CHAPTER 5

Climate Risks and Vulnerabilities in African Agrifood Systems

Sambane Yade, Khadim Dia, and Delia Grace Randolph

Introduction

In an era when the impacts of climate change are becoming increasingly pronounced, understanding and mitigating climate risk is paramount, especially for regions highly vulnerable to environmental change. Africa, with its rich biodiversity and varied climates, stands on the front line, facing unique challenges posed by climate change and climate variability. The continent's susceptibility around climate change is not just a matter of environmental concern but a multifaceted issue affecting socioeconomic development, agricultural sustainability, and the overall well-being of its inhabitants. The imperative to assess, comprehend, and adapt to these risks is more critical now than ever, necessitating a detailed analysis of various climate-related parameters and their long-term implications.

This chapter addresses climate change in African agrifood systems through the lenses of environmental changes, health outcomes, and household vulnerabilities. The overall objective is to provide a comprehensive overview of how climate change influences these interconnected domains, driving home the necessity for integrated and adaptive strategies. By exploring environmental indicators, health outcomes, and household vulnerabilities, the chapter aims to paint a holistic picture of the challenges and potential pathways to resilience.

The first section, Environmental Risks of Climate Change, focuses on how climate change alters key environmental parameters such as temperature, precipitation, and vegetation health. These changes have profound implications for Africa's ecosystems, affecting agricultural productivity, water resources, and overall environmental stability. This section aims to identify and analyze temperature anomalies, assess precipitation variability, evaluate vegetation health, and determine drought risks. By doing so, it seeks to inform and support the development of effective climate risk management and adaptation strategies.

The second section, Health Risks of Climate Change, examines the direct and indirect effects of climate change on human health. Africa's vulnerability to health impacts is significant, with climate-sensitive diseases and health conditions exacerbating the already high burden of disease. This section explores how climate change affects the epidemiology of infectious diseases, impacts noncommunicable diseases, and influences overall health determinants through environmental changes. By exploring these health risks, the chapter aims to contribute to the development of robust health systems and interventions that can mitigate the adverse effects of climate change on health.

The third section, Households' Vulnerability to Climate Change, evaluates the extent of households' vulnerability to climate change impacts in Africa using two case countries: Rwanda and Senegal. This section uses a composite vulnerability to climate change (VCC) index to assess household exposure, sensitivity, and adaptive capacity. By focusing on these dimensions, it highlights the differential impacts of climate change on various regions and communities, underscoring the need for targeted policies and adaptive measures. The analysis aims to provide examples of how to support the design and implementation of effective climate adaptation actions at the household level, thereby enhancing resilience.

In summary, this chapter aims to provide a detailed and integrated analysis of climate change impacts on Africa's environment, health, and households. The broader objective is to foster a deeper understanding of these interconnected issues and to support the development of comprehensive strategies that enhance resilience and sustainability across the continent. Through this exploration, we hope to contribute valuable insights and practical recommendations for policymakers, stakeholders, and communities facing the multifaceted challenges of climate change.

After the ratification of the Paris Agreement by African countries, expressing their strong political will to act on climate change, countries have also engaged to implement their nationally determined contributions (NDCs) and national adaptation plans (NAPs). The goals of the NAPs are to reduce vulnerability to the impacts of climate change by building adaptive capacity and to integrate adaptation into development policies and strategies. In this context, climate change vulnerability assessments will contribute to more efficient implementation of NAPs, which are essential tools for understanding the risks and opportunities associated with climate change, guiding adaptation efforts, and building climate resilience at the local, national, and global scales.

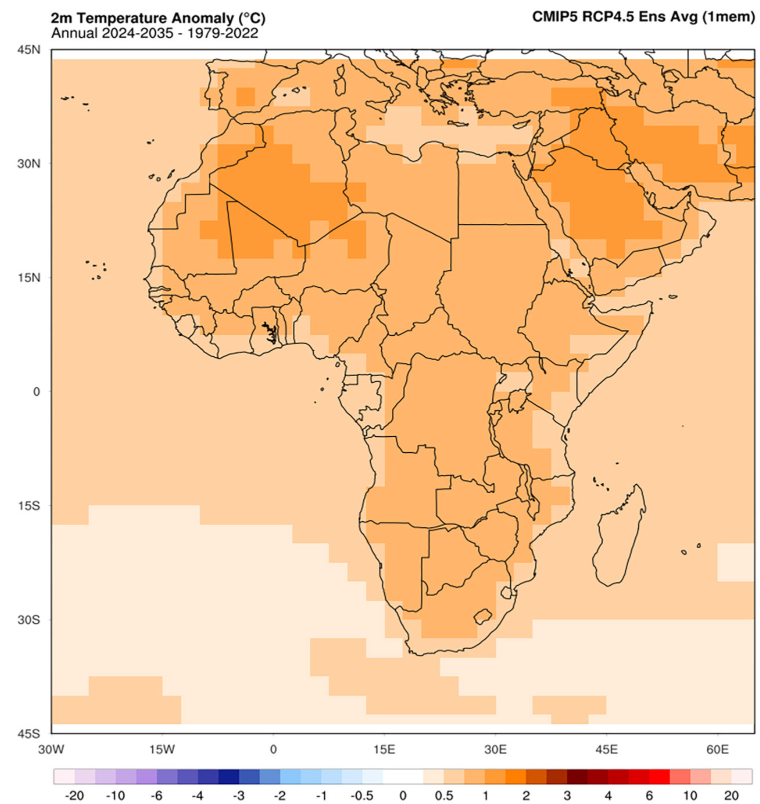
Environmental Risks of Climate Change

The primary objective of this section is to deepen our understanding of climate risk in Africa, with a focus on the implications of environmental changes and their potential impacts on the continent's ecosystems, socioeconomic development, and human well-being. By systematically assessing a range of environmental indicators, our study aims to achieve five specific objectives: First, it aims to evaluate the extent of land surface temperature (LST) variations across Africa by identifying regions that have experienced significant temperature changes compared to historical averages. This analysis will highlight areas most affected by warming trends, contributing to a broader understanding of climate change impacts. Second, the study seeks to assess precipitation variability by examining patterns over the continent to distinguish areas of rainfall deficiency or excess. This objective aims to shed light on the evolving dynamics of water availability, potential drought conditions, and their implications for agriculture and water resource management. Third, the study will evaluate vegetation health and coverage using normalized difference vegetation index (NDVI) data to identify regions with robust vegetation cover as well as areas facing vegetative stress. This aspect is crucial for understanding the impacts of climate variability on agricultural productivity and ecosystem resilience. Fourth, the study plans to determine drought risk and impact by employing a modified vegetation water supply index (MVWSI) for a detailed assessment of drought risk across various regions of Africa. By identifying drought-prone areas, this objective aims to inform strategies for drought mitigation and adaptation, with a particular focus on agricultural sustainability and food security. Finally, the study intends to provide actionable insights and data-driven recommendations for policymakers, stakeholders, and communities across Africa. By offering a comprehensive analysis of climate risks and their multifaceted impacts, the study supports the development of effective strategies for climate adaptation and resilience building.

Climate Projection and Implications in Africa

Figure 5.1 shows projected temperature anomalies for Africa based on the CMIP5 model ensemble under the RCP4.5 scenario. CMIP5 (Coupled Model Intercomparison Project Phase 5) compares climate models to assess future climate impacts (Taylor, Stouffer, and Meehl 2012). The RCP4.5 scenario assumes moderate emissions reductions, with greenhouse gas levels peaking around 2040 and a radiative forcing of 4.5 W/m² by 2100 (Thomson et al. 2011). The data also includes projections from Climate Reanalyzer, an online tool for visualizing climate datasets (Climate Reanalyzer 2024). It compares the expected annual temperatures for the period 2024–2035 with the historical baseline period of 1979–2022. The RCP4.5 scenario is a stabilization pathway that assumes some level of global mitigation efforts. Greenhouse gas emissions under this scenario peak around 2040 before declining. The radiative forcing is expected to reach 4.5 W/m² by 2100, leading to a moderate level of warming compared to more aggressive scenarios like RCP8.5. The map indicates widespread warming across the African continent. Temperature anomalies, which represent deviations from the historical average, are uniformly positive, signaling that temperatures are projected to increase throughout the continent. The color scale reveals that these anomalies range from about 0.5°C to over 3°C. Regions colored in darker

FIGURE 5.1—PROJECTION OF TEMPERATURE ANOMALIES FOR AFRICA



Source: Climate Reanalyzer (2024).

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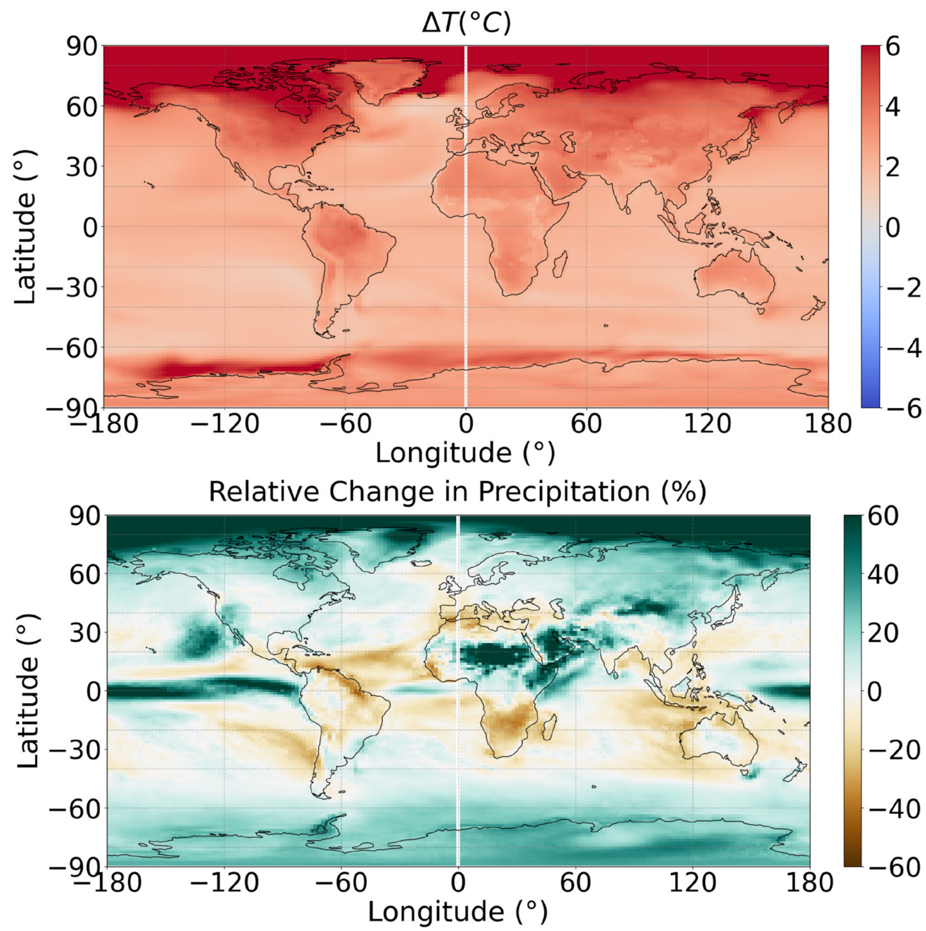
shades of orange indicate more significant warming, particularly in the northern and eastern parts of Africa. The Sahara Desert and its surrounding regions exhibit some of the highest temperature anomalies, with values exceeding 3°C in some areas. This is consistent with the understanding that desert regions are particularly sensitive to changes in climate, often experiencing more extreme temperature shifts. The Horn of Africa and parts of the Rift Valley are also projected to see substantial warming, with anomalies likely exceeding 2°C. This region is already vulnerable to climate variability, and further warming could exacerbate issues related to water sufficiency, agriculture, and food security. While this region shows significant warming, the anomalies are generally less extreme than in the northern parts of the continent. However, even moderate increases in temperature could have profound effects on agriculture, biodiversity, and water resources in this region.

