climate change compared to business-as-usual. In Mali, the number of poor people would increase by about 1 percent in the climate change scenario relative to the business-as-usual scenario. For Nigeria, simulations reveal that as a result of climate change shocks, the poverty rate would increase by 2.1 percent overall and (not shown) by 2.9 percent for rural households, against 0.7 percent for urban households. With the occurrence of an adverse climatic shock, the poverty rate in Senegal would increase by more than 5 percent.

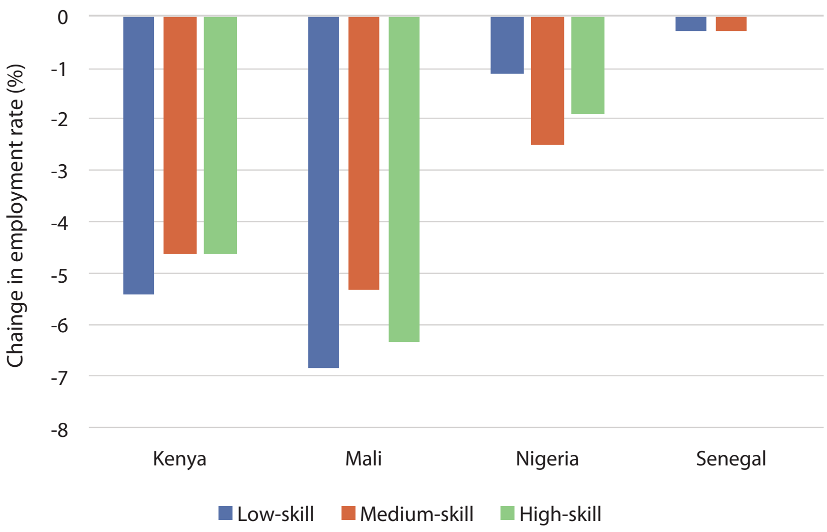
Although not shown here, for Nigeria the contraction of the economy due to climate change also leads to a drop in consumption expenditure, which is especially pronounced for rural households and those in the lowest income quintile.

FIGURE 8.6—PERCENTAGE CHANGE IN GDP UNDER BUSINESS-AS-USUAL AND CLIMATE CHANGE SCENARIOS



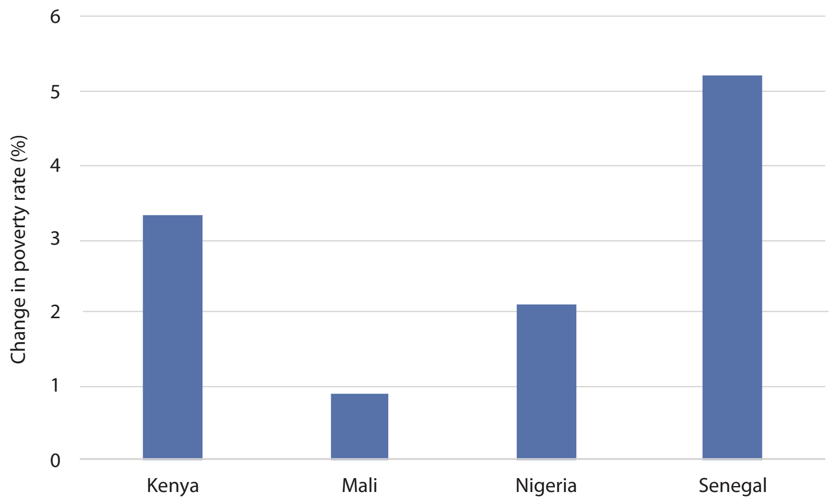
Source: Authors' computations.