Under the RCP4.5 scenario, Africa is projected to experience significant warming, which could have far-reaching impacts on various sectors:

- **Agriculture:** Higher temperatures could reduce crop yields, increase evapotranspiration rates, and stress water resources, potentially threatening food security across the continent.
- **Water resources:** Changes in temperature and precipitation patterns could affect water availability, with regions already experiencing water stress likely to be most impacted.
- **Human health:** Increased temperatures can exacerbate health issues, particularly in vulnerable populations. Heat waves, vector-borne diseases, and food and water insecurity could all increase.
- **Biodiversity:** The warming temperatures could threaten biodiversity, particularly in ecosystems that are highly sensitive to temperature changes, such as savannas, wetlands, and coastal areas.

Figure 5.2 illustrates projected changes in temperature and relative changes in precipitation across the globe, with a specific focus on the African region. These projections are based on the CMIP6 (Coupled Model Intercomparison Project Phase 6) multi-model ensemble under the SSP2-4.5 scenario, which represents a medium-emission pathway associated with intermediate challenges in climate change mitigation and adaptation (Eyring et al. 2016; O'Neill et al. 2016).

FIGURE 5.2—TEMPERATURE AND PRECIPITATION CHANGE PROJECTION ACROSS THE GLOBE FROM 2015 TO 2100



Source: Simulations from the CMIP6 models.

The top panel of the map shows a significant increase in temperature across Africa, with the most pronounced warming observed in northern Africa and the Sahara region. This result aligns with findings that high-latitude and continental regions are expected to warm more rapidly than coastal and equatorial regions due to various factors, including the land–sea contrast and polar amplification effects. The projected temperature rise in Africa is consistent across different regions, though the extent of warming varies, with the northern part of the continent experiencing some of the highest temperature increases. This heightened warming in northern Africa could exacerbate existing challenges related to water scarcity, agriculture, and human health.

The bottom panel of the map highlights changes in precipitation patterns, with notable drying trends in some regions of Africa, particularly in parts of southern Africa, while central and eastern Africa show potential increases in rainfall. The drying trends in southern Africa and the Mediterranean region are particularly concerning as they suggest an increased risk of drought, which could have severe implications for agriculture, water resources, and overall livelihoods in these regions. In contrast, the increase in precipitation in central and eastern Africa could lead to more frequent flooding events, posing risks to infrastructure and agriculture, and potentially leading to displacement of communities. The projected increase in temperatures and changes in precipitation patterns will likely exacerbate existing vulnerabilities in Africa, particularly in regions already prone to droughts or floods. Northern Africa's significant warming could lead to more intense heat waves and stress on water resources. At the same time, varying precipitation changes across the continent could complicate efforts to adapt to climate change, requiring region-specific strategies.

Incidence of Climate Risks in Africa

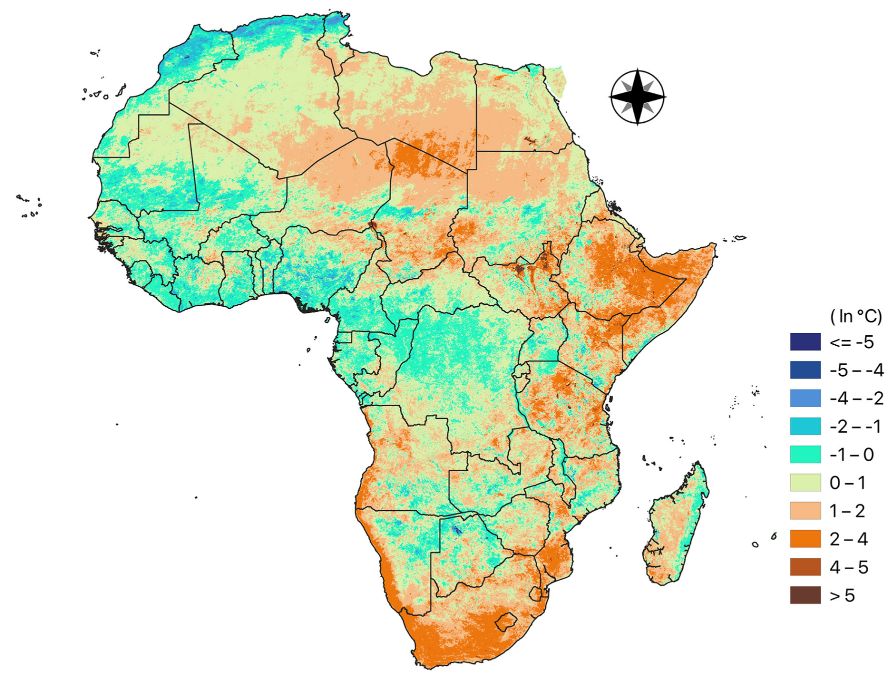
Our approach to analyzing climate risk involves a comprehensive examination of key environmental indicators that serve as proxies for understanding the broader impacts of climate change. Specifically, we focus on LST, precipitation anomalies, vegetation health as indicated by the NDVI, and drought conditions, each offering insights into different aspects of climate variability and its effects on the African continent. El Niño—since it causes changing patterns of both rainfall and LST—will also be discussed in this section.

Our analysis is underpinned by data from reputable sources, including the Moderate Resolution Imaging Spectroradiometer (MODIS) for Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI) metrics (Justice et al. 2002; Didan 2015), and the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) database for precipitation data (Funk et al. 2015).The integration of these datasets, complemented by the application of the MVWSI for drought analysis, forms the backbone of our methodology, allowing for a nuanced understanding of climate risk in Africa. Through this multifaceted approach, we aim to contribute valuable insights into climate risk management and adaptation strategies suitable for safeguarding Africa's future against the adversities posed by climate change.

Land Surface Temperature

LST is a crucial indicator in Earth observation and climate science. LST is the temperature of the Earth's surface, which includes various types of land cover such as soil, vegetation, water bodies, and built-up areas. It is a significant parameter, providing valuable insights into surface temperature variations and environmental changes over time. In Figure 5.3 we have shown the difference

FIGURE 5.3—AFRICA 2023 LAND SURFACE TEMPERATURE DIFFERENCE FROM THE AVERAGE OF THE LAST 20 YEARS



Source: Data processing and map by authors, based on MODIS data.

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between LST in 2023 and the average LST over the last 20 years to capture temperature anomalies in Africa.

LST is a fundamental indicator of the Earth's surface condition and plays a pivotal role in the physical processes of the Earth's surface energy balance (Li et al. 2013). The analytical comparison of 2023 LST data with the 20-year historical average reveals pronounced thermal anomalies across Africa, with a significant uptick in temperatures across southern, eastern, northern, and selected western African nations. Such anomalies underscore the escalating concern over rising global temperatures and their direct and indirect impacts on ecosystems and human livelihoods (IPCC 2021).

The results reveal that in 2023, most of Africa recorded temperatures above the average for the period 2003–2022, except for the desert areas of northern Africa. The most significant temperature anomalies were recorded in southern Africa (Mozambique, Namibia, South Africa, Swaziland), eastern Africa (Djibouti, Ethiopia, Kenya, South Sudan, Sudan), northern Africa (Egypt, Libya), and some western African countries (Chad, Niger). The lowest temperature anomalies in 2023 are noted in countries in western, northwestern, and west-central Africa.

Precipitation Anomalies

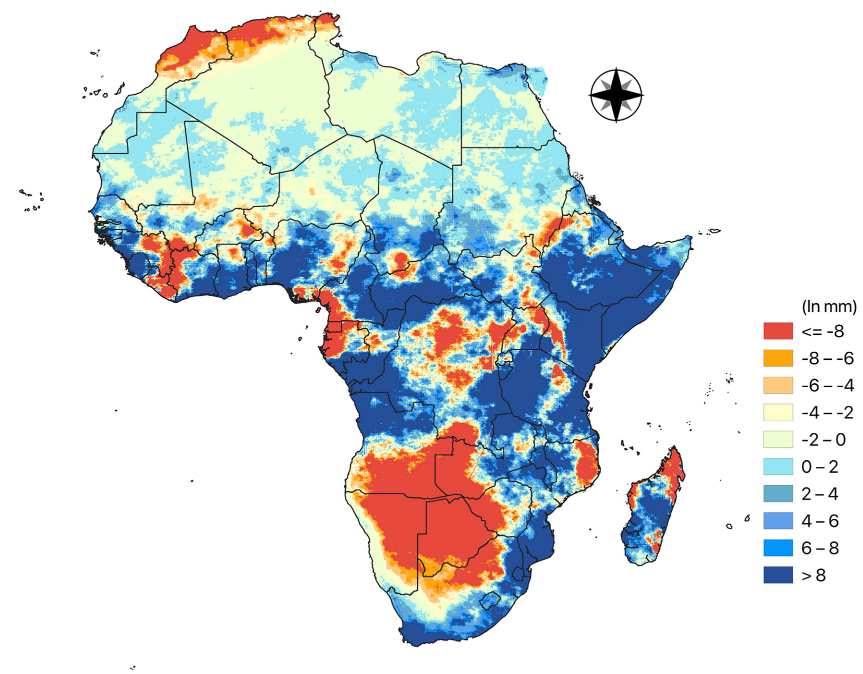
A precipitation anomaly is a deviation from the average or expected precipitation pattern for a given area over a certain period. Anomalies are characterized by above-average (excess) or below-average (deficient) precipitation in comparison to the long-term average. The rainfall anomaly between 2023 and the average of the last 20 years is computed using the CHIRPS datasets and shown in Figure 5.4. The results reveal two forms of rainfall anomaly in Africa. On the one hand, there is a sharp decrease in precipitation in 2023 on average, compared to the previous 20 years, in the northern African zone, in part of western Africa (Chad, Liberia, Mali, Mauritania, Niger) and in part of southern Africa (Angola, Botswana, Namibia, Zambia, Zimbabwe). On the other hand, rainfall anomalies exceeded the average for the period 2003–2023 in northeastern Africa, large parts of western Africa, the eastern Sahel region, Sudan, and parts of South Africa.

Vegetation Health

The NDVI is a widely used numerical indicator in remote sensing and vegetation studies. It quantifies the presence and health of vegetation by measuring the difference between near-infrared (NIR) and red-light reflectance from the Earth's surface. NDVI relies on the fact that healthy vegetation strongly absorbs red light (which is used in photosynthesis) and reflects NIR light. It is a significant parameter, providing valuable insights into vegetation dynamics, health, and distribution across different landscapes over time. Figure 5.5 shows the difference between NDVI in the current year (2023) and the average LST over the last 20 years to capture temperature anomalies in Africa.

The health and distribution of vegetation across Africa are critical indicators of ecosystem vitality. The NDVI, by quantifying the difference between NIR and visible light reflectance, offers insights into the health and stress levels of vegetation ecosystems. Our findings for 2023 indicate both robust and stressed vegetation zones, highlighting the need for targeted ecological management and conservation efforts (Pettorelli et al. 2005).

FIGURE 5.4—AFRICA 2023 RAINFALL DIFFERENCE FROM THE AVERAGE OF THE LAST 20 YEARS



Source: Data processing and map by authors, based on CHIRPS datasets.

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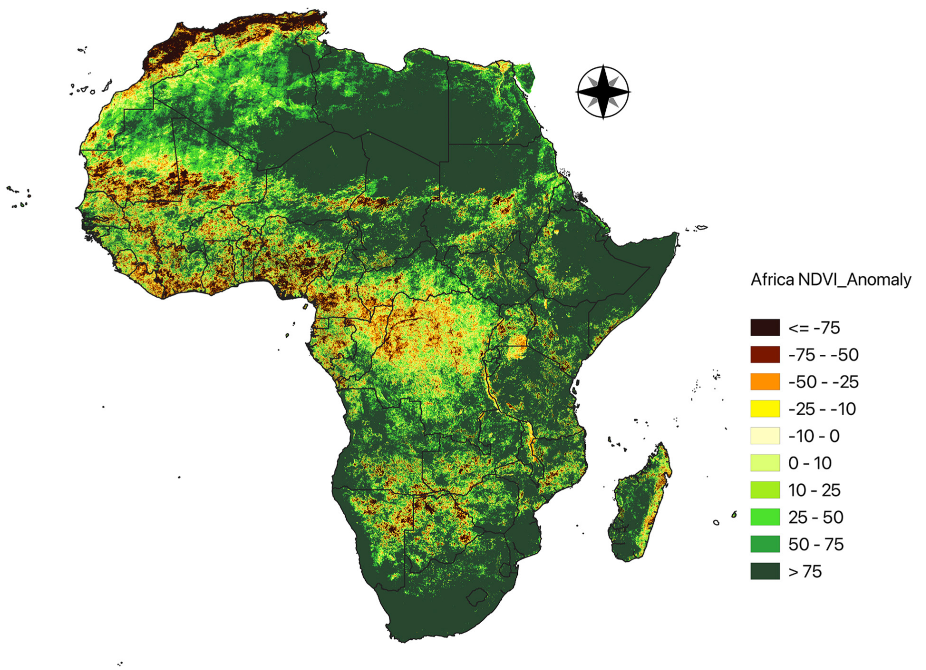
FIGURE 5.5—AFRICA 2023 NORMALIZED DIFFERENCE VEGETATION INDEX ANOMALY



Source: Data processing and map by authors, based on MODIS datasets.

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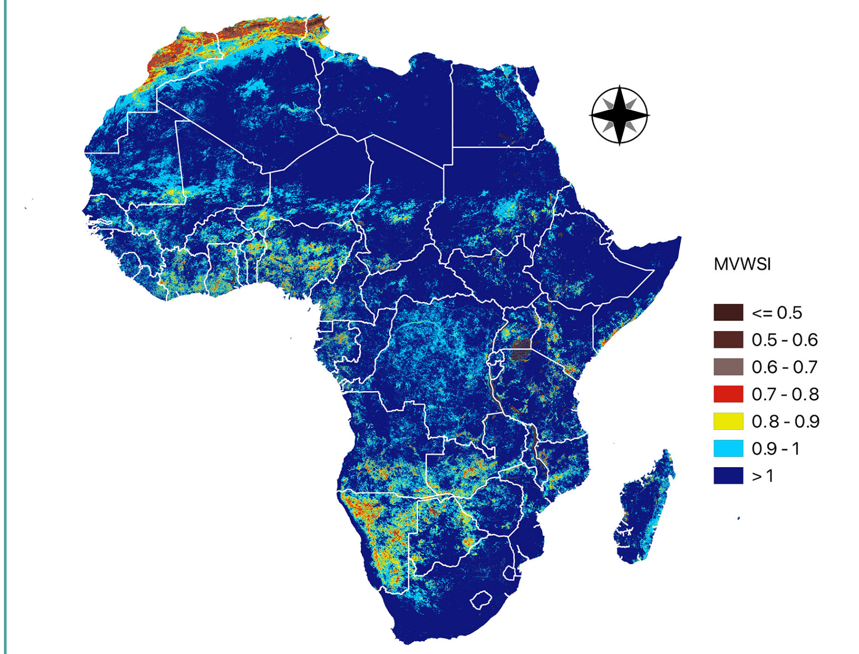
FIGURE 5.6—AFRICA 2023 MODIFIED VEGETATION WATER SUPPLY INDEX



Source: Data processing and map by authors, based on MODIS datasets.

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Figure 5.5 offers insight into the anomalies in vegetation cover between 2023 and the average of the preceding 20 years. The findings indicate that in regions such as northeastern Africa, eastern Africa, and a significant portion of southern Africa, there are no noticeable deviations in vegetation cover for the year 2023. Conversely, the data also uncover anomalies in the Horn of Africa and across a vast expanse of western Africa, highlighting areas where vegetation cover significantly diverges from historical norms.

Agricultural Drought Risk

Drought, characterized by extended periods of dry weather, leads to severe water shortages that adversely affect lives, assets, and livelihood activities (World Bank 2017). Such conditions have been notably detrimental in western Africa, where they exacerbate natural resource scarcity, diminish agricultural yields, and trigger crop failures, escalating food prices, hunger, and malnutrition (UNDRR 2021). The World Bank (2017) delineates drought into four distinct types: meteorological, hydrological, agricultural, and socioeconomic, each defined by its specific impact parameters. Our study focuses primarily on agricultural drought, which is assessed through soil moisture levels. For this purpose, we employ the modified vegetation water supply index (MVWSI) , conceived by Wu and Lu (2016) as a tool for agricultural drought risk and mitigation analysis. The MVWSI scale, when ranging from 0 to 1+, serves to identify areas at risk of drought; a lower MVWSI indicates reduced vegetation water supply, signifying more severe drought conditions. Conversely, MVWSI values exceeding 1 denote regions unaffected by drought. Droughts significantly undermine water security, agricultural productivity, and overall livelihood sustainability. Through the lens of the MVWSI, our 2023 analysis identifies critical regions across western Africa, southern Africa, and northern Africa. These findings underscore the urgent need for robust water management and drought resilience strategies to mitigate the adverse effects of these conditions (Wu and Lu 2016).

The MVWSI classification primarily focuses on agricultural drought, which is why much of Africa where agriculture is less prominent is not marked as drought-prone. In contrast, other maps highlight regions like the Sudano-Sahelian belt where agriculture is central, showing these areas as highly drought-prone. The difference lies in the specific focus—general aridity versus agricultural vulnerability.

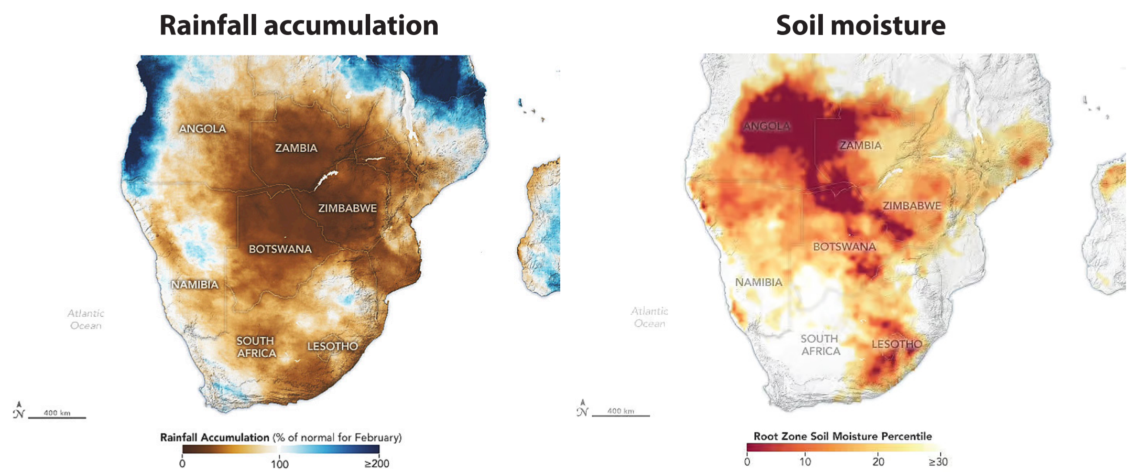
Figure 5.6 illustrates widespread areas characterized by dark blue hues, indicating MVWSI values greater than 1 across nearly all surveyed countries, suggesting these regions are currently not experiencing drought. Nonetheless, areas within western Africa, Namibia in southern Africa, and significant portions of northern Africa (Morocco, Tunisia) are identified as drought-prone, necessitating vigilant monitoring and the implementation of preemptive drought mitigation measures.

El Niño and La Niña Effects

El Niño is part of a natural climatic phenomenon called the El Niño–Southern Oscillation, which originates from a temperature anomaly in the surface waters of the South Pacific. When this is particularly marked and positive (at least +0.5°C), there is an El Niño episode; in the opposite case (a significant heat deficit), it is called the La Niña phenomenon. These two opposing states both significantly alter global weather patterns. During the onset of El Niño, the surface waters of the tropical Pacific Ocean, which are warmer, release more moisture and heat into the atmosphere, which usually leads to a rise in global temperatures. For example, 2016 was the hottest year on record and was a year marked by El Niño. However, the regional effects of the phenomenon remain variable and complex, with some places being both warmer and cooler than expected at different times of the year (Gaudiaut 2023).

In 2024, southern Africa has been experiencing one of its most severe droughts in recent decades, largely driven by an intense El Niño event. This drought has had devastating impacts on agriculture, food security, and livelihoods across the region. Figure 5.7 reveals that the El Niño phenomenon has led to a significant reduction in rainfall across southern Africa, particularly during the crucial months of December 2023 to February 2024. This period is typically when the region receives most of its annual rainfall, which is essential for the growth of rainfed crops like maize. The lack of sufficient rainfall has directly impacted soil moisture levels, which are crucial for crop growth and agricultural productivity. Figure 5.7 shows the soil moisture conditions as of March 2024, emphasizing the areas most severely affected by the drought. As shown in the map, the soil moisture levels across much of southern Africa are critically low, particularly in key agricultural zones. This situation has led to a drastic reduction in crop yields, especially for maize, which is a staple food for millions of people in the region (The United Nations in South Africa 2024).