FIGURE 8.7—PERCENTAGE CHANGE IN EMPLOYMENT RATE UNDER CLIMATE CHANGE



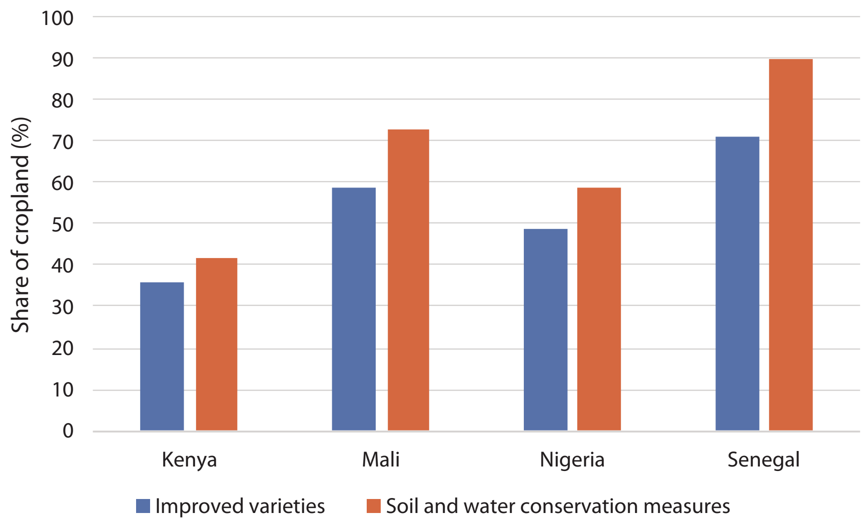
Source: Authors' computations.

FIGURE 8.8—PERCENTAGE CHANGE IN NATIONAL POVERTY RATE UNDER CLIMATE CHANGE



Source: Authors' computations.

FIGURE 8.9—ADDITIONAL SHARE OF CULTIVATED AREA THAT NEEDS TO BE COVERED BY CLIMATE-SMART AGRICULTURE STRATEGIES TO COMPENSATE FOR CLIMATE CHANGE



Source: Authors' computations.

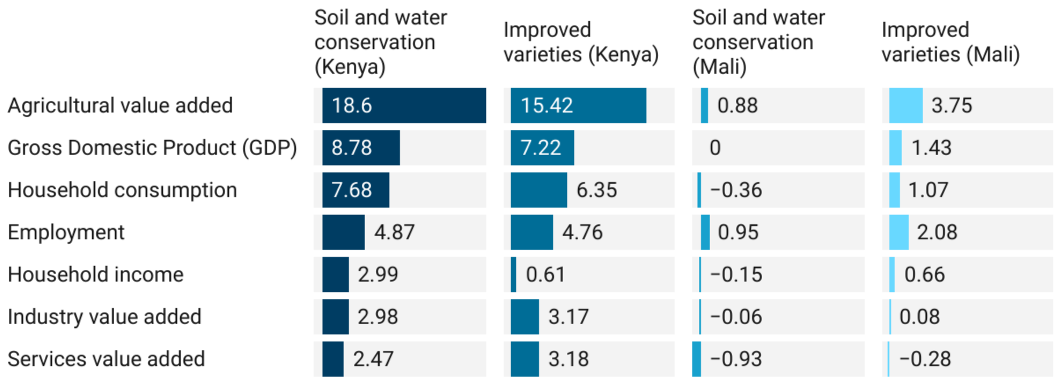
The Potential of Adaptation Strategies

We also used the CGE model outlined above to simulate the shock-mitigating effects of two climate-smart agriculture strategies: soil and water conservation measures and use of improved seed varieties. Figure 8.9 shows that to mitigate the effects of climate change on the economy in Kenya, the share of cropland under improved varieties would need to increase by 36 percent compared to 2019 levels, while the share of land with soil and water conservation measures would need to increase by 42 percent. In Mali, the share of the area cultivated with improved varieties would need to increase by 59 percent compared to 2018, and the share of the area cultivated under soil and water conservation by 73 percent. In Nigeria, an additional 49 percent of total crop area would need to be cultivated using improved varieties to recover the GDP loss due to climate change shocks, and soil and water conservation would need to cover an additional 59 percent of total crop area. In Senegal, the share of cultivated area planted with improved varieties or under soil and water conservation measures would need to increase by, respectively, 71 percent and 90 percent in comparison to 2018. These are sizable increases that will also have important implications for public expenditure.

Beyond mitigating the climate shock, investments in the two climate-smart agriculture techniques yield economywide benefits. Figure 8.10 reveals that for Kenya and Mali, the contribution of agriculture to GDP growth increases as a result of the two adaptation strategies, although much more so in the former country. GDP, employment, consumption, and income increase as a result of the implementation of both strategies in Kenya. In Mali, only adoption of improved seed varieties is projected to yield positive returns beyond climate shock mitigation to GDP, consumption, income, and employment.

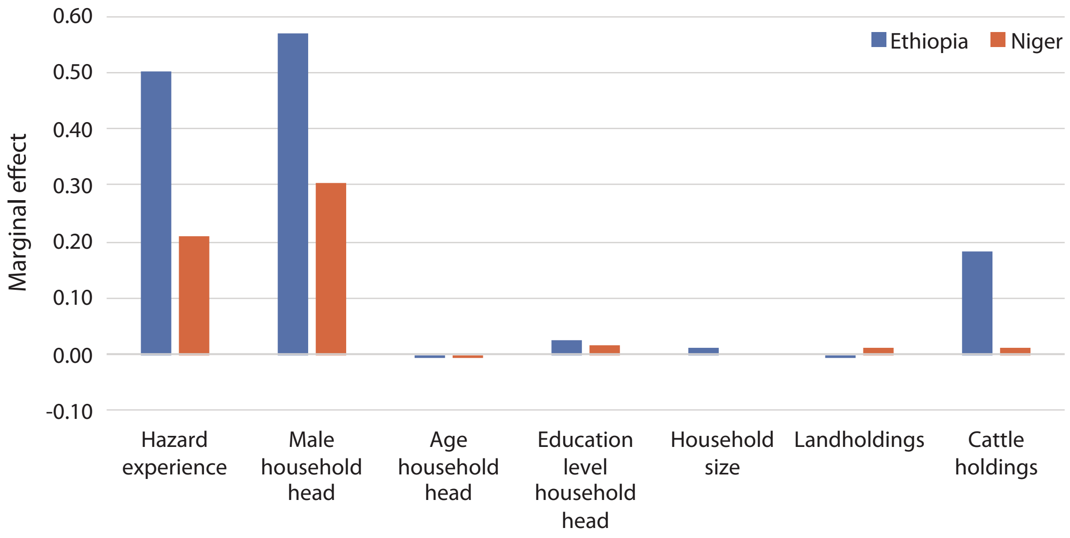
As shown in Figure 8.10, large-scale implementation of soil and water conservation measures and extensive use of improved seed both have the potential to mitigate the yield shocks projected to arise from climate change. These findings thus support the need for increased investments in these strategies, and such strategies already figure in many NAPs or the adaptation section of the Nationally Determined Contributions. But investments in these technologies do not necessarily equate adoption. To enhance sustained uptake, interventions must be designed in such a way as to account for the diverse needs of farm households and must leverage the main adoption drivers for these adaptation strategies.

FIGURE 8.10—ECONOMYWIDE EFFECTS OF CLIMATE-SMART AGRICULTURE STRATEGIES IN KENYA AND MALI (%)



Source: Authors' computations based on simulation results

FIGURE 8.11—DRIVERS OF ADOPTION OF ON-FARM ADAPTATION STRATEGIES



Source: Authors' computations based on Wouterse, Andrijevic, and Schaeffer (2022).

Adoption Drivers

At the farm household level, Wouterse, Andrijevic, and Schaeffer (2022) have used farm household data and regression analysis to uncover some of the drivers of adoption of on-farm adaptation technologies such as the ones outlined above.[8] The results are reproduced in Figure 8.11.

For Ethiopia, we see that hazard experience is positively correlated with the adoption of an adaptive production strategy. This finding implies that households that had experienced a drought or a flood in the 12 months preceding the survey were more likely to have engaged in on-farm adaptation. In terms of human capital, we find that better-educated household heads are more likely to have put in place on-farm adaptation measures or diversified their livelihoods through, for example, engagement in nonfarm activities. These results corroborate earlier findings that education is an effective enabler of adaptation (Walker and Salt 2012). Acquiring basic literacy, numeracy, and abstraction skills is thought to enhance individuals' cognitive capacity. Accordingly, more education is associated with greater risk awareness due to a better understanding of the consequences of pursuing adaptive strategies (Lutz, Muttarak, and Striessnig 2014). Figure 8.11 also shows that male household heads in Ethiopia are more likely to have put in place on-farm adaptation measures. In terms of productivity shifters, higher cattle holdings are associated with on-farm adaptation. This makes sense, as cattle can easily be liquidated to invest in on-farm adaptation, but higher cattle holdings may also make it more challenging to diversify, due to, for example, lack of available labor. Hazard experience in Niger is also associated with more on-farm adaptation. Again, the role of education as an enabler of adaptation is seen clearly, as better-educated