FIGURE 5.7—RAINFALL ACCUMULATION AND SOIL MOISTURE CONDITIONS IN SOUTHERN AFRICA (FEBRUARY–MARCH 2024)



Source: NASA Earth Observatory (2023).

Health Risks of Climate Change

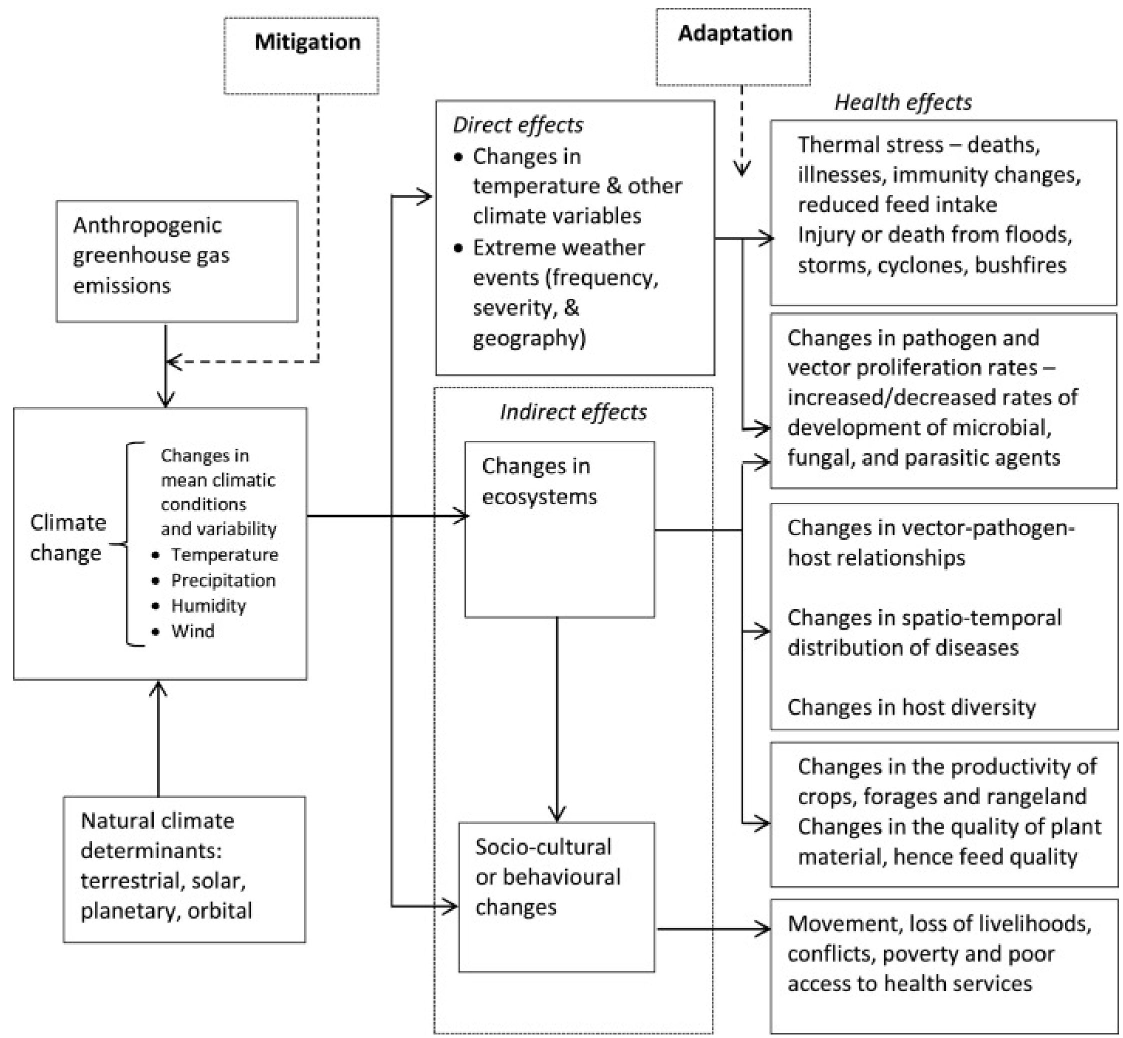
Connections Between Climate and Health

Worldwide, climate change poses a significant threat to the health and well-being of humans, animals, and ecosystems. Africa is the continent with the highest vulnerability to climate change overall and specifically to the health impacts of climate change (Birkmann et al. 2022). Nearly two-thirds (63 percent) of the countries most vulnerable to the health impacts of climate change are in Africa, with Burundi, Eritrea, Ethiopia, Gabon, Madagascar, and Niger at particularly high risk (World Bank 2017). As well as impacts on human health, climate change affects the health of animals, plants, soils, and ecosystems. The One Health (OH) approach provides a conceptual framework for both understanding and addressing the vulnerabilities around climate change by recognizing the intrinsic connections between human, animal, and environmental health.

The OH approach has been defined as "an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals, and ecosystems… The approach mobilizes multiple sectors, disciplines, and communities at varying levels of society to work together to foster well-being and tackle threats to health and ecosystems, while addressing the collective need for healthy food, water, energy, and air, taking action on climate change, and contributing to sustainable development" (Mettenleiter et al. 2023, 3). This approach has been endorsed by the Quadripartite.[1]

The pathway through which climate change impacts health can be conceptualized as follows: climate hazards lead to landscape changes, which in turn affect various

FIGURE 5.8—PATHWAYS THROUGH WHICH CLIMATE CHANGE IMPACTS ONE HEALTH



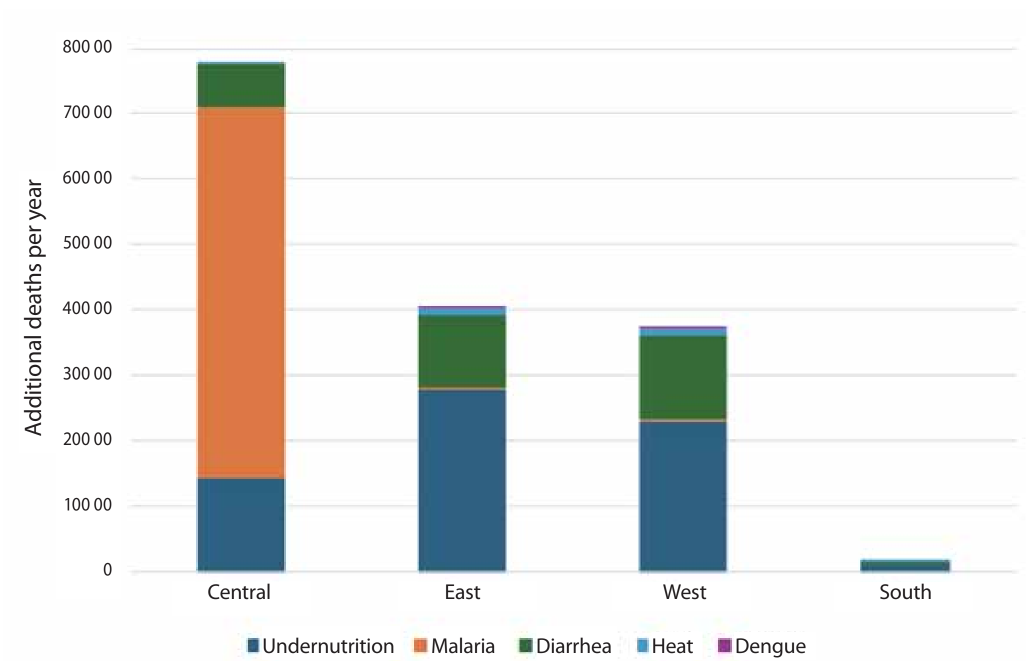
Source: Bett et al. (2017).

1 The OH Quadripartite is composed of the World Health Organization (WHO), the Food and Agriculture Organization of the United Nations (FAO), the United Nations Environment Programme (UNEP), and the World Organisation for Animal Health (WOAH).

health determinants, ultimately resulting in health outcomes. Climate hazards such as rising temperatures, changes in precipitation patterns, and extreme weather events can cause landscape changes like deforestation, desertification, soil erosion, and habitat loss. These landscape changes can then influence health determinants, including air quality, water availability, food security, and the spread of disease vectors (Bett et al. 2017). Ultimately, these changes in health determinants can lead to adverse health outcomes for humans, animals, and plants as shown in Figure 5.8.

Between 2030 and 2050, climate change is predicted to cause a million extra deaths every six years in Africa south of the Sahara (SSA) (Figure 5.9); these are preventable (WHO 2014). More recently, global mortality has been modeled under various socioeconomic futures that incorporate varying approaches to climate change and mitigation (Sellers 2020). Sustainable development is the most optimistic future, where challenges to mitigation and adaption are low; in this scenario, mortality in Africa is lower than in the more pessimistic scenarios (regional rivalry and inequality) (Sellers 2020).

FIGURE 5.9—EFFECTS OF CLIMATE CHANGE ON SELECTED CAUSES OF DEATH IN AFRICA SOUTH OF THE SAHARA, 2020–2030



Source: Authors, adapted from WHO (2014).

Climate-Sensitive Diseases

The epidemiology, or pattern, of climate-sensitive infectious diseases (CSIDs) changes as the result of climate-induced changes in the environment, especially in rainfall and temperature (Omazic et al. 2019). Reviews find that 50 to 60 percent of human and animal infectious diseases are climate-sensitive (McIntyre et al. 2017; Mora et al. 2022). CSIDs can be categorized by transmission pathways, the most important being vector-borne, waterborne, and foodborne (Cissé, Menezes, and Confalonieri 2018). Many zoonotic diseases are climate-sensitive. Climate also affects noncommunicable diseases (NCDs) by affecting the social and environmental determinants of health.

Vector-borne diseases

For vectors such as mosquitoes, ticks, and flies, warmer is better, and vector-borne diseases (VBDs) are often considered the most important category of CSID. Climate change is already creating favorable conditions for the breeding and survival of mosquito species that transmit important human diseases in Africa including malaria and arboviruses (dengue, chikungunya, yellow fever, and West Nile) (Thomson et al. 2018). The last three listed diseases were all first identified in Africa. Malaria is the most important human VBD in Africa, and climate change is predicted to increase transmission in the East African highlands and shift the malaria epidemic fringe southward (Caminade, McIntyre, and Jones 2019).

The two most important livestock VBDs are African animal trypanosomiasis (AAT), transmitted by tsetse flies, and East Coast fever (ECF), transmitted by the brown ear tick (Okello et al. 2022). Warmer temperatures could enable tsetse expansion into new areas, including the East African highlands, while conversely, population growth and agricultural development may reduce tsetse habitats in other regions. Similarly, ECF's vector, the brown ear tick, may decline in some western arid regions due to rising temperatures but may expand its range into cooler highland areas with increased rainfall (Bett et al. 2017).