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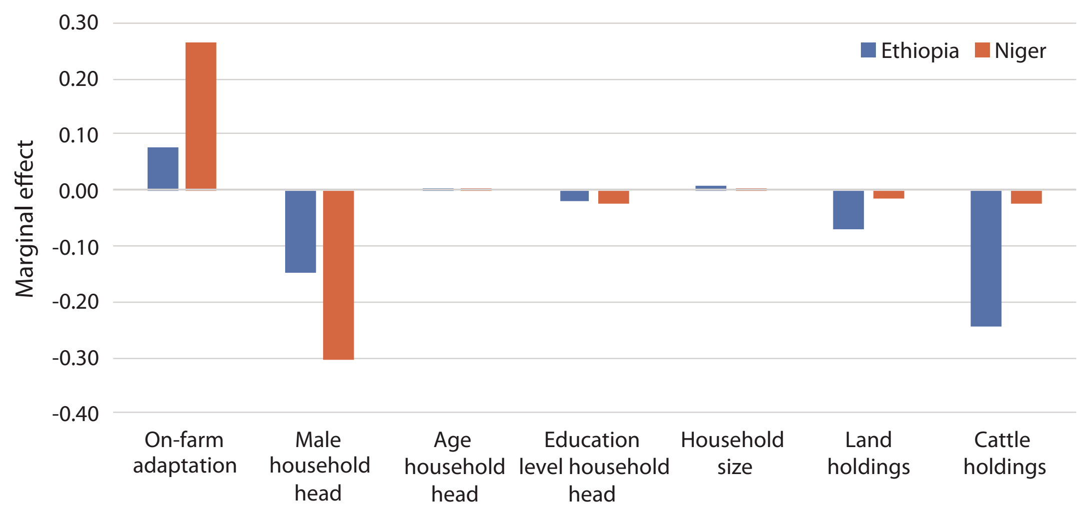
[8] Data used for the regression analysis are the most recent wave of the World Bank LSMS-ISA survey, the 2015–2016 ESS in Ethiopia, and the 2014 ECVMA in Niger.

household heads are more likely to have engaged in on-farm adaptation. Female-headed households are less likely to have adopted adaptive productive strategies in Niger.

However, Figure 8.12, also based on the regression analysis of Wouterse, Andrijevic, and Schaeffer (2022), shows that on-farm adaptation is not associated with lower food insecurity in either country. Because data are cross-sectional only, reverse causality may be at play here, with more food-insecure households being more likely to have engaged in on-farm adaptation. In contrast, education is associated with lower food insecurity, as is being a male head of household. Cattle holdings and landholdings are also associated with lower food insecurity.

There are two main takeaways from this analysis. First, adaptive capacity—particularly in the form of land, livestock, and formal education—is important for uptake of on-farm adaptation strategies. Second, there is an important gender dimension to adaptation. In both countries, female household heads are less likely to have taken up adaptive production strategies and are also more food insecure. Perceptions of risk and experience with shocks and stressors also vary significantly between gender groups. For example, the underrepresentation of women in many spheres is said to influence risk prioritization and responses to shocks and stressors, such as the purchase of insurance (Quisumbing, Meinzen-Dick, and Njuki 2019). Delavallade and colleagues (2015) indicate that in West Africa, men tend to weigh risks to their farm activities more heavily, while women are more concerned about shocks affecting the health and schooling of household members. This points to a sharp difference in the kinds of shocks that men and women are likely to insure against, and their willingness to pay for a given coping instrument. This difference could be relevant here because of the relationship between hazard experience and adaptation, with female-headed households adapting much less. These findings also point to the fact that smallholder farmers' responses to climate-induced agricultural changes are not uniform but rather diverse.

FIGURE 8.12—ADAPTATION AND FOOD INSECURITY



Source: Authors' computations based on Wouterse, Andrijevic, and Schaeffer (2022).

Microregion Climate Risk Typology

Adaptation strategies are embedded in heterogeneous local agronomic, social, economic, and institutional conditions. Soil fertility conditions, for example, can vary at short distances, and enabling conditions for adaptive production strategies are variable (Van Lauwe, Coe, and Giller 2019). Also, due to a lack of connectivity to regional, national, or international markets, heterogeneous local-level food systems exist. Typology construction provides an efficient method to understand farmer diversity by delineating groups with common characteristics. A typology of microregions is an alternative way to classify and analyze very small areas within a country (see also Torero 2014). The typology presented below centers on the risk of food insecurity and its two components: exposure and vulnerability.

To develop a microregion climate risk typology for Ethiopia and Niger, we analyze the most recently available nationally representative dataset and consider a household as food insecure if it expressed a fear of not having enough to eat in the seven days preceding the survey.[9] Exposure takes the value of 1 if the household's livelihood is solely dependent on agriculture and 0 if the household has diversified its livelihood by engaging in migration or non- or off-farm activities. Vulnerability takes the value of 0 if the household uses improved seed and/or has put in place soil and water conservation measures or planted trees on plots and 1 if not (see also Wouterse, Andrijevic, and Schaeffer 2022).