Waterborne Diseases

Waterborne diseases are caused by pathogens such as bacteria, protozoa, and viruses transmitted through water; these include cholera, amoebiasis, hepatitis, and schistosomiasis. In Africa, where conducive factors often coincide, water-related diseases cause over 10 percent of infant mortality, which is 25 times higher than in developed countries (Ligtvoet et al. 2018). Cholera is one of the most climate-sensitive diseases and has been increasing in range and incidence in recent years. In 2023, 19 African countries reported outbreaks causing a quarter of a million cases and thousands of deaths (Africa CDC 2024).

Foodborne Diseases

Only recently has it been recognized that the burden of foodborne diseases (FBDs) is comparable to that of malaria, HIV and AIDS, or tuberculosis and that the highest per capita burden occurs in Africa (Havelaar et al. 2015). The 2023 Annual Trends and Outlook Report estimated that 160 million FBD episodes and 210,000 FBD deaths occurred in Africa in 2023 (including northern Africa); most of these are preventable (Ayalew, Kareem, and Grace 2023). Climate change can also impact food safety and increase the risk of FBD. Higher temperatures and changes in precipitation patterns can facilitate the growth of harmful pathogens, such as mycotoxins, in food crops (Jagger et al. 2016).

Noncommunicable Diseases

Infectious diseases still dominate the burden of disease in SSA, but a demographic transition is leading to the increased importance of noncommunicable diseases (NCDs), which predominate in high-income regions, with cardiovascular disease followed by cancers as the two leading causes (Gouda et al. 2019). The link between climate change, agrifood systems, and NCDs is becoming increasingly evident (Nugent and Fottrell 2019).

One of the most important NCDs in Africa is malnutrition. Children whose weight is too low for their height are said to be affected by wasting, and children whose height is too low for their age are affected by stunting. Although progress has been seen over the last decade, 150 million children were stunted in 2022, nearly half of them (43 percent) in Africa, where progress on stunting is lagging most (UNICEF, WHO, and WB 2023). Climate change impacts stunting by reducing crop yield and animal productivity and by increasing disease and extreme events (Agostoni et al. 2023).

The psychological impacts of disasters may exceed the physical effects of the injuries they cause (Hayes et al. 2018). There have been few studies on climate change and mental health in Africa, but effects have already been seen on African cultural heritage markers such as historic buildings, archaeological sites and museum collections, seasonal festivals, sacred sites, traditional fishing practices, and traditional crops and foodways (Atwoli, Muhia, and Merali 2022). Higher rates of substance misuse have been reported among people displaced and exposed to extreme climate stressors in South Africa (Myers et al. 2011).

Climate-Related Health Shocks and Emergencies

Public Health Emergencies

Africa reports the heaviest burden of public health emergencies globally, experiencing an average of around 100 emergencies each year, almost all due to infectious diseases (Koua et al. 2023). These include emerging diseases and diseases associated with extreme events. Around 30 percent of public health emergencies are due to zoonoses (including COVID-19), and zoonotic public health emergencies are increasing over time (Koua et al. 2023). As well as infectious diseases, extreme weather events have direct and indirect impacts on public health. An investigation by Carbon Brief (Dunne 2023) found that at least 15,700 people were killed by drought, heat wave, cyclone, flood, and landslide in Africa in 2023 and a further 34 million were adversely affected. CSIDs are often triggered by extreme climatic events. A comprehensive review found most outbreaks followed floods (38 percent) or tropical cyclones (26 percent), with fewer following drought, heavy rainfall, or heat waves (Alcayna et al. 2022).

Emerging Infectious Diseases

Emerging diseases have been of great concern over the last several decades following pandemics caused by COVID-19, avian influenza, and other diseases. Considering CSID, western Africa is an emerging hotspot for dengue (Badolo et al. 2022), and chikungunya is predicted to expand into central Africa (Tjaden et al. 2017).

Health Impacts Associated With Extreme Events

Flooding accounts for nearly half (47 percent) of all recorded natural disasters and is responsible for nearly half (44 percent) of the deaths from disasters (UN 2015; UNEP 2020). A recent review of flood-associated disease in SSA found that around 40 million people were affected by floods between 2010 and 2020; this has been linked to enormous spikes in cholera, increased risk of scabies, increased prevalence of arboviruses (chikungunya, dengue), and more diagnosed cases of malaria (Suhr and Steinert 2022). Even without flooding, extreme precipitation events have been consistently associated with waterborne disease outbreak events (Semenza 2020). In addition to diseases, floods cause drowning, trauma, hypothermia, and food insecurity from loss of crops and animals.

Climate change contributed to the recent deadly drought in the Horn of Africa, which left more than 20 million people facing food insecurity and more than 5 million children facing acute malnutrition, while also decimating the livestock on which communities depend (WFP 2023). Droughts also cause decreased river flows, which in turn increase the concentration of waterborne pathogens, leading to unclean water and disease.

Households' Vulnerability to Climate Change

The aim of this section is to provide a household vulnerability assessment to support the design and implementation of ongoing climate adaptation actions through prioritization of the most affected areas and households. To this end, we first explain the methods used to estimate vulnerability to climate change at the household level using the Intergovernmental Panel on Climate Change (IPCC) framework, and then we present two case studies, from Rwanda and Senegal.

Methods of Estimating Households' Vulnerability to Climate Change

A climate vulnerability assessment is an extension of a climate impact assessment that evaluates the potential effects of one or several climate change scenarios on one or more impact domains and compares them to projected effects of a constant climate. We distinguish between two generations of climate vulnerability assessments. The first-generation vulnerability assessment is characterized primarily by the evaluation of climate impacts in terms of their relevance for society and by the consideration of potential adaptation. The second-generation vulnerability assessment is the more thorough assessment of the adaptive capacity of people, thus shifting the focus from potential to feasible adaptation. Therefore, the second generation of climate vulnerability assessments emphasize vulnerability with three components: exposure, sensitivity, and adaptation capacity.

The *exposure* of a system to climate change refers to the magnitude of climatic variations that the system is expected to face. Thus, it depends on the level of global climate change and, due to the spatial heterogeneity of anthropogenic climate change, on the system's location. Burton (1997) suggests a hierarchy of weather and climate phenomena (denoted as type 1, 2, and 3 variables) to distinguish between single climate variables (such as local temperature), specific weather events (such as a convective storm), and long-term processes (such as anthropogenic climate change). Which of these aspects are included in the exposure definition of a particular vulnerability assessment depends on its specific circumstances. The *sensitivity* of a system refers to the degree to which a system may be affected by exposure to climate change risks. It denotes the (generally multifactorial and dynamic) dose–response relationship between its exposure to climatic stimuli and the resulting impacts. *Adaptive capacity* refers to the ability of a system to adjust to climate change. Brooks (2003) classifies factors that determine adaptive capacity as either climate hazard-specific or generic and either endogenous or exogenous. Generic determinants of adaptive capacity in social systems comprise such nonclimatic factors as economic resources, technology, information and skills, infrastructure, institutions, and equity (Smit and Pilifosova 2003; Yohe and Tol 2002). Endogenous factors are the characteristics and behaviors of the subject population group, whereas exogenous factors include the wider economic and geopolitical context.

In terms of empirical estimations, the composite household vulnerability indicator is guided by the conceptual framework of climate-related risks contained in the (IPCC 2014) report which explores the potential impacts of climate change on agriculture and food security (Adger 2006; O'Brien et al. 2007; Sharma and Ravindranath 2019). The IPCC defines vulnerability as the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC 2014). In line with this definition, household vulnerability at each administration level of a given country is estimated by calculating the administration-level score, I, for each of the three dimensions (exposure, sensitivity, and adaptation capacity). Subsequently, these dimension scores are summed up to obtain the overall VCC index. The results obtained from this estimation are used to compare and assess household vulnerability to climate change across the spatially disaggregated administrative units of the country.

Specifically, the VCC is estimated using the following formula:

$$\boldsymbol{VCC_i = \frac{1}{3}(Exposure\ score_i + Sensitivity\ score_i - Adaptation\ capacity\ score_i)},$$

$$\text{where} \begin{cases} \text{Exposure score}_i = \frac{1}{n_E}\sum_{k=1}^{n_E} V_{k,i}^{\text{Exposure}} \\ \text{Sensitivity score}_i = \frac{1}{n_S}\sum_{k=1}^{n_S} V_{k,i}^{\text{Sensitivity}} \\ \text{Adaptation capacity score}_i = \frac{1}{n_{IA}}\sum_{k=1}^{n_{IA}} V_{k,i}^{\text{Adaptation capacity}} \end{cases}.$$

Index $\boldsymbol{i}$ represents the administration level; $\boldsymbol{n_E}$, $\boldsymbol{n_S}$, and $\boldsymbol{n_{IA}}$ correspond to the number of select variables for each dimension. $V_{k,i}^{Exposure}$ corresponds to the k^{th} normalized variable of the region $\boldsymbol{i}$ for the exposure dimension.

In addition to estimating the composite indicator, one can analyze the vulnerability level of each administration level according to two categories. The first category is called "relative" (see Figure 5.10) and helps to compare and prioritize the districts of the country and to distinguish within an administration level which districts are "much more vulnerable," "more vulnerable," "less vulnerable," and "much less vulnerable" than others. The second category is called "absolute," as it helps to compare the VCC index across countries or over years.

Case Study 1: Households' Vulnerability to Climate Change in Rwanda

For the case of Rwanda, we have estimated the composite VCC index using household data collected by the National Institute of Statistics of Rwanda (NISR) in 2021, under the Comprehensive Food Security and Vulnerability Analysis (CFSVA) survey. Results of the VCC index, shown in Figure 5.11, reveal that the overall level of household vulnerability in Rwanda is 0.43 on a scale of 0 to 1 (the closer the value is to 1, the higher the vulnerability level). This score is largely attributable to the inability of households to adapt to climate shocks (0.61), followed by their exposure to climate change risks (0.38), and finally the level of household sensitivity (0.29). These results indicate that although the level of sensitivity is somewhat low, households in Rwanda have a high exposure to climate change risks and limited capacity to adapt to adverse effects. The major source of vulnerability among households in Rwanda is their limited adaptive capacity to climate shocks, indicating that policy actions should focus on strengthening this factor.