Table 8.1 presents the various microregion climate risk types that were generated through cluster analysis. Five types of microregions can be distinguished: critical, high priority, medium priority with high exposure, medium priority with high vulnerability, and low priority. In critical areas, food insecurity is high, as are exposure and vulnerability. In high-priority areas, food insecurity remains high but livelihoods are less exposed and vulnerability is moderate. There are two types of medium-priority areas. In the first, exposure is still moderate or high, and vulnerability is low to moderate, meaning that livelihoods have remained largely based on agriculture but that households have engaged in some on-farm adaptation. The second type of medium-priority area is less exposed in the sense that livelihoods are diversified, but more vulnerable because less on-farm adaptation has taken place in these microregions. Finally, low priority areas have low food insecurity but can still have moderate exposure and vulnerability.

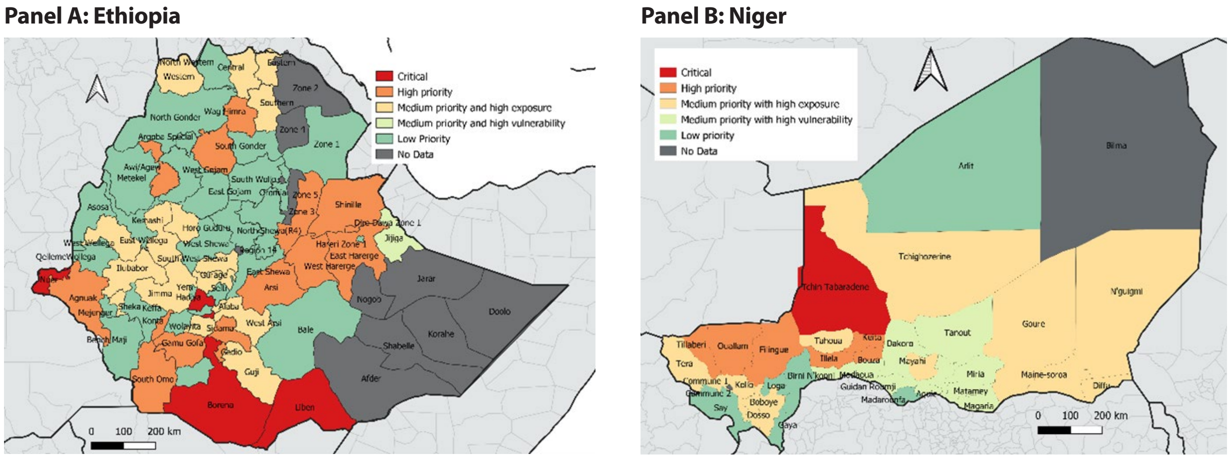
Figure 8.13 presents a visualization of the microregion climate risk typology and shows that, indeed, the impact of climate change in the form of food insecurity is unequally distributed. There is one department in Niger and four in Ethiopia that can be considered critical. These microregions have high food insecurity, and farmers are highly exposed and highly vulnerable to climate hazards. In Niger, the critical department is Tchin Tabaradene. This department in the north of the Tahoua region, which is partly in the Sahelian zone, is hyperarid and houses large numbers of transhumance and nomadic pastoralists; it was identified as experiencing stress in terms of food security by the Famine Early Warning Systems Network (FEWS NET) in 2014–2015. In Ethiopia, the critical zones are Nuer, Borena, and Liben. All three zones are in the lowlands and have a high share of pastoralists. Nuer is prone to flooding, and

TABLE 8.1—MICROREGION CLIMATE RISK TYPOLOGY

	Microregion type	Food insecurity	Vulnerability	Exposure
1	Critical	High	High	High
2	High priority	High	Moderate	Moderate
3	Medium priority with exposure	Moderate	Low or moderate	Moderate or high
4	Medium priority with vulnerability	Moderate	Moderate or high	Low or moderate
5	Low priority	Low	Moderate	Moderate or low

Source: Wouterse, Andrijevic, and Schaeffer (2022).

FIGURE 8.13—MICROREGION CLIMATE RISK MAPS


Panel A: Ethiopia

Panel B: Niger

Source: Wouterse, Andrijevic, and Schaeffer (2022).

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[9] Data are from the World Bank LSMS-ISA 2015–2016 for Ethiopia and 2014 for Niger.