Figure 5.11 shows that Karongi, Nyaruguru, and Gisagara were the three districts with the largest share of vulnerable households among all districts in 2021, as they recorded scores that ranged between 0.53 and 0.56. These three

FIGURE 5.10—CATEGORIZATION OF VULNERABILITY

Relative categorization: k-means approach

The k-means clustering algorithm is a technique used for partitioning a dataset into a predetermined number of clusters. The Steps for the k-means method:

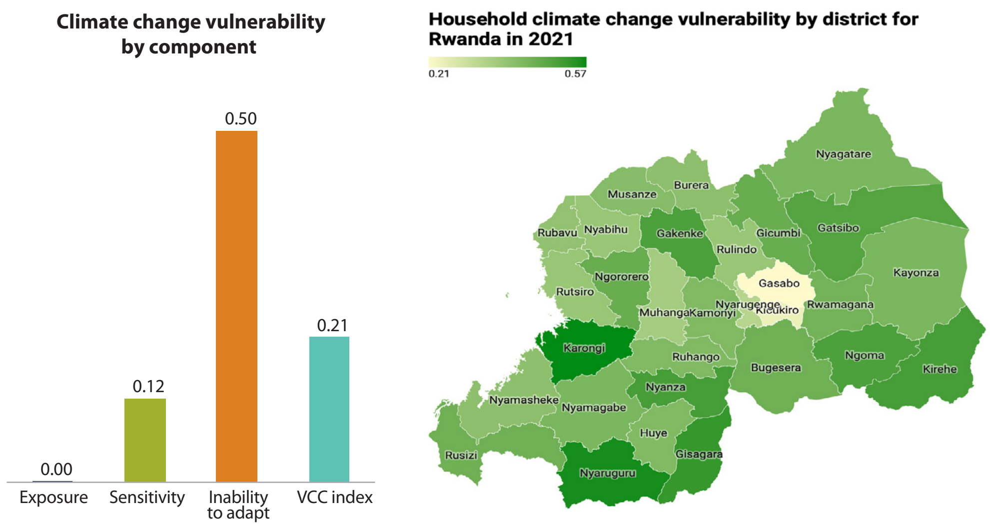
- Step 1: Randomly select *k* initial cluster centroids (points in the feature space). These centroids represent the initial cluster centers.
- Step 2: Assign each data point to the nearest cluster centroid based on a distance metric, commonly the Euclidean distance. Each data point is assigned to the cluster whose centroid is closest to it.
- Step 3: Recalculate the cluster centroids by taking the mean of all data points assigned to each cluster. This moves the centroids to the center of their respective clusters.
- Step 4: Iterate steps 2 and 3 until convergence is reached, typically when the cluster assignments no longer change or when a specified number of iterations is reached.
- Step 5: Once convergence is achieved, the final clustering is obtained. Each data point belongs to the cluster associated with the nearest centroid.

As results, we will obtain the four following clusters:

- Much more vulnerable
- More vulnerable
- Less vulnerable
- Much less vulnerable

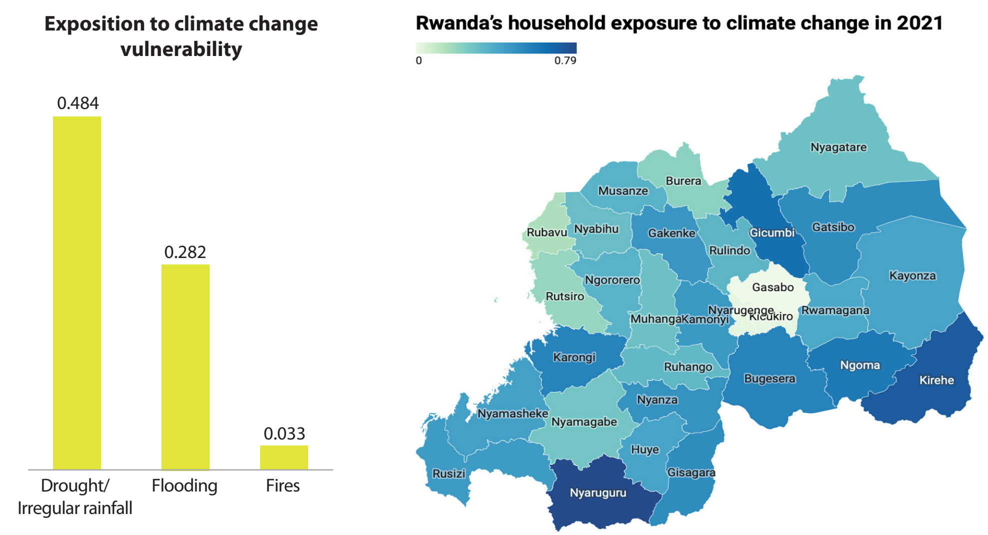
Source: Authors' compilations.

FIGURE 5.11—RWANDA'S HOUSEHOLD VULNERABILITY TO CLIMATE CHANGE IN 2021



Source: Authors' calculations using the 2021 CFSVA data (NISR 2023).

FIGURE 5.12—RWANDA'S HOUSEHOLD EXPOSURE TO CLIMATE CHANGE IN 2021



Source: Authors' calculations using the 2021 CFSVA data (NISR 2023).

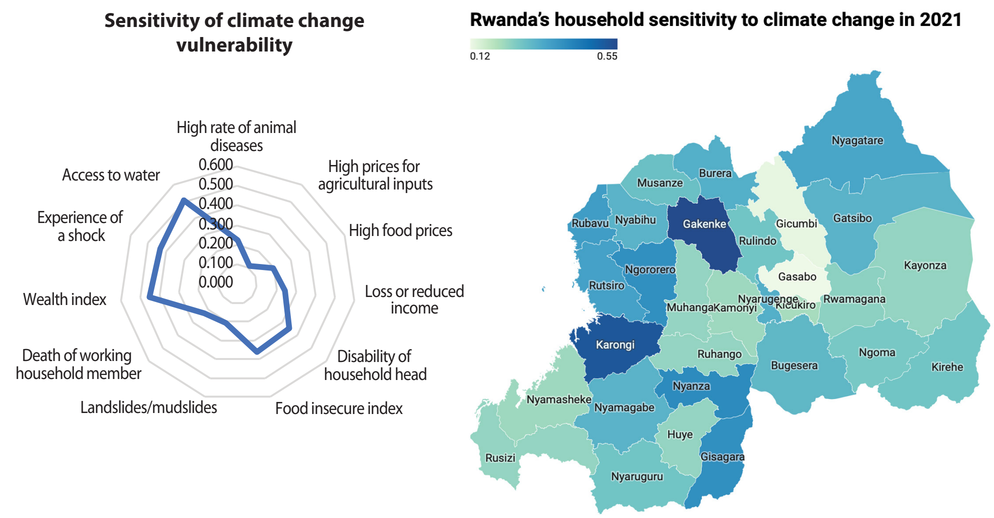
were followed by Kirehe, Nyanza, Gakenke, and Ngoma, which all recorded scores above 0.5. The two districts with the fewest vulnerable households are Gasabo (0.21) and Kicukiro (0.24), which are both located in Kigali province. This indicates that households in urban areas are less vulnerable to climate change than rural households, as they have options for income diversification, as well as better access to markets and public services. The other districts have a medium level of vulnerability, with scores ranging between 0.38 and 0.49.

At the national level, the results shown in Figure 5.12 reveal that heavy rainfall as well as frequency and intensity of flooding are the variables that most explain the exposure of households to climate change risks, while fire plays a minor role. The results show that households in the districts of Nyaruguru, Kirehe, Gicumbi, Ngoma, Karongi, Bugesera, Gisagara, and Gatsibo face high exposure to climate change risks, which is reflected in their scores, all above 0.5. Households in the districts of Gasabo, Kicukiro, Nyarugenge, Rubavu, Rutsiro, Burera, Nyamagabe, and to a lesser extent, Nyagatare and Muhanga, have the lowest exposure to climate change risks, with scores of under 0.3. Households residing in the other districts are moderately exposed to climate change risks.

The results of the sensitivity analysis, presented in Figure 5.13, show that households in Gakenke and Karongi districts are the most sensitive to climate change risks, with scores over 0.5. In contrast, the districts of Gasabo, Gicumbi, Kicukiro, Kamonyi, Nyamasheke, Ruhango, Kayonza, Rusizi, Muhanga, Huye, and Rwamagana have the lowest scores, as does Ngoma to a smaller extent. Households in the other districts are moderately sensitive to climate change risks. The sensitivity of households to climate change risk is mainly associated with low access to water. Other associated variables are low wealth index scores, experiences of shocks, and food insecurity.

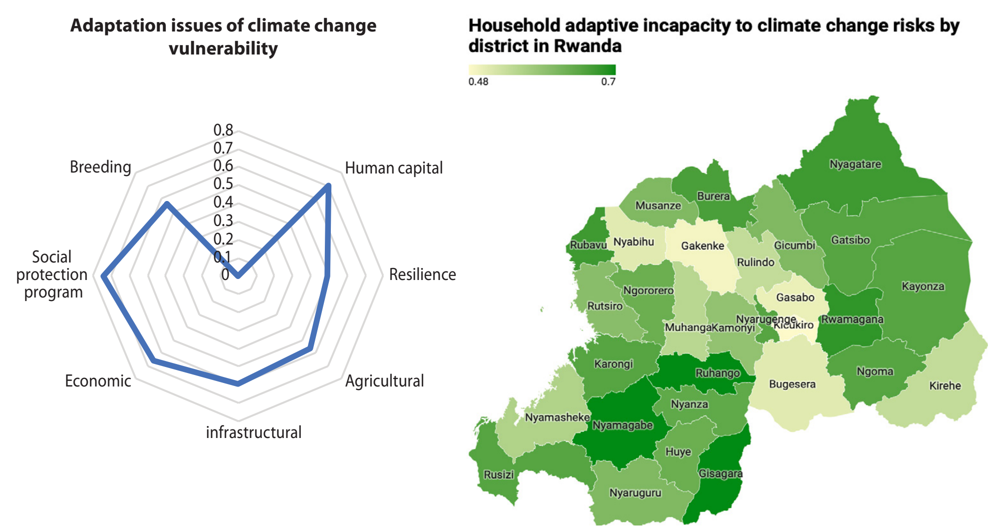
Regarding households' adaptation capacity, the results shown in Figure 5.14 reveal that households in the districts of Gisagara, Nyamagabe, and Ruhango have the highest incapacity (that is, the lowest capacity) to adapt to climate change, with a score equal to 0.70. This interpretation remains valid for households in the districts of Rwamagana (0.68), Rubavu (0.67), Nyagatare (0.67), Burera (0.66), Gatsibo (0.65), Kayonza (0.65), Rusizi (0.65), Nyarugenge (0.65), Ngoma (0.65), and Karongi (0.65). Kicukiro and Gakenke districts have the

FIGURE 5.13—RWANDA'S HOUSEHOLD SENSITIVITY TO CLIMATE CHANGE IN 2021



Source: Authors' calculations using the 2021 CFSVA data (NISR 2023).