Borena and Liben are at risk of drought. According to FEWS NET, in 2015 both Borena and Liben (though not Nuer) were stressed in terms of food insecurity.

Both countries also contain a high number of medium-priority regions with high exposure. In contrast to Ethiopia, Niger also counts a high number of medium-priority areas with high vulnerability. The low-priority microregion of Arlit contains uranium mines, which means that incomes are likely to be more diversified. The Niger River flows through the departments of Say and Gaya, allowing for flood recession agriculture and gardening. The departments of Birni N'Konni and Madarounfa border the seasonal Maggia River, and households there engage in irrigated cash cropping of primarily onions for urban areas of Nigeria.

Given their high level of food insecurity, critical and high-priority areas should be prioritized to accelerate adaptation. Because the typology contains two additional layers of information, on vulnerability and on exposure, the findings can also point to the types of interventions that would be appropriate in a particular microregion. Critical and high-priority regions would benefit from combined investments that reduce food insecurity in the short run, for example, in the form of a social protection scheme, and longer-term investments that reduce exposure and vulnerability. In medium-priority areas with high exposure, targeted investments, for example, through education programs, could enable households to diversify their livelihoods away from agriculture. For medium-priority microregions with high vulnerability, community work programs that include on-farm adaptation activities could help reduce vulnerability, as could the increased provision and improved quality of climate-informed advisory services. Big data technologies present an important opportunity to address the data barrier hampering the provision of these services. The use of big data technology enables timely and accurate climate risk prediction and impact assessment of extreme events with reduced uncertainties, thus making climate-informed advisory services more targeted. Finally, in low-risk areas, there would be a need to invest in a more anticipatory manner, with the objective of mitigating future climate risk—for example, through nature-based solutions and weather-index insurance, where penetration of the latter could be increased using big data technologies.

Conclusions and Policy Implications

Food systems are failing to produce the foods essential for healthy diets in sufficient quantity and at affordable prices (FAO 2023). Climate change is likely to further undermine the functioning of food systems in African countries, and food insecurity is one of the main risks associated with a changing climate. Despite its vulnerability, the agriculture sector holds enormous potential for mitigating the risk of food insecurity and strengthening food systems across the continent. But adaptation solutions (the changes required to reduce climate risk to agrifood-system-based livelihoods) as well as increased adaptive capacity (the ability to take advantage of the changes induced by climate change) need to be integrated into the effort to transform food systems.

In this chapter, we have examined the food systems–climate change nexus in six African countries focusing on the food security function to build the evidence base for policymakers to mainstream climate risk and adaptation solutions in food system transformation efforts. We can draw the following conclusions from our findings.

First, the economic implications of climate change are likely to be substantial across African countries. Through backward and forward linkages, changes in agricultural value added stemming from yield reductions will affect those in the industry and services sectors, although results differ by country. A sizable reduction in GDP by 2050 is expected in all four case study countries—Kenya, Mali, Nigeria, and Senegal—but is more pronounced for the former two, which have a larger agricultural sector. The contraction of the economy has implications for employment, poverty, and consumption expenditures. For Nigeria, the reduction in consumption expenditure is more pronounced for rural households and those in the lowest income quintile.

Second, climate-smart agriculture production strategies—soil and water conservation measures and improved seed—could mitigate the economic shocks associated with climate change in the four case study countries. However, the investments required are substantial, as, in the four case study countries, between 42 and 90 percent of arable land would need to be equipped with soil and water conservation measures and between 36 and 71 percent would need to be planted with improved seeds.

Third, findings from Ethiopia and Niger reveal that to ensure the sustained uptake of climate-smart strategies by farm households, there is a need to build their adaptive capacity, for example, through enhancing their asset base or enhancing human capital. Also, additional interventions may be required to induce female-headed households to implement adaptive production strategies on their farms. These interventions may also have a direct effect on food security.

Fourth, within a country, different areas have different needs for adaptation-related interventions, depending on their level of food security, exposure, and vulnerability.

These four findings could be used to align a country's policies and direct investments so that the planned food systems transformation is also resilient. Critical and high-priority regions would require combined short-term risk reduction and long-term productivity-enhancing investments, while medium-priority areas with high vulnerability would benefit from interventions supporting on-farm adaptation, and medium-priority areas with high exposure may benefit more from interventions that build up their human capital and allow them to diversify their sources of income. Mainstreaming the above-mentioned interventions into planned projects and programs around food system reforms and targeting them in the manner outlined above would ensure that interventions are both efficient and sustainable.