FIGURE 5.14—RWANDA'S HOUSEHOLD ADAPTATION CHALLENGES TO CLIMATE CHANGE IN 2021



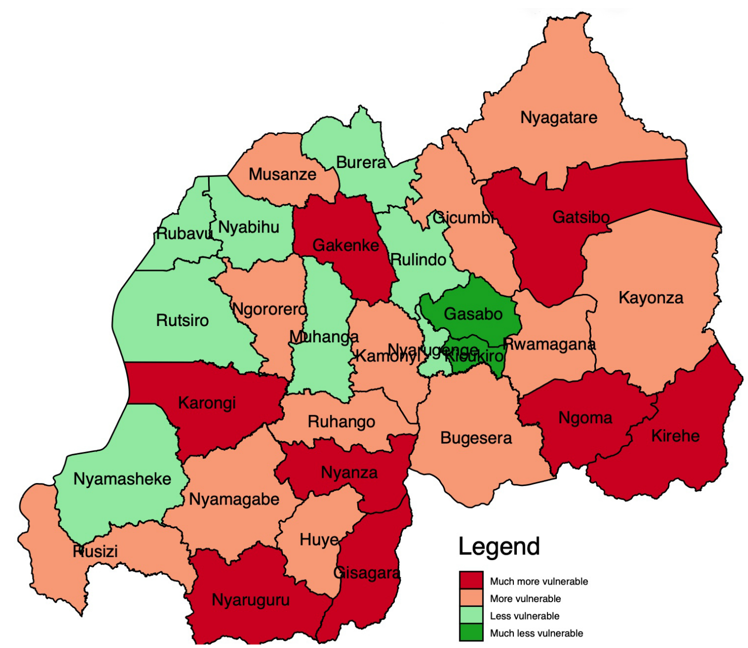
Source: Authors' calculations using the 2021 CFSVA data (NISR 2023).

lowest scores for this dimension among all the districts. This means that households in these two districts have greater capacity to adapt to climate change shocks than households in other districts.

In terms of the seven subdimensions used to calculate this score, low access to social protection programs (0.74), limited human capital (0.70), and low income level (0.66) best explain the inability of households to adapt to climate change. The human capital score is generally attributable to the low levels of membership in any association or cooperative, limited weather and climate information, and lack of training and technical assistance in improved agricultural and livestock practices.

Figure 5.15 shows the results of relative categorization. Relative categorization helps to compare and prioritize the districts of the country. The results reveal that Gasabo and Kicukiro districts have the greatest share of households in the "much less vulnerable" category in Rwanda in 2021.

FIGURE 5.15—CATEGORIZATION OF HOUSEHOLDS' VULNERABILITY IN RWANDA'S DISTRICTS IN 2021



Source: Authors' calculations using the 2021 CFSVA data (NISR 2023).

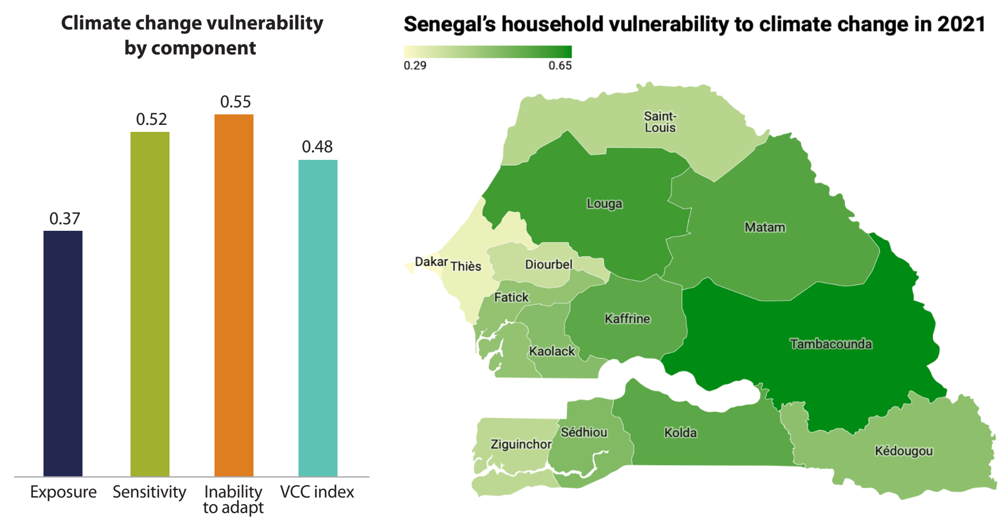
Burera, Rutsiro, Nyamasheke, Rubavu, Muhanga, Rulindo, and Nyabihu have the greatest share of "less vulnerable" households in 2021. Gatsibo, Ngoma, Kirehe, Nyanza, Nyaruguru, Gisagara, Karongi, and Gakenke have the greatest share of "much more vulnerable" households, and the remaining districts have the greatest share of "more vulnerable" in 2021 based on the results of the VCC index.

Case Study 2: Households' Vulnerability to Climate Change in Senegal

For the case of Senegal, the VCC index results, shown in Figure 5.9, reveal that the overall level of household vulnerability is 0.48 on a scale of 0 to 1 (the closer the value is to 1, the higher the vulnerability). The composite VCC index is explained more by the inability of households to adapt (0.57), followed by their sensitivity to climate change (0.49) and, finally, their level of exposure (0.37). The result indicates that though the level of exposure is somewhat low, households in Senegal are very sensitive to any climate risk exposure and have very limited capacity to adapt to the adverse effects. Looking at Figure 5.16, we note that the Tambacounda region stands out as the most vulnerable region, with a score of 0.65. It is followed by Louga, Matam, Kolda, Kaffrine, and Sédhiou, with scores above 0.5. The two regions with the least vulnerable households are Dakar (0.29) and Thiès (0.32), indicating that households in urban areas are less vulnerable to climate change than rural households, as they have options for income diversification and better access to markets and public services. The other regions have a medium level of vulnerability, with scores ranging between 0.38 and 0.49. Beyond these results, this section has shown how each of the three dimensions of vulnerability evolves simultaneously in each region.

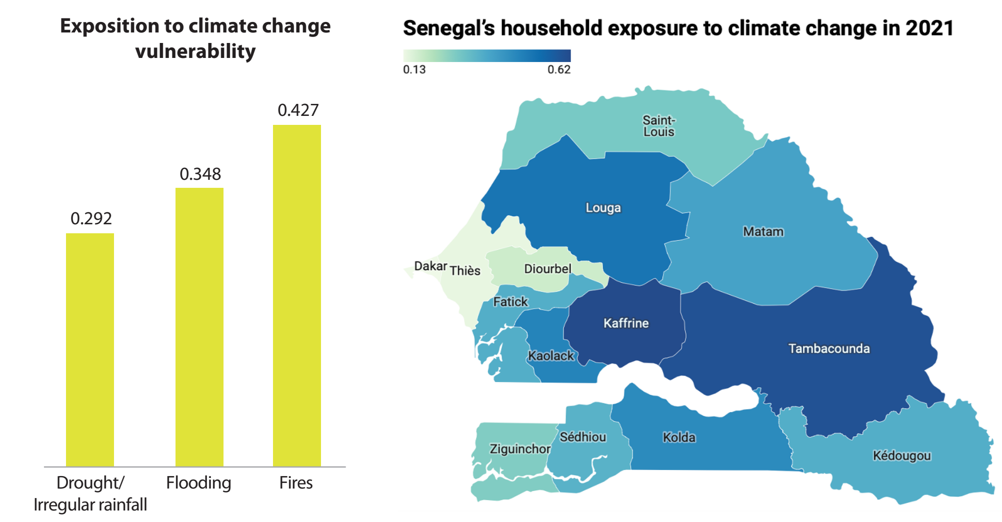
In view of the results shown in Figure 5.17, we note that households residing in the regions of Tambacounda, Kaffrine, and Louga are very exposed to climate change because they have scores above 0.5. Households in the regions of Dakar, Thiès, Diourbel, Ziguinchor, and to a lesser extent, Saint-Louis are the least exposed to climate change, with scores under 0.3. Households residing in other regions of Senegal are moderately exposed to climate change. The exposure dimension was computed based on four variables: precipitation, drought/irregular rainfall, flooding, and fires. At

FIGURE 5.16—SENEGAL'S HOUSEHOLD VULNERABILITY TO CLIMATE CHANGE IN 2021



Source: Authors' calculations using data from EHCVM and DAPSA.

FIGURE 5.17—SENEGAL'S HOUSEHOLD EXPOSURE TO CLIMATE CHANGE IN 2021



Source: Authors' calculations using data from EHCVM and DAPSA.

the national level, the results show that heavy rainfall and the frequency and intensity of fires better explain the exposure of households to climate change than do flooding and drought/irregular rainfall.

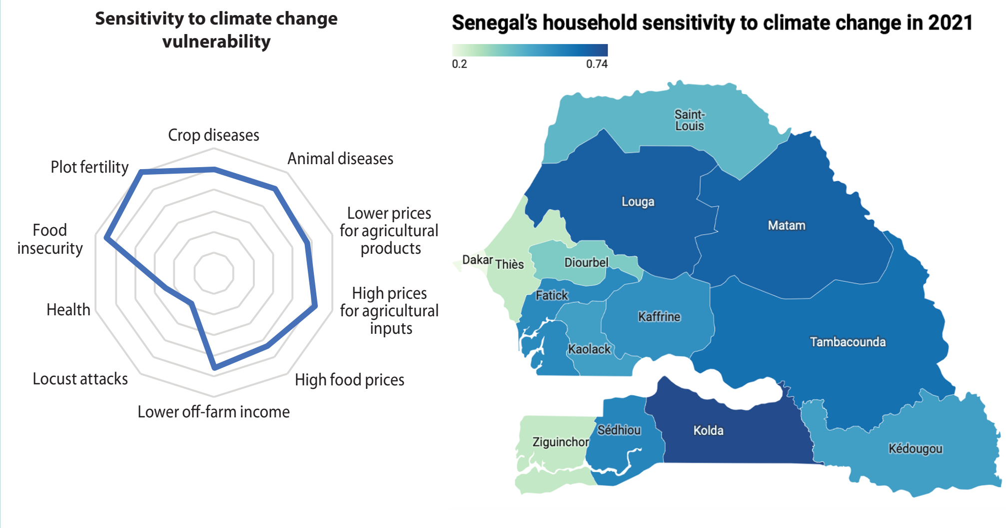
The results of the sensitivity dimension, presented in Figure 5.18, reveal that households in the Kolda region are the most sensitive to climate change risks, with a score of 0.74. Households in Louga (0.68), Matam (0.67), and Tambacounda (0.63) are also very sensitive to climate change. In the regions of Sédhiou, Fatick, and Kaffrine, scores vary between 0.54 and 0.57, also reflecting the sensitivity of their households. The lowest scores are obtained in Dakar, Thiès, Ziguinchor, and to a lesser extent, Diourbel. The sensitivity of households to climate change is mainly associated with the low incidence of irrigated cultivation by farmers. Added to this are the infertility of cultivated areas, a high demographic dependency rate, food insecurity, high prices for agricultural inputs, animal diseases, and crop diseases.

The results in Figure 5.19 reveal that households residing in the Tambacounda region have the lowest capacity (that is, the highest incapacity) to adapt to climate change, with a score of 0.71. The index score is also higher in the regions of Matam (0.66), Ziguinchor (0.65), and Louga (0.62), which means that households in these regions have low capacity to adapt to climate change. The regions of Kolda and Kaffrine have the lowest scores in this dimension. This means that households in these two regions have more capacity to adapt to climate change than households in other regions of Senegal. Regarding the four subdimensions that we defined to calculate the scores, low agricultural performance (0.66) and limited human capital (0.58) best explain the inability of households to adapt to climate change.

The highest score in agriculture is explained by the low share of households who used or practiced improved seed variety, animal or household waste, inorganic fertilizer, and multiple cropping or irrigated plots. The inability of households to adapt to climate change through the human capital subdimension is generally explained by a very low levels of female entrepreneurship, household heads using agricultural information, households having processed agricultural products, and women with access to agricultural land, by region.

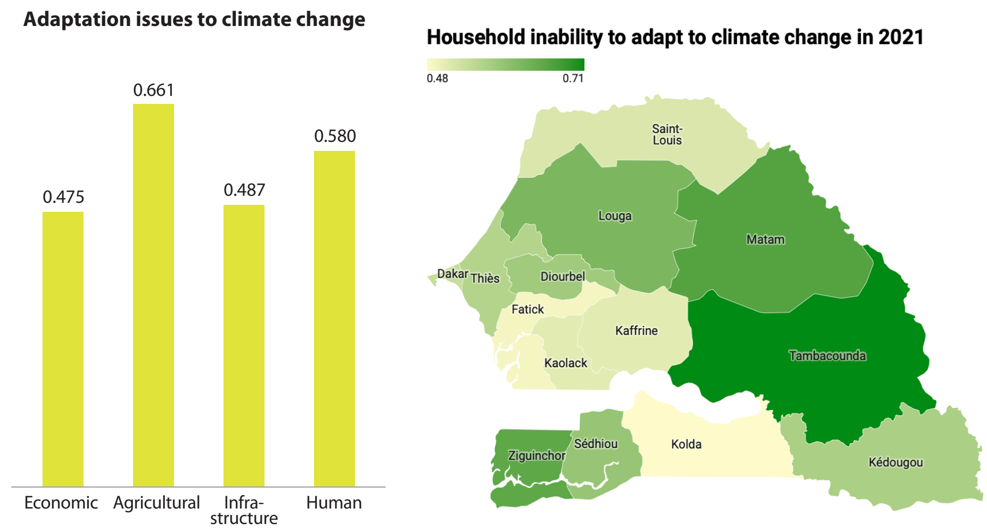
Figure 5.20 shows the results of relative categorization, which helps to compare and prioritize the regions of Senegal. The results reveal that the

FIGURE 5.18—SENEGAL'S HOUSEHOLD SENSITIVITY TO CLIMATE CHANGE IN 2021



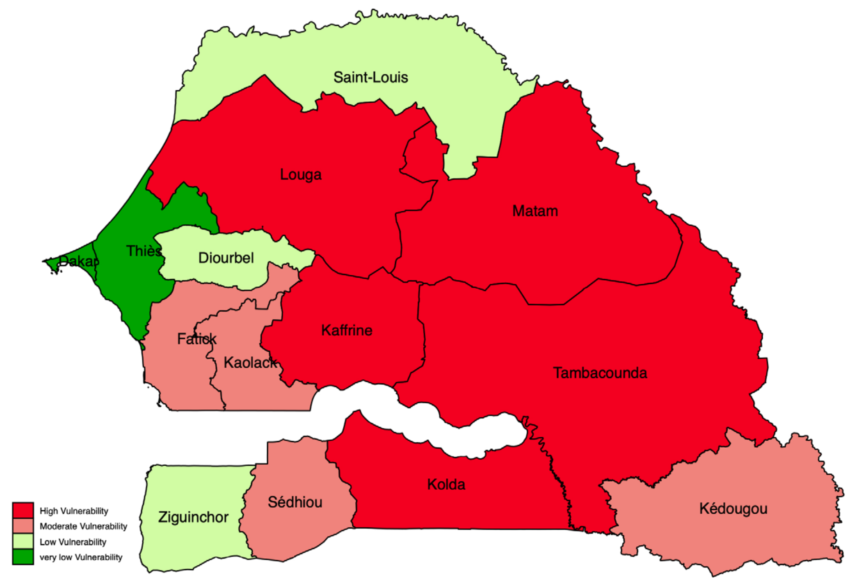
Source: Authors' calculations using data from EHCVM and DAPSA.

FIGURE 5.19—SENEGAL'S HOUSEHOLD ADAPTATION CHALLENGES TO CLIMATE CHANGE IN 2021



Source: Authors' calculations using data from EHCVM and DAPSA.

FIGURE 5.20—CATEGORIZATION OF HOUSEHOLDS' VULNERABILITY IN SENEGAL'S REGIONS IN 2021



Source: Authors' calculations using data from EHCVM and DAPSA.

regions of Matam, Louga, Kaffrine, Tambacounda, and Kolda have a higher incidence of households with VCC scores in the "much more vulnerable" category than those in other categories in 2021. Fatick, Kaolack, Sédhiou, and Kédougou have a higher share of "more vulnerable" households. The central western part of the country (Dakar and Thiès) has a greater share of "much less vulnerable households" than other categories. Finally, the regions of Saint-Louis, Diourbel, and Ziguinchor have a higher proportion of "less vulnerable" households.

Conclusion and Policy Recommendations

This chapter addresses climate change in African agrifood systems through the lenses of environmental changes, health outcomes, and household vulnerabilities. The insights gained from this research are vital for policymakers, stakeholders, and communities as they help to identify priority risks and sources of vulnerability to climate change across communities and at the household level.

The analysis of environmental risks associated with climate change in Africa reveals significant and varied impacts across the continent, highlighting several critical areas requiring immediate attention and strategic intervention. The evaluation of LST data indicates a notable increase in temperatures across various regions, particularly in southern, eastern, and parts of western Africa. These temperature anomalies underscore the urgent need for policies aimed at mitigating the effects of rising temperatures, which threaten both ecosystems and human livelihoods. Precipitation anomalies, identified through the CHIRPS dataset, reveal areas with significant deviations from historical rainfall patterns. The assessment of vegetation health using the NDVI shows regions with both robust and stressed vegetation. The MVWSI, used to focus on agricultural drought risk, reveals critical areas at risk of drought. All of this analysis shows that climate change poses a significant threat to the health and well-being of humans, animals, and plants worldwide.

The impacts of climate change on health are multifaceted, ranging from the increased prevalence of infectious diseases and NCDs to the direct impacts of climate shocks and disasters. Africa is the continent most vulnerable to climate change and its health impacts, with 63 percent of the most at-risk countries located there, including Burundi, Eritrea, Ethiopia, Gabon, Madagascar, and Niger. CSIDs, which account for 50 to 60 percent of human and animal diseases, are primarily transmitted through vectors, water, and food. Climate change is expected to cause 1 million additional deaths every six years in SSA between 2030 and 2050. The continent faces the highest global burden of public health emergencies, mainly due to infectious diseases, with around 100 emergencies annually. Floods affected about 40 million people in SSA between 2010 and 2020, while recent droughts in the Horn of Africa have severely impacted food security, affecting more than 20 million people and leading to increased waterborne diseases due to reduced river flows and unclean water.

The chapter also sheds light on vulnerability to climate change using case studies from two countries (Rwanda and Senegal). We believe that climate change vulnerability assessments of these countries will contribute to making the implementation of NAPs more efficient by answering these three questions: Who is vulnerable? To what? Where? The assessments are made following the standardized method developed by the IPCC. The results of the household vulnerability assessment reveal that the overall level of household vulnerability in Senegal in 2021 is 0.48 while it is 0.43 for Rwanda (the closer the value is to 1, the higher the vulnerability level). In these two countries, the inability to adapt to climate change is the dimension that most explains the vulnerability, followed by the sensitivity dimension for Senegal and the exposure dimension for Rwanda.

The following policy recommendations are drawn from the three analyses presented above:

- The temperature anomalies underscore the urgent need for policies aimed at mitigating the effects of rising temperatures, which threaten both ecosystems and human livelihoods.
- The variability in precipitation is a precursor to potential drought conditions, impacting water availability and agricultural productivity. The findings emphasize the necessity for adaptive water resource management and the implementation of drought-resistant agricultural practices.
- The NDVI highlights the dynamic nature of vegetation response to climatic variations and the importance of targeted conservation and land management strategies to sustain agricultural productivity and ecosystem health.
- The MVWSI indicates a pressing need for comprehensive drought mitigation strategies, particularly in western Africa and parts of southern and northern Africa. Ensuring food security and sustainable agricultural practices in these regions is paramount to mitigating the adverse effects of drought conditions.
- Addressing the complex challenges posed by climate change to health requires integrated OH policies that consider the interconnections between climate change, agriculture, and health. These policies should prioritize the development of climate-resilient agrifood systems and health adaptation strategies to enhance the resilience of communities and safeguard human, animal, and plant health. Central to the OH paradigm is multisectoral collaboration and community participation to facilitate the exchange of knowledge, resources, and best practices, ensuring that policies and interventions are tailored to the specific needs and contexts of different regions and communities.
- Well-functioning surveillance systems and timely responses may reduce the cost of disease outbreaks by 95 percent (Grace 2014). Many African countries lack capacity to detect disease, especially in livestock and wild animals. Several important zoonotic outbreaks have been discovered only when humans have died, although they must have already caused animal deaths. There are human, livestock, wildlife, and plant surveillance systems in Africa, but they are both siloed and underfunded. Investment in improving and integrating surveillance could have large benefits in the control of CSIDs.
- While much information exists on the impact of climate on human, animal, and plant health in Africa, it is mostly drawn from one-off studies using various methodologies, covering various areas and times. Given the enormous impact of different climate and health problems, and the possible synergies from tackling them in a coordinated way, there would be much value in an integrated dashboard to track and report annually all climate-driven sickness and death in people, livestock, and plants.
- Collaborative efforts involving policymakers, researchers, healthcare professionals, and local communities are crucial for developing effective policies and interventions that can mitigate the impacts of climate change and improve health outcomes globally.
- For each African country, a representative sample of all households is needed. This database should contain data about households' perception of climate shocks (drought/irregular rainfall, flooding, heavy rainfall) in recent years. Second, the database must inform researchers about households' sensitivity to these shocks as well as their adaptation strategies.
- The two case studies, for Rwanda and Senegal, reveal that household vulnerability is largely attributable to the inability of households to adapt to climate shocks. This result indicates a strong need for targeted interventions to build adaptive capacity. Adaptive capacity is a functional transformation that involves the use of available opportunities more effectively and efficiently. For example, farm households may have access to irrigation, but unless they use it effectively, their adaptative capacity does not change. Similarly, while farmers may have access to weather and climate information, they remain vulnerable to climate shocks if they do not use this information in their decision-making. Efforts to strengthen resilience should therefore focus on effective and efficient utilization of available opportunities and emerging options